The development and evaluation of a fitness test battery and web-based platform for monitoring key indicators of adolescent health in school settings

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Submitted to the University of Limerick, April 2020
Abstract

Title: The development and evaluation of a fitness test battery and web-based platform for monitoring key indicators of adolescent health in school settings.

Author: Brendan O’Keeffe

Despite World Health Organisation recommendations, and unlike several countries internationally, the Republic of Ireland lacks a clearly specified strategy for monitoring health-related physical fitness (HRPF) levels in adolescents. The primary aim of this thesis was to develop a pedagogically sound and scientifically rigorous HRPF test battery, and web-based platform, to facilitate monitoring key markers of adolescent health in school settings.

This project involved four distinct periods of data collection, including: a national audit of current physical fitness monitoring practices in secondary school-based physical education programmes (O’Keeffe et al. 2020c); an examination of the test-retest reliability of a peer facilitated approach to administering fitness tests in schools (O’Keeffe et al. 2020b); the delivery of a HRPF test battery (entitled Youth-fit) to 1215 adolescents (age 13.4±.41) from a randomised and stratified sample of 20 schools, and the design of a web-based platform to facilitate large-scale collection and transfer of HRPF results to a centrally hosted database; and finally, a systematic evaluation of both students and teachers experiences of the Youth-fit test battery and software platform.

Positive feasibility benchmarks including, recruitment capability, data collection procedures, resources, and participant responses, indicate that the Youth-fit test battery and software platform represents a feasible, pedagogically sound and scientifically rigorous approach to monitoring HRPF among adolescent populations in the Republic of Ireland.
Declaration

I hereby declare that the work contained in this thesis is my own, and was completed under the supervision of Prof Alan Donnelly and Dr Ciaran MacDonncha of the Department of Physical Education and Sport Sciences, University of Limerick. This work has not been submitted for any academic award at this, or any other, third level institution.

Chapter Three was published in the *Journal of Teaching Physical Education* in January 2020. Chapter Five was published in the journal of *Paediatric Exercise Science* in January 2020. Chapter Six has been submitted for publication to *Plos One*. Chapter Seven has been accepted for publication in the *European Physical Education Review* journal. A version of Chapter Eight will be submitted for consideration of publication in *BMC Public Health* in April 2020.

Signed: _______________________________

Brendan O’Keeffe

Signed: _______________________________

Prof Alan Donnelly

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Dr Ciaran MacDonncha

Date: April 2020
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<tr>
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<th>Full Form</th>
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<tbody>
<tr>
<td>AAAPE</td>
<td>American Association for the Advancement of Physical Education</td>
</tr>
<tr>
<td>AAHPER</td>
<td>American Association of Health Physical Education and Recreation</td>
</tr>
<tr>
<td>ACSM</td>
<td>American College of Sports Medicine</td>
</tr>
<tr>
<td>ALPHA</td>
<td>Assessing Levels of Physical Activity</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>ASSO</td>
<td>Adolescents surveillance system for obesity prevention</td>
</tr>
<tr>
<td>BA</td>
<td>Bland-Altman</td>
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<tr>
<td>BC</td>
<td>Body composition</td>
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<tr>
<td>BIA</td>
<td>Bio-electrical impedance analysis</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>BP</td>
<td>Blood pressure</td>
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<tr>
<td>BSR</td>
<td>Back-saver sit and reach</td>
</tr>
<tr>
<td>CDC</td>
<td>Centre for Disease Control</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>CNPFT</td>
<td>China’s National Physical Fitness Test</td>
</tr>
<tr>
<td>CRE</td>
<td>Cardiorespiratory endurance</td>
</tr>
<tr>
<td>CSPAP</td>
<td>Comprehensive School Physical Activity Plan</td>
</tr>
<tr>
<td>CSPPA</td>
<td>Children’s Sports Participation and Physical Activity</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>CVE</td>
<td>Cardiovascular endurance</td>
</tr>
<tr>
<td>DEIS</td>
<td>Delivering equality of opportunity in schools</td>
</tr>
<tr>
<td>DES</td>
<td>Department of Education and Skills</td>
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<tr>
<td>DEXA</td>
<td>Dual energy x-ray absorptiometry</td>
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<tr>
<td>DSRM</td>
<td>Design Science Research Methodology</td>
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<tr>
<td>HELENA</td>
<td>Healthy Lifestyle Europe by Nutrition in Adolescence</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>HG</td>
<td>Handgrip</td>
</tr>
<tr>
<td>HRPF</td>
<td>Health-related physical fitness</td>
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<tr>
<td>ICC</td>
<td>Intraclass correlation coefficient</td>
</tr>
<tr>
<td>IOM</td>
<td>Institute of Medicine</td>
</tr>
<tr>
<td>IPAQ</td>
<td>International physical activity questionnaire</td>
</tr>
<tr>
<td>ME</td>
<td>Muscular endurance</td>
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<tr>
<td>MRC</td>
<td>Medical Research Council</td>
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<tr>
<td>MS</td>
<td>Muscular strength</td>
</tr>
<tr>
<td>NCCA</td>
<td>National Council for Curriculum and Assessment</td>
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<tr>
<td>NHANES</td>
<td>National Health and Nutrition Examination Survey</td>
</tr>
<tr>
<td>PACER</td>
<td>Progressive aerobic cardiovascular endurance run</td>
</tr>
<tr>
<td>PE</td>
<td>Physical Education</td>
</tr>
<tr>
<td>PF</td>
<td>Physical fitness</td>
</tr>
<tr>
<td>SAFTS</td>
<td>Students attitudes towards fitness tests scale</td>
</tr>
<tr>
<td>SBJ</td>
<td>Standing broad jump</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SE</td>
<td>Standard error</td>
</tr>
<tr>
<td>SEE</td>
<td>Standard error estimate</td>
</tr>
<tr>
<td>SES</td>
<td>Socioeconomic status</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>SRT</td>
<td>Shuttle run test</td>
</tr>
<tr>
<td>TPB</td>
<td>Theory of Planned Behaviour</td>
</tr>
<tr>
<td>VO2max</td>
<td>Maximum volume of oxygen uptake</td>
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<td>WHO</td>
<td>World Health Organisation</td>
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Glossary of Terms

**Body composition**: The components which make up total body mass including, muscle, bone, fluid and fat.

**Cardiorespiratory endurance**: The integrated function of the heart, lungs, vasculature and skeletal muscles to deliver and use oxygen during physical activity.

**Developing equality of opportunity for all**: The Department of Education Skills categorisation framework for identifying disadvantaged schools.

**Field-based tests**: A test conducted under actual-use conditions, instead of under controlled conditions in a laboratory.

**Fitness test battery**: A combination of two or more tests that measure one or more components of physical fitness.

**Health-related physical fitness**: A multidimensional construct containing the components cardiorespiratory endurance, muscular strength, muscular endurance flexibility, and body composition.

**Musculoskeletal fitness**: A theoretical construct that comprises three dimensions including, muscle strength (the ability of skeletal muscle to produce force under controlled conditions), muscle endurance (the ability of skeletal muscle to perform repeated contractions against a load), and muscle power (the peak force of a skeletal muscle multiplied by the velocity of the muscle contraction).

**Pedagogy**: The method and practice of teaching, especially as an academic subject or theoretical concept.

**Performance-related fitness**: The components of fitness that are necessary for optimal work or sports performance, which depend heavily on motor skills, power, speed, body size, motivation and nutritional status.

**Physical fitness**: A multifaceted construct integrating a wide set of bodily functions including morphological, muscular, motor, cardiorespiratory, and metabolic.

**Student-centred learning**: Categorised as learner oriented and teacher facilitated learning, where the learner has increased autonomy and accountability.

**Surveillance**: The systematic collection, analysis and interpretation of data.

**Theory of Planned Behaviour**: This theory states that intention toward attitude, subject norms, and perceived behavioural control, together shape an individual's behavioural intentions and behaviours.
List of Publications

Journal publications


O’Keeffe, B.T., MacDonncha C. and Donnelly A.E. (accepted for publication) ‘Profiling the health-related fitness of Irish adolescents: A school level socioeconomic status divide’, PLOS One [Accepted].

Conference presentations (oral)


O’Keeffe, B.T., MacDonncha C. and Donnelly, A.E. (2018) ‘Cardiorespiratory fitness and musculoskeletal health-related physical fitness levels of adolescents in the
mid and south west of Ireland.’ Health Research Institute Inaugural Research Day, University of Limerick, December 6th. *Awarded best overall oral presentation.*


**Conference presentations (posters)**


Chapter One: Introduction
1.1 Background

Physical fitness is a complex and multifaceted construct that includes performance-related components and health-related components (Caspersen et al. 1985). In recent years, evidence regarding the predictive capacity of the components of health-related physical fitness (HRPF) as indicators of health in youth has accumulated (Ortega et al. 2008b; Ruiz et al. 2009a). This burgeoning evidence-base has resulted in a shift in focus from monitoring performance-related fitness towards health-related fitness (Bouchard et al. 2012). The components of health-related physical fitness, including, cardiorespiratory endurance, musculoskeletal fitness, and body composition, have emerged as powerful predictors of future health in youth (Smith et al. 2014; Högström et al. 2015; Schmidt et al. 2016). Well publicised declines in both physical activity (WHO 2018) and physical fitness levels in youth (Tomkinson and Olds 2007) have led to increasing calls for the establishment of large-scale systems to monitor secular trends (Meusel et al. 2007; Lang et al. 2018). Furthermore, adolescence is a critical period for the acquisition of health-related behaviours. Indeed, behaviours learned during these years are known to track into adulthood (Andersen et al. 2004; Van Oort et al. 2013). However, despite World Health Organisation recommendations (Hallal et al. 2012), and unlike several countries internationally, the Republic of Ireland lacks a clearly specified strategy for monitoring HRPF in youth.

Monitoring or surveillance involves the systematic collection, analysis and interpretation of data from well-defined populations (Hallal et al. 2012). HRPF can be objectively measured in laboratory settings, however, the use of these tests is limited in population-based research due to the necessity of sophisticated instruments, qualified technicians, and time constraints (Lacy and Williams 2018). Field-based tests provide a reasonable alternative for monitoring HRPF in large-scale studies since they are time-efficient, low in cost and equipment requirements, and can be easily administered to a
large number of people simultaneously (Ruiz et al. 2011). Standardised assessments of HRPF using field-based measures provides a way to systematically monitor patterns and trends in youth fitness, to evaluate policies, and build awareness for prevention and health promotion efforts (Welk 2017). Studies that have tracked physical fitness longitudinally generally suggest moderate to moderately high coefficients from adolescence through to adulthood (Trudeau et al. 2003; Da Silva et al. 2013). It has also been reported that improvements in HRPF during childhood and adolescence can mitigate the impact of negative health outcomes later in life (Ortega et al. 2011b). A wealth of research has recently confirmed the reliability (Artero et al. 2011), validity (Castro-Pinero et al. 2009) and predictive capacity (Ruiz et al. 2009a) of field-based measures of HRPF in youth. In light of the emerging evidence illustrating the reliability and validity of field-based measures of physical fitness, many national (Woods et al. 2019) and international (CDC 2008; Ortega et al. 2011a) surveys of health have been updated to include measures of HRPF. Indeed, several states in the United States (Mercier et al. 2016) and countries including Hungary (Csányi et al. 2015), Columbia (Ramírez-Vélez et al. 2015) and Slovenia (Jurak et al. 2019), have mandated monitoring HRPF in youth, mostly through the medium of school-based physical education programmes.

The Republic of Ireland education system is made up of three levels, namely: primary (age 5–12 years); secondary (age 13–18 years); and third level (i.e. universities, institutes of technology). Specialist physical education teachers are only required at secondary level, which is comprised of junior cycle (age 13–15 years), a transition year (age 16 years), and senior cycle (age 17–18 years). Schools, and physical education programmes, specifically, are broadly acknowledged as the most powerful location within which to systematically influence the health of children and adolescents (Pate et al. 2006). Indeed, mounting evidence has confirmed that healthy lifestyle behaviour interventions delivered through schools can lead to improvements in physical activity and fitness,
reductions in sedentary behaviour (Kriemler et al. 2011), and increases in healthy eating habits (Gortmaker et al. 1999). The ability to capture data through schools provides a tremendous opportunity to systematically evaluate educational, environmental, and policy variables that may influence youth fitness (Kelly et al. 2010; Kim 2012). Morrow and colleagues (2009) described the systematic collection and tracking of physical fitness as a common, if not defining, characteristic within physical education. In fact, the practice of monitoring fitness in school-based physical education programmes dates back the middle of the 20th century, and a recent world-wide survey of school physical education (UNESCO 2014) reported that HRPF was the number one ranked curriculum theme.

Physical fitness is commonly assessed in the form of a fitness test battery in schools (Bianco et al. 2015). A fitness test battery can be defined as a group of two or more tests that measure one or more components of fitness. A systematic review by Castro-Pinero and colleagues (2009) reported that there were 12 field-based HRPF test batteries in use among adolescent populations. A cohort of leading researchers in paediatric exercise science recently conducted a pan-European project entitled ALPHA (Assessing Levels of Physical Activity) with the aim of developing a field-based test battery to enable monitoring physical fitness in a standardised manner across Europe (Ruiz et al. 2011). Fitnessgram®, the most commonly administered fitness test battery and software monitoring platform globally, is currently used in 20 countries and administered to over 10 million students in the United States alone each year (Pluim and Gard 2016). Software tracking technology to facilitate monitoring students’ health-related fitness is a key component of many test batteries internationally, including Fitnessgram® in the United States (Welk and Meredith 2013), SLOfit in Slovenia (Jurak et al. 2019), and Netfit in Hungary (Csányi et al. 2015). Indeed, the concept of using computers to track students’ fitness test results had its origin as far back as 1977, when Charles L. Sterling recognised school administrators and parents’ interest in a physical fitness report
card (Plowman et al. 2006). Leading experts in paediatric exercise science have called for the development disruptive technological solutions to facilitate large-scale collection of HRPF data in schools, and the transfer of this data to centrally located databases (Ruiz et al. 2006b; Lang et al. 2018). The availability of such data in real-time could serve as a crucial information source for policy-makers, healthcare professionals, and education authorities, in the timely planning of prevention programs (Froberg 2014).

Despite its long history and continued prevalence, the place of fitness testing in physical education remains a divisive topic. Proponents have highlighted the proposed educational and health benefits of HRPF monitoring (Cohen et al. 2015), while critics have questioned the continued unproblematic use of fitness tests in physical education (Wrench and Garrett 2008), with some scholars suggesting that it may well represent a misdirected effort in health promotion (Cale and Harris 2009; Alfrey and Gard 2014). Notwithstanding the serious consequences of inappropriately implementing fitness tests (Ernst et al. 2006), there is general agreement that, if incorporated as just one component of a broad and balanced programme, using pedagogically sound approaches, there is no reason why fitness testing should not be part of school-based physical education programmes (Cale et al. 2014). Rather surprisingly, much of the research that is commonly cited when debating the role of fitness testing in physical education is based on a very small number of empirical studies, many of which were conducted more than quarter of a century ago (Luke and Sinclair 1991; Hopple and Graham 1995). Therefore, there is a need to move beyond the critique of fitness testing towards a better understanding of pedagogically sound approaches for ways in which fitness testing could be used in a safe and reliable manner, with an educational focus (Alfrey and Gard 2017).

The paucity of research pertaining to HRPF monitoring practices and HRPF levels of adolescents in the Republic of Ireland provided the impetus to conduct this investigation. In an effort to address this gap, our research team developed a systematic
eight step plan (Figure 1.1) divided into three distinct phases according to the Medical Research Council’s framework for developing and evaluating feasibility studies (Craig et al. 2008). Steps one to five were addressed as part of the development phase (phase one). This included a survey of HRPF monitoring practices involving a nationally representative sample of secondary schools in the Republic of Ireland, in addition to a comprehensive literature review of valid and reliable field-based fitness tests, feasible for administration in school settings. Informed by the results of the literature review and national survey, the Youth-fit test battery, software platform, and administrators guidance manuals were also developed as part of phase one (Appendix A and Appendix C). An examination of the test-retest reliability of student administered fitness tests was conducted at the conclusion of phase one. Steps six and seven focused on the feasibility (phase two) of the project, which involved administering the Youth-fit test battery to a randomised sample of 20 schools stratified for sex, location and socioeconomic status. A workshop detailing test administration protocols, hall set up, and software user guidelines was delivered by the lead investigator in each of the 20 schools involved in the feasibility phase. Finally, the aim of step eight (phase three) was to conduct a comprehensive evaluation of the overall project, including an examination of both students and teachers’ experiences of the Youth-fit test battery and supporting resources. The overall aim and objectives of this thesis are outlined in the proceeding sections.
1. Review of HRPF monitoring practices nationally
- Conduct a survey on current HRPF monitoring practices in secondary schools and determine the perceived need for the development of a standardised test battery.

2. Fitness test battery item selection (review of literature)
- Conduct a review of valid and reliable test items suitable for school settings and examine the history, secular trends and prevalence of physical fitness monitoring internationally.

3. Development of Youth-fit software platform
- In collaboration with our project partners, develop a software platform to facilitate hosting and tracking of HRPF data.

4. Youth-fit test battery and software platform guidance manuals
- Development of the test administration and software guidance manuals and video tutorials. Secure funding for test battery equipment and resources.

5. Test-retest reliability study
- Examine the test-retest reliability of peer-assessed measures of HRPF and compare these reliability indices to those of experienced test administrators.

6. Feasibility study (stage 1): school recruitment and training
- Deliver a workshop detailing administration protocols and hall set up, and provide Youth-fit resource pack and equipment to all 20 schools involved in feasibility phase.

7. Feasibility study (stage 2): Test battery completion
- Administration of the Youth-fit test battery to schools and inputting of results to the web-based platform.

8. Feasibility phase evaluation
- Conduct a comprehensive evaluation of students and teachers experiences of participating in and delivering the Youth-fit test battery.

**Figure 1.1** Schematic overview of the steps involved in the development and evaluation of the Youth-fit test battery and software platform.

### 1.2 Thesis aim

The primary aim of this research project was to develop a scientifically rigorous and pedagogically sound system for monitoring health-related physical fitness among adolescent youth in secondary school-based physical education programs.
1.3 Thesis objectives

1. To conduct a national survey examining current HRPF monitoring practices in secondary school-based physical education programs in the Republic of Ireland. (Phase One, Step One)

2. To develop a student-centred HRPF test battery feasible for administration during timetabled school-based physical education lessons. (Phase One, Step Two and Three)

3. In collaboration with our project partners (iMosphere), design a web-based application to facilitate monitoring HRPF, and the transfer of data in anonymised form to a centrally hosted database. (Phase One, Step Four)

4. To determine the test-retest reliability of student-administered health-related fitness tests in school settings. (Phase One, Step Five)

5. To coordinate a feasibility study involving a randomised sample of 20 schools, stratified by gender, location and socioeconomic status. (Phase Two, Step Six)

6. To conduct the first multi-component examination of HRPF levels among a representative sample of Irish adolescents. (Phase Two, Step Seven)

7. To evaluate the feasibility of the Youth-fit test battery and software platform for monitoring HRPF in secondary school-based physical education programs. (Phase Three, Step Eight)

1.4 Thesis structure

The current chapter has provided a brief overview of the overall thesis, highlighting the rationale, primary aim, and seven key objectives of the research project. Chapter Two provides a comprehensive review of the current evidence-base regarding HRPF, its
prevalence, and relationship with health in youth, in addition to a review of the latest research on the reliability and validity of field-based fitness tests. This chapter also addresses current trends in monitoring fitness in school-based physical education programs. Chapter Three contains a national review of HRPF monitoring practices in secondary school-based physical education programs in the Republic of Ireland (published in The Journal of Teaching in Physical Education). Chapter Four comprises two sections; section one provides a systematic breakdown of the steps involved in the design, development and administration of the Youth-fit test battery; section two details the design and development of the Youth-fit software platform. Chapter Five contains a test–retest reliability analysis of student-administered HRPF tests in school settings (published in Paediatric Exercise Science). Chapter Six profiles the HRPF levels of a stratified sample of Irish adolescents who completed the Youth-fit test battery (accepted for publication PLOS one). Chapter Seven summarises students’ attitudes towards and experiences of the Youth-fit test battery (accepted for publication in the European Physical Education Review journal). Chapter Eight addresses the feasibility of the Youth-fit test battery and software platform using a comprehensive evaluation framework for feasibility studies. Finally, an in-depth discussion of the research presented in this thesis is provided in Chapter Nine, along with potential impacts, limitations, future directions in research and practice, and conclusions from this body of work.
Chapter Two: Literature review
2.1 Preface

This chapter provides a comprehensive overview of health-related physical fitness (HRPF), its components, prevalence and relationship with health in youth. The predictive capacity of each component of HRPF as an indicator of health is reflected upon, followed by an analysis of some key modifying factors that influence physical fitness levels in youth. A brief history of HRPF monitoring practices internationally and nationally is provided, and the current evidence regarding the validity and reliability of field-based physical fitness tests is explored. The chapter concludes with a review of the opportunities and obstacles associated with monitoring physical fitness in the context of school-based physical education programmes, and a review of HRPF test batteries and software monitoring platforms, currently in use internationally, is outlined. The focus of this literature review, and research project more broadly, is on school-going adolescents (also termed ‘youth’ for the purposes of this review) between the ages of 12 and 19. Adolescence is a crucial time in establishing positive health-related behaviours, and behaviours learned during these years are highly likely to track into adulthood (Trudeau et al. 2003; Andersen et al. 2004; Telama 2009). Overall, the rationale for conducting this study, as detailed in Chapter One, is well supported by the findings from the current literature review, which also serves to guide the research and content of subsequent chapters.
### 2.2 An introduction to physical fitness

A seminal paper by Caspersen and colleagues (1985) noted that the epidemiologic study of any concept requires that the item being investigated be defined and measured. The authors suggested that the terms physical activity, exercise and physical fitness were often confused with one another, and occasionally used interchangeably. It is now universally accepted that physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure, while exercise refers to a subcategory of physical activity that is planned, structured, repetitive, and purposeful (WHO 2018). Despite the prominence of physical fitness as a concept in both academia and industry for the most part of two centuries (Shephard 2018), there has been no universally accepted definition of the term. Physical fitness has been described as a multifaceted construct integrating a wide set of bodily functions including morphological, muscular, motor, cardiorespiratory, and metabolic (Bouchard et al. 1994). Warburton and colleagues (2006) extended this definition to include a psychological component, describing it as a combination of physical and psychological attributes, defined by a physiologic state of well-being, that allows one to meet the demands of daily living or that provides the basis for sport performance. In contrast with physical activity, which includes any bodily movement, physical fitness is a set of attributes that people have or achieve. Caspersen et al. (1985) suggested that the attributes of physical fitness can be categorised as either performance-related or health-related. Bouchard and Shephard (1994) defined performance-related fitness as the components of fitness that are necessary for optimal work or sports performance, which depend heavily on motor skills, power, speed, body size, motivation and nutritional status. Health-related physical fitness (HRPF) has been defined as a multidimensional construct containing the components cardiorespiratory endurance (CRE), muscular strength (MS), muscular endurance (ME), flexibility, and body
composition (Caspersen et al. 1985; Pescatello et al. 2014). An overview of each component of HRPF is provided in the following paragraph.

2.2.1 Components of health-related physical

In recent years, there has been a shift away from monitoring performance-related components of fitness to health-related components of fitness in population based-studies (Plowman et al. 2006). CRE has been defined as the integrated function of the heart, lungs, vasculature and skeletal muscles to deliver and use oxygen during physical activities (Bouchard et al. 2012). CRE has also been referred to as aerobic capacity or cardiovascular fitness, and has been the most commonly assessed and researched component of HRPF (Armstrong et al. 2011). Plowman and Meredith (2013) defined body composition as the components which make up one’s total body mass including, muscle, bone, fluid and fat. Although body composition is not a demonstrative action like other HRPF components, it has been identified as a significant health marker and modifier of fitness in youth (Pillsbury et al. 2013). Musculoskeletal fitness has been described as a theoretical construct that comprises three dimensions including, muscle strength (the ability of skeletal muscle to produce force under controlled conditions), muscle endurance (the ability of skeletal muscle to perform repeated contractions against a load), and muscle power (the peak force of a skeletal muscle multiplied by the velocity of the muscle contraction) (Pillsbury et al. 2013). Flexibility is defined as the range of motion of muscle and connective tissues at a joint or group of joints (Knudson et al. 2000). In contrast to other components of HRPF, flexibility is highly specific to each of the joints of the body, therefore, linking it to one or more health outcomes has proven difficult. The relationship between each component of HRPF and health will be explored in the following paragraphs.
2.3 Youth fitness and health

The predictive capacity of physical fitness in youth as an indicator of current and future health status was, until recently, contested (Ruiz et al. 2009a). This is because, despite the presence of risky behaviours, unfavourable health outcomes such as heart disease, stroke, hypertension, diabetes mellitus and fracture are not typically present among youth. However, considerable progress has been made in understanding the relationship between physical fitness and health in children and adolescents, with a shift in focus from examining unfavourable health outcomes prevalent among adults to studying risk factors including insulin resistance, cholesterol, blood lipids, adiposity, skeletal health and mental health (Zhu et al. 2011). As a result, physical fitness has recently emerged as one of the most powerful predictors of future health among children and adolescents (Ortega et al. 2008b). There is now a consistent body of evidence from longitudinal studies (Carnethon et al. 2005; Mikkelsen et al. 2006; Grøntved et al. 2015) and systematic reviews (Ruiz et al. 2009a; Ortega et al. 2013) confirming the favourable effects of moderate-to-high levels of physical fitness in childhood and adolescence to health-related outcomes later in life, including cardio-metabolic health (Schmidt et al. 2016), musculoskeletal health (Smith et al. 2014), and cognitive traits (Bezold et al. 2014).

2.3.1 Cardiorespiratory endurance in youth and future health

Low CRE in youth is a well-established marker for developing cardiovascular-disease risk factors such as obesity, metabolic syndrome and raised blood pressure (Ruiz et al. 2009a). Furthermore, substantial evidence has been published indicating that low CRE tracks from youth in to adulthood (Trudeau et al. 2003; Andersen et al. 2004). A cohort study of over 700,000 Swedish adolescents, with a median follow-up of 29 to 34 years, identified that individuals with low CRE in late adolescence had an increased risk of myocardial infarction and early mortality in adulthood (Högström et al. 2015). Similarly,
the European Youth Heart Study (Ekelund et al. 2007), which involved 1709 nine to ten and 15 to 16 year-old boys and girls from three European countries, found that CRE was significantly associated with clustered metabolic risk (waist circumference, blood pressure, fasting glucose, insulin, triacylglycerol and high density lipoproteins). In a study examining the relationship between CRE, physical activity and cardio-metabolic disease risk factors among one hundred 10-14 year old adolescents, Bailey et al. (2012) reported that those classified with high levels of CRE had a significantly lower risk of cardio-metabolic disease compared to those classified with low levels of CRE. Notably, Bailey and colleagues also reported that differences in objectively measured PA levels did not have a significant effect on children’s risk for cardio-metabolic disease, indicating that CRE was a more effective predictor of future health outcomes than physical activity. A recent systematic review, examining the association between CRE and health by the Institute of Medicine (now the National Academy of Medicine) (2013), similarly concluded that there was a consistent relationship between measured CRE and health risk factors including adiposity and cardio-metabolic risk factors. These findings support the notion that CRE levels among youth are not only an indicator of current health, but also a potential indicator of future population disease burden (Lang et al. 2018).

2.3.2 Body composition in youth and future health

The relationship between body composition and various health indicators has also been well established in youth. Both body mass and body fat (absolute fatness and relative fat distribution) are elements of body composition that have implications for health and fitness, however, no single element of body composition can adequately and comprehensively describe an individual’s overall body composition, and each element has been linked with various health markers (Pillsbury et al. 2013). A multitude of studies have reported an association between obesity and various health outcomes including
metabolic syndrome, type 2 diabetes and cardiovascular disease risk factors (Freedman et al. 2007; Buffart et al. 2008; Freedman et al. 2008; Morrison et al. 2008). A meta-analysis of HRPF levels among youth internationally reported that those classified as overweight or obese scored significantly lower across all HRPF outcome measures in comparison to their normal weight peers, with the exception of flexibility (Tomkinson et al. 2003). Interestingly, Brouwer and colleagues (2013) reported that good fitness attenuated the risk of poor cardio-metabolic health in overweight/obese boys. Several studies among adult populations have also reported that higher CRE attenuates cardio-metabolic risk (Earnest et al. 2013; van der Velde et al. 2015; Schmidt et al. 2016). These findings generated the ‘fat but fit’ paradigm which suggests that overweight or obese but fit people have healthier cardio-metabolic outcomes than overweight or obese but unfit people, and are sometimes even as healthy as those classified as healthy weight but unfit (Duncan 2010). Like CRE, there is also strong evidence demonstrating that obesity tends to track from childhood to adulthood (Clarke and Lauer 1993; Parsons et al. 1999; Da Silva et al. 2013), again emphasising the importance of screening from an early age.

2.3.3 Musculoskeletal fitness in youth and future health

The relationship between musculoskeletal fitness and health outcomes in youth has not been as extensively examined as that in adults. Indeed, a systematic review by the Institute of Medicine (2013) concluded that there was a lack of high-quality studies supporting a strong link between musculoskeletal fitness and health outcomes in youth. However, a recent systematic review and meta-analysis of 110 studies by Smith and colleagues (2014), encompassing six distinct health outcomes, reported strong evidence for an inverse association between musculoskeletal fitness and adiposity, cardiovascular disease and metabolic risk factors in children and adolescents. Typically, after puberty, boys show a dramatic acceleration of muscular strength until the age of 17 and beyond, while girls
show a pronounced plateauing and regression in late adolescence and beyond (Gallahue and Ozmun 2006). A study by Artero et al. (2014) involving 639 adolescents aged 12.5 to 17.5 years reported that overweight and obese adolescents who presented with inflammatory biomarkers may be counteracted, to some extent, by maintaining appropriate levels of muscular fitness. This study also reported that musculoskeletal fitness was inversely related with inflammatory biomarkers during adolescence, independently of CRE and insulin resistance. In a 24 year longitudinal study of over one million Swedish male adolescents investigating the relationship between muscular strength and premature death, Ortega and colleagues (2012) reported that the effect size for those with poor muscular strength, observed for all-cause mortality, was equivalent to that for well-established risk factors such as elevated body mass index or blood pressure.

2.3.4 Flexibility in youth and future health

Given the specificity of flexibility to individual joints in the body, it is difficult to quantify flexibility measures with health indicators. Interestingly, Wolf et al. (2011) reported that excessive flexibility may actually increase the chance injury during activity. Indeed, some authors have argued the case for retiring flexibility as a major component of physical fitness in order to simplify test batteries and save time and resources dedicated to flexibility instruction (Nuzzo 2019). A recent review of health-related fitness in European youth reported those categorised as overweight or obese scored significantly poorer (p <.001) across all HRPF tests, with the exception of flexibility, which did not vary significantly (Tomkinson et al. 2018). Health outcomes hypothesized to be associated with flexibility include reducing the risk of low-back pain, reducing the risk of musculoskeletal injury, and improved posture (Plowman and Meredith 2013). The Institute of Medicine’s report on fitness measures and health outcomes in youth (2013) suggested that, although the evidence is not yet clear, flexibility in youth may in fact be
linked to various health outcomes, and called for further studies to explore such associations.

2.3.5 Blood pressure in youth and future health

Although the relationship between blood pressure (BP) and cardiovascular health is well established in adult populations, it is less understood among youth (Chen and Wang 2008). However, there is mounting evidence to suggest that elevated BP during childhood and adolescence increases the risk of hypertension in adulthood (Bao et al. 1995; Sun et al. 2007). In a meta-analysis of BP trends among youth in the United States, Din-Dzietham and colleagues (2007) reported that pre-high BP and high BP increased by 2.3% (p = 0.0003) and 1% (p = 0.17), respectively, between 1988 and 1999. Mark and Janssen (2008) found a modest dose-response relationship between physical activity and mean systolic and diastolic blood pressure values in youth, while strong correlations between high BP and sedentary time have also been noted in children as young as three to eight years (Martinez-Gomez et al. 2009). Hofman et al. (1987) reported that systolic and diastolic blood pressure in children was associated with physical fitness, and that changes in BP in childhood may be related to changes in physical fitness. It has also been reported that higher CRE may attenuate the association between body fat and blood pressure in school-aged children (Ruiz et al. 2007). In light of emerging evidence indicating that hypertension can originate early in life, there has been increasing calls for regular monitoring of BP among population-based samples from childhood to adulthood (Lane and Gill 2004; Chen and Wang 2008).

2.3.6 Youth fitness and academic achievement

A wealth of research has confirmed the potential benefits of physical fitness for enhancing academic achievement among children and adolescents. In one of the first studies to examine this relationship, Castelli and colleagues (2007) reported that CRE and BMI
were associated with achievement in reading and mathematics, whereas muscular strength and flexibility were unrelated to general academic achievement, reading, and mathematics in third and fifth grade students. Bezold et al. (2014) reported that a substantial decrease in fitness was associated with a decrease in academic performance in a sample of over eighty thousand New York City middle-school students. The authors also reported that effects of fitness on academic achievement were stronger in high-poverty boys and girls than in low-poverty boys and girls. Sardinha et al. (2016) concluded that increases in physical fitness over a one year period increased the likelihood of higher academic achievement, a finding supported by Booth and colleagues (2014) who conducted a five year prospective longitudinal study and found negative associations between obesity and academic achievement for adolescent girls. A recent study by McLoughlin et al. (2020) investigating the longitudinal associations between physical fitness and academic achievement reported modest associations between the two variables. The authors did caution that, although physical fitness is important for health and well-being in youth, one cannot necessarily expect that gains will contribute to measurable improvements in academic achievement.

### 2.3.7 Consideration of modifying factors

Variations in physical fitness are caused by a network of social, behavioural, physical, psychosocial and physiological factors (Tomkinson and Olds 2007), thus it is imperative that those who evaluate fitness among paediatric populations are cognisant of these modifying factors. A modifying factor can independently affect an individual’s level of fitness, and can be both measurable (e.g. gender, age, socioeconomic status) and unmeasurable (e.g. heredity) (Pillsbury et al. 2013). Well established modifying factors of physical fitness among youth include age, gender and physical activity levels (Zaqout et al. 2016). Pillsbury et al. (2013) recommended that, until more research is undertaken,
only age- and gender-based criterion referenced cut-points be established. However, the authors did note the dearth of research on the relationship between demographic factors, such as ethnicity and socioeconomic status, and fitness test performance. A conceptual framework has been developed to graphically depict the relationship between the components of HRPF, key modifying factors and health markers (Figure 2.1). Body composition appears as a component of fitness, modifying factor, and health marker on the framework. However, this is perhaps unsurprising given that body composition has been identified as both a modifying factor of overall HRPF and key determinant of the other components. For example, in a longitudinal study exploring the determinants of physical fitness in European children aged 6 to 11 years, Zaqout and colleagues (2016) highlighted the significance of BMI as a key determinant of physical fitness, independent of physical activity. A detailed summary of all modifying factors and their relationship with HRPF was beyond the scope of the current review, therefore, a brief overview of three of the most pertinent modifying factors in the context of monitoring fitness in youth, namely age, sex and socio-economic status (SES), is provided in the following paragraph.

![Figure 2.1 Physical fitness measures and health outcomes: Conceptual framework (Institute of Medicine 2012, p.51)](image-url)
2.3.7.1 Age and sex
The underlying causes of sex- and age-related differences are clear for most fitness test performances, such as those for muscular strength, power and speed which are largely explained by physical differences (e.g. differences in muscle mass or height), while CVE appears to be explained primarily by physiological differences (e.g. mechanical efficiency) (Rowland 2007; Catley and Tomkinson 2013). A consistent body of evidence has indicated that physical fitness in youth improves linearly until the early post pubertal years in both boys and girls (Ortega et al. 2011a; Santos et al. 2014; Tomkinson et al. 2018). In a worldwide review of 20 metre shuttle run test (20m SRT) performance involving 37 countries, Olds et al. (2006) reported that performance improved until about age 12 years in girls and 16 years in boys, and then plateaued. Kemper et al. (2013) similarly reported that VO\textsubscript{2}max tends to increase from childhood into adolescence, with the increase usually lasting into late adolescence for boys, but for girls a plateau occurs in VO\textsubscript{2}max much earlier by about 13 or 14 years. In terms of sex related differences, a recent meta-analysis of physical fitness among youth internationally reported that boys consistently scored higher than girls on fitness tests, except on the sit-and-reach test of flexibility, in which girls scored higher (Catley and Tomkinson 2013). Tomkinson et al. (2018) also reported that, among a sample of 2,779,165 European youth aged 9 to 17 years, boys performed substantially (standardised differences >0.2) better than girls on muscular strength, muscular power, muscular endurance, speed-agility and CRE tests, but worse on the flexibility test.

2.3.7.2 Socioeconomic status
The relationship between SES and physical fitness has been less examined, with much of the research to date producing inconsistent results (Jiménez Pavón et al. 2010; Guedes et al. 2012). Freitas et al. (2007) found considerable variation in physical fitness among Portuguese adolescents of contrasting socioeconomic profiles, with boys from low SES
performing better in both aerobic and muscular strength tests than those categorised as middle class. In contrast, Coe et al. (2013) reported that SES was positively associated with physical fitness, independently of total body fat and habitual physical activity, in school-aged youth. Bohr and colleagues (2013) similarly reported that the prevalence of overweight and unhealthy behaviours has been shown to be much higher in girls from families categorised as low SES. The authors in this study assessed the physical fitness of 1,314 girls (age= 16.2 SD= 0.9) using the Fitnessgram® battery of fitness tests, and significant differences were found between high and low SES groups for body composition, mile run, and physical activity, with members of the lower SES group having lower levels of overall fitness. In one of the few empirical studies to investigate the impact of school sociodemographic characteristics on physical fitness variables, Welk et al. (2010) reported that physical fitness was consistently higher among students in schools categorized as low diversity and high socioeconomic status. Bel-Serrat and colleagues (2018) similarly reported that school socioeconomic status was a strong determinant of overweight and obesity in Irish schoolchildren. Interestingly in the context of the current research project, Merola (2005) suggested, if collecting information regarding SES directly from parents is not feasible, it may be estimated from official school level statistics, such as percentage of students eligible for free or reduced-price lunch, illustrating the utility of schools as suitable contexts within which to conduct research. The history of measuring fitness in youth from an international and national perspective is addressed in the following paragraphs, followed by a review of the validity and reliability of field-based fitness tests in youth.

2.4 History of measuring fitness in youth

Although standardised testing did not begin until the middle of the 20th century, it has been reported that the foundation of youth fitness testing originated a century earlier
(Plowman et al. 2006). National physical education organisations in the United States, including the American Association for the Advancement of Physical Education (AAAPE), were established in the late 1800s with a strong focus on the measurement of fitness attributes (Park 1989). By the early 1900s the focus of fitness testing had expanded beyond anthropometric measures to include measures of various body systems including the respiratory and muscular systems (Park 1989). The advent of World War One led to a shift in focus of fitness testing among youth toward military preparedness, and although the Great Depression resulted in a reduced emphasis on physical education, the onset of World War Two during the 1940s re-established societal interest in the physical fitness levels of youth, again with a focus on military preparedness (Pillsbury et al. 2013). Countries like the USSR (now Russia), China and Japan also began to coordinate population-based standardised fitness tests among youth during this time, mostly in schools, through the medium of physical education (Keating et al. 2018).

Following the World Wars of the early and mid-20th century, the initial focus of fitness testing on preparation for military service gave way to a more general emphasis on sporting and athletic capacity (Pillsbury et al. 2013). Seminal research by Kraus and Hirschland (1953; 1954), in which it was reported that youth in the United States were significantly less fit than their European counterparts, is collectively recognised as the point at which the impetus toward the first standardised approach to youth fitness testing began in the United States. Yet again, the outbreak of a war, this time the Cold War, raised major concerns regarding the fitness of American youth, to such an extent that President Eisenhower established the President’s Council on Youth Fitness (Plowman et al. 2006). Morrow et al. (2009) highlighted that the first test battery developed by the American Association of Health Physical Education and Recreation (AAHPER) had a strong emphasis on performance related objectives. This was also a prevalent theme in fitness test batteries in European countries including Belgium and the Netherlands.
(Kemper and Mechelen 1996). However, as research linking fitness to positive health outcomes began to increase from the 1970s onward, interest grew in the development of test batteries focused on assessing health-related components of fitness, as evidenced by the development of Fitnessgram® in the United States (Plowman et al. 2006) and the Eurofit test battery in Europe (Kemper and Mechelen 1996). Furthermore, concern about the effect of normative comparisons, plus a growing awareness of the burgeoning literature on intrinsic motivation, led calls for more educationally oriented fitness test batteries in school settings (Whitehead et al. 1990).

During the 1980s and 1990s, the role of physical fitness testing in physical education was a keenly debated topic among academics and practitioners in physiology, motor development and sport pedagogy (Rowland 1995). Despite efforts to develop a unified battery of fitness tests in the United States throughout the latter part of the 20th century, it was not until 1994 that AAHPERD (American Association of Health Physical Education Recreation and Dance) adopted Fitnessgram® as its national fitness test (Plowman et al. 2006). As the evidence for the importance of physical fitness as an indicator of health continued to emerge in recent years (Ortega et al. 2008b), several longitudinal surveys of health in youth, including the National Health and Nutrition Examination Survey (NHANES) in the United States (CDC 2008) and the European Youth Heart Study (Riddoch et al. 2005), were updated to include measures of physical fitness. Significant efforts to examine the reliability and validity of field-based measures of fitness have also been made since the turn of the 21st century (Ruiz et al. 2011). According to a recent systematic review of field-based testing in youth (Bianco et al. 2015), there are currently 12 health-related fitness test batteries in use internationally with adolescent populations in schools, of which Fitnessgram®, the ALPHA (Assessing Levels of Physical Activity) test battery, China’s National Physical Fitness Test and Russia’s GTO test battery are the most popular (Keating et al. 2018). Fitness testing has
now been part of school-based physical education programs for over half a century and has been reported as one of the most common forms of assessment used in physical education (Ferguson et al. 2007). A recent global survey of physical education reported that health-related physical fitness was ranked as the most popular curriculum theme in physical education by teachers internationally (UNESCO 2014).

2.4.1 History of measuring fitness in youth: A national context

Despite the prominence of fitness testing in youth for the most part of a century internationally, and unlike the US, Australia, China, Russia and several European countries, there has been no coordinated effort to monitor health-related fitness among adolescents in the Republic of Ireland. A survey of physical fitness was conducted on a representative cohort of 1015 adolescents aged 12 and 15 years from Northern Ireland by Boreham et al. (2001) in which it was reported that the observed relationships between CRE and cardiovascular disease risk status in adolescents were mediated by fatness, whereas the observed relationships with fatness were independent of fitness. Woods et al. (2010; 2018) conducted two reviews of activity and fitness levels among youth in the Republic of Ireland as part of the Children’s Participation in Sport and Physical Activity (CSPPA) survey. However, only two components of HRPF were measured as part of this survey, namely, CRE (20m shuttle run) and body composition (body mass index). Therefore, there is a paucity of data on objectively measured physical fitness levels in Irish youth, with many of the existing health and activity surveillance surveys including Growing Up in Ireland (Williams et al. 2018) and the Healthy Behaviour in School Aged Children (Morgan et al. 2016) utilising self-reported measures. From an educational perspective, although the ability to measure and evaluate health-related fitness is identified as a key learning outcome in all four physical education curriculum options in the Republic of Ireland at junior (ages 13 to 15 years) and senior cycle (ages 16 to 18
years), neither the Department of Education and Skills nor the National Council for Curriculum and Assessment (NCCA) provide specific guidelines for teachers on test items or administration protocols.

2.5 Field-based measures of health-related fitness

Health-related physical fitness can be objectively measured in laboratory settings, however, the use of these tests is limited in field-based settings due to the necessity of sophisticated instruments, qualified technicians, and time constraints (Espana-Romero et al. 2010a; Lacy and Williams 2018). Field-based tests provide a reasonable alternative since they are time-efficient, low in cost and equipment requirements, and can be easily administered to a large number of people simultaneously (Ruiz et al. 2011). Vanhelst et al. (2016) similarly highlighted the many advantages of field-based tests, including, ease of administration, low cost, safety, and the opportunity to assess multiple components of HRPF in a short period of time. From a laboratory research perspective, it was perceived that field-based tests of physical fitness did not have sufficient validity or reliability, however, the recent surge in research confirming the validity (Artero et al. 2012) and reliability (Artero et al. 2011) of field-based measures of HRPF, in addition to mounting evidence on the predictive capacity of physical fitness (Ruiz et al. 2009a), has led to increasing calls for the development of simple, accurate, and inexpensive systems to facilitate large-scale monitoring of HRPF in youth (Meusel et al. 2007; Hallal et al. 2012; Lang et al. 2018). Domone and colleagues (2016) stated that any large-scale fitness testing of children would need to be conducted in the field as opposed to the laboratory, as the provision of resources required for the latter would be prohibitive in the extreme. Pillsbury et al. (2013) did note that laboratory measures, such as dual energy x-ray absorptiometry (DEXA), may be appropriate for some national surveys, like NHANES, for which equipment is transported in a trailer, tests are administered by trained
technicians and only small samples of youth are studied. However, for large population-based national surveys, field-based measures are more suitable than laboratory measures (Castro-Pinero et al. 2009). Furthermore, a recent paper by Lang et al. (2018) recommended using field-based estimates of cardiorespiratory endurance as an objective measure that could complement the evaluation process of the World Health Organisation’s global physical activity plan (WHO 2018) by providing a proximal outcome of physical activity levels in individuals of all ages and for countries across income categories.

Despite these recommendations from leading scholars and international organisations, some experts in the field of paediatric exercise science remain opposed to field-based testing serving as a proxy for laboratory tests, particularly estimates of CRE. For example, a recent paper by Armstrong and Welsman (2019a) refutes the validity of the most commonly administered test of CRE among youth internationally (20m SRT) as an accurate estimate of peak VO₂. The paper also identifies the limitations and potential ramifications of the use of health-related cut-points or ‘clinical red flags’ with children and adolescents. The authors described the 20mSRT performance as “not a measure of CRE, but a function of willingness and ability to run between two lines 20 metres apart” (Welsman and Armstrong 2019a, p.9). Whitehead, Pemberton and Corbin (1990) stated while most laboratory based tests are too cumbersome for use in field settings such as schools, some pragmatic sacrifice of validity and reliability is inevitable if testing is to be done at all. Notwithstanding the concerns raised by Armstrong and Welsman, the majority of articles reviewed supported the practice of field-based fitness testing, subject to strict administration protocols and validation procedures, particularly in settings where access to expensive laboratory based equipment is not available. A summary of research, pertaining to the validity and reliability of field-based measures of fitness in youth is presented in the next section.
2.5.1 Validity of field-based fitness tests

2.5.1.1 Criterion-related validity of field-based tests

In any testing situation, it is important that the results are derived from high-quality measurement techniques. Administrators, politicians, educators, and researchers should be able to trust data gathered from field-based measures of HRPF (Martin et al. 2010). Reliability and validity are paramount for meaningful interpretation and inference of results (Morrow et al. 2010). Validity, which has been proposed as the most important concept in testing (Mahar and Rowe 2008), refers to the ability of a test to reflect what it is designed to measure. Criterion-related validity refers to the extent to which a test correlates with an established criterion or ‘gold standard’ measure (Docherty 1996). A systematic review by Castro-Pinero and colleagues (Castro-Pinero et al. 2009) reported strong evidence confirming the criterion-related validity of the 20m SRT and BMI. Ruiz et al. (2008) developed an equation to estimate $\dot{V}O_2\text{max}$ from 20mSRT performance using artificial neural network modelling and reported very strong correlation indices with estimated $\dot{V}O_2$ generated from portable gas analyzers ($R^2=0.92$, percentage error: 7.30%, SEE: 2.84 ml/kg/min). Plowman et al. (2013) also highlighted that, because the speed of running is controlled in the 20m SRT, variation in pacing has little influence on test outcome in comparison to other distance run tests such as the one mile run. However, as alluded to in the previous paragraph, Armstrong and Welsman (2019a) recently reported that the 20m SRT estimated using the Leger et al. (1988) equation was not a valid estimate of CRE, and thus, it has been suggested to avoid the use of predictive equations when comparing performance on the 20m SRT, and use the number of levels and shuttles completed instead (Lang et al. 2017).

In terms of body composition, studies reporting Pearson correlations between BMI and body fat measured by more advanced methods in youth generally exceeded $r = 0.50$ and were frequently much higher (Goulding et al. 1996; Pietrobelli et al. 1998).
Weight for height indices like BMI do not provide information about the amounts of various tissues that together make up body mass, however, as noted by Plowman and colleagues (2013), because BMI is moderately to strongly correlated with percent fat, it could be used as a surrogate measure of body composition in field-based settings, such as schools. The limitations of BMI as a measure among certain populations, particularly those with high muscle mass, have been well established (Ode et al. 2007; Nevill et al. 2005). However, these variations in classification are not as pronounced among children and adolescents, particularly in advance of puberty (Freedman et al. 2008). Therefore, although measurements such as skinfolds, BMI, and waist circumference are, to a large extent, indirect estimates of body composition, according to the Institute of Medicine (2013), the association between these field-based measures and health markers, including type 2 diabetes and metabolic syndrome, justifies their use in population-based studies as a means of tracking health status.

A systematic review of the criterion related validity of muscular fitness tests in youth by Artero et al. (2012) reported that handgrip strength and standing broad jump produced the most valid scores when compared to isokinetic strength. Castro-Pinero et al. (2010) concluded that the standing broad jump test was strongly associated with other lower body muscular strength tests including vertical jump and countermovement jump ($R^2 = 0.83-0.86$). Milliken and colleagues (2008) reported significant ($p < .01$) correlations of $\geq 0.70$ and $\geq 0.52$ between handgrip strength and one rep max chest press and one rep max leg press, respectively. A recent study also identified handgrip strength and standing broad jump as the most accurate field tests for detecting the presence of metabolic syndrome in European adolescents 12.5 to 17.5 years, independent of CRE (Castro-Piñero et al. 2019). The criterion related validity of field-based measures of muscular endurance are difficult to determine due to the absence of an agreed gold-standard measure. Furthermore, the inability to isolate specific muscle groups in whole body tests of
muscular endurance makes it difficult to identify specific criterion measures. Correlations between field tests of muscular endurance vary from low \((r = 0.31)\) to moderately high \((r = 0.81)\), depending on the commonality of musculature (Welk and Meredith 2013). Such discrepancies emphasise the need for further research to confirm the criterion validity of field-based tests of muscular endurance. Contrasting findings have been reported for the criterion validity of field-based measures of flexibility. Both the passive straight leg raise and the active knee extension measured by flexometer, goniometer, or inclinometer have been used as criterion tests of hamstring (hip) flexibility. Castro-Pinero et al. (2009) concluded that the criterion-related validity of the sit-and-reach test and the back-saver sit-and-reach test for estimating hamstring flexibility is weak. However, in a review of the validity of field-based measures of flexibility, Plowman and Meredith (2013) stated the overwhelming pattern has been that the sit and reach is moderately to highly related to hamstring flexibility \((r = 0.39-0.89)\), and as such is a valid measure of hamstring flexibility.

Although not commonly administered as part of field-based fitness test batteries, there have been increasing calls for longitudinal tracking of BP among population-based samples in youth (Ruiz et al. 2007; Chen and Wang 2008). Technological advances have enhanced the validity and reliability of field-based measures of BP (Graves and Althaf 2006; Christofaro et al. 2009; Stergiou et al. 2009), and an increasing number of national (Woods et al. 2010) and international (Rosner et al. 2013) large-scale health surveys have included a measure of BP as an indicator of cardiovascular health. Indeed, a comparison between cuff measured BP and automated digital device recordings among 150 ten to 16 year old adolescents showed an equal to, or lower than, 10mmHg difference in 87.3% and 90.6% of systolic and diastolic values, respectively (Christofaro et al. 2009).
2.5.1.2 Predictive validity of field-based tests

In the context of HRPF in youth, predictive validity refers to the extent to which a test can predict future health. The predictive capacity of HRPF has been comprehensively addressed previously in this chapter. A systematic review of 42 studies on the predictive validity of HRPF in youth (Ruiz et al. 2009a) confirmed that CRE, body composition, and muscular strength and power were powerful indicators of future health. The authors reported strong associations between CRE in childhood and adolescence, and a healthier cardiovascular profile later in life. Furthermore, it was reported that muscular strength improvements from childhood to adolescence were negatively associated with changes in overall adiposity, and a healthier body composition was associated with a healthier cardiovascular profile later in life and with a lower risk of premature all-cause mortality (Ruiz et al. 2009a). Perhaps more importantly in the context of monitoring fitness in youth, it has also been reported that positive changes to CRE, musculoskeletal fitness and body composition in childhood and adolescence can mitigate the impact of negative health outcomes later in life (Ortega et al. 2013). The specificity of flexibility to a particular joint or joints of the body precludes any relationship between a given measure and a health marker. Despite this, the Institute of Medicine recommended measuring flexibility to “educate youth and their parents about flexibility as a component of overall musculoskeletal fitness, function, and performance” (Pillsbury et al. 2013, p.201).

2.5.2 Reliability of field-based fitness tests

Reliability can be described as the reproducibility of a test result in repeated tests on the same individual under the same conditions (Atkinson and Nevill 1998). A multitude of research has been conducted on the reliability of field-based tests of physical fitness. Artero and colleagues (2011) reviewed reliability indices reported in 32 studies and concluded that the 20m SRT, handgrip strength, standing broad jump and BMI were adequately reliable field-based fitness tests. ICC values from 0.78 to 0.93 were reported
for the 20m SRT among children and adolescents aged 8 to 18 years in five studies (Liu et al. 1992; Mahar et al. 1997; Pitetti et al. 2002; Beets and Pitetti 2006). Reliability coefficients of 0.96 to 0.98, and non-significant differences \( p > 0.05 \) between test and retest measures were also reported for handgrip strength (Espana-Romero et al. 2010b; Artero et al. 2011). In a study examining the reliability of fitness measures administered by physical education teachers in school settings, Espana-Romero et al. (2010a) reported relatively small percentage error values of 2.3% for handgrip strength and 6.3% for standing broad jump. Ortega and colleagues (2008a) similarly reported non-significant \( p > 0.05 \) mean test-retest differences for handgrip strength and standing broad jump among 69 boys and 53 girls with a mean age of 13.6 years. In the same study, the 4×10 metre shuttle run test of motor fitness had a non-significant \( p > 0.05 \) mean inter trial difference of 0.1 ±0.7s for boys, and 0.1 ±0.8s for girls. The reliability of field-based measures of muscular endurance is far more variable than other components of HRPF. Acceptable reliability of the isometric plank hold test among children aged 8–12 years has been reported (Boyer et al. 2013), however, both Lubans et al. (2011a) and Morrow et al. (2010) reported poor reliability indices for the 90° push-up test. Lubans and colleagues reported inter-test CV values of greater than 15%, while Morrow et al. reported percentage agreement of 0.74 for the repeated push-up test. In contrast, Jackson et al. (2006) and Baumgartner (2002) reported excellent reliability for the 90° push-up with college-age subjects. Plowman and Meredith (2013) noted that the 90° push-up was selected as the recommended test item in Fitnessgram® because it has some very practical advantages over other commonly used tests such as the pull-up.

The reliability of BMI measures, administered in school-based physical education programs, has been shown to be higher when compared with other estimates of body composition such as skinfolds or waist circumference. Test-retest error values of less than 1% for BMI were reported by Espana-Romero et al. (2010a) in an analysis of the
reliability of teacher-administered fitness tests in school settings. In an examination of the reliability of the Fitnessgram® test battery administered by 23 teachers to 1010 students in the United States, Morrow and colleagues (2010) also reported very high test-retest agreement of 97%. Reliability data, spanning a period of 50 years, have shown that the sit and reach test, and its various alternatives including the back-saver and modified versions, are extremely consistent (Plowman and Meredith 2013). For example, Chillón and colleagues (2010) tested 138 adolescents (57 girls) on both versions of the sit and reach test (back saver and traditional) while simultaneously measuring hip (sacral), lumbar (back), and thoracic (chest) angles using angular kinematic analysis and reported a mean difference between the two tests of 0.41 cm, which was deemed meaningless from a practical point of view. Hartman and Looney (2003) found similarly high ICC levels of 0.98 for the sit and reach test in a study involving 87 boys and 62 girls, aged 6 to 12 years.

The challenges of youth fitness testing conducted in field-based settings, particularly in schools, are such that they are prone to various sources of measurement error (Mahar and Rowe 2008). A comprehensive analysis of these challenges specific to a school context is provided in the penultimate section of this chapter. Some contend that physical fitness cannot be measured accurately in field settings (Welsman and Armstrong 2019b), however, as Welk (2008) noted, a high level of precision is not essential when goals are focused on teaching physical activity and fitness concepts, or teaching behavioural skills. Nonetheless, just like any other academic subject, confidence in test results depend upon careful test design and administration, that incorporate a sound understanding of the aforementioned principles of validity and reliability. Mahar and Rowe (2008) stated, although it may seem that researchers and educators have very different purposes for administering youth fitness tests, there are fundamental measurement principles that underlie sound fitness testing regardless of the purpose and who is administering the test. While no testing situation can be perfect, there are various
steps that field-based practitioners can take to minimize the potential sources of error and, therefore, optimize the likelihood that test scores will be reliable (Mahar and Rowe 2008). Specific examples of pedagogically sound and scientifically rigorous approaches to maximising the reliability of fitness tests in school settings are addressed in Chapters Four and Five of the current thesis. The role of schools, and physical education programmes specifically, in measuring and monitoring HRPF is addressed in the following section.

2.6 Schools, physical education and health promotion

Schools have been identified as the best setting to promote healthy lifestyle behaviours in youth (Cooper et al. 2010), and physical education has been described as the most powerful tool to systematically influence the health of children and adolescents (Pate et al. 2006). Although schools have not been implicated as a cause for global trends of declining physical activity and physical fitness levels, Welk et al. (2011) stated that they are clearly an integral part of the solution due primarily to the ability to reach and influence large numbers of children in a comprehensive and systematic way. It has been suggested that physical education teachers should assume a more prominent public health role (Bulger and Housner 2009), however, some scholars have noted that the role physical education has played in health promotion has been overlooked and taken for granted by governments and the wider public (Green and Hardman 2004). Nonetheless, the unique position of physical education, as one of the primary vehicles to promote the importance of health and activity among young people (Pate et al. 2006) has been increasingly acknowledged in recent years by national (Department of Health 2016) and international (Hallal et al. 2012) policy makers. The surge in research promoting the concept of comprehensive school physical activity programmes (CSPAP) (Castelli et al. 2014), of which physical education is collectively recognised as the cornerstone, further illustrates the enhanced status of the subject. However, Kennedy et al. (2017) caution that although
it is collectively recognised as a key component of CSPAPs, much research has confirmed that physical education programmes have historically focused largely on traditional competitive team games and sports, and that such activities, although enjoyable for some, are unlikely to prepare most young people for lifelong physical activity. This further illustrates the need, both from an educational and public health viewpoint, for health-related physical fitness to become a priority in physical education settings (Csányi et al. 2015).

2.6.1 Fitness testing in school-based physical education programmes

Despite its long history and continued prevalence in schools, much debate has enveloped the place of fitness testing in physical education (Lloyd et al. 2010). Over the course of the past three decades, multiple research articles have been published debating the role of fitness testing in schools (Whitehead et al. 1990; Rowland 1995; Keating 2003; Alfrey and Gard 2014). One of the original commentaries, entitled “The Horse is dead, now let’s dismount” published by T.W Rowland in 1995, suggested that the practice of fitness testing children should be stopped because the results are meaningless and not used appropriately. This article sparked a range of opinion pieces on the role of HRPF testing from leading experts in paediatric exercise science and sport pedagogy (Cale et al. 2007; Liu 2008; Cohen et al. 2015). Critics argued that fitness testing in physical education has enjoyed a ‘privileged position’ (Alfrey et al. 2019), and that it may well represent a misdirected effort in health promotion due to a lack of evidence supporting its role in promoting physical activity (Cale and Harris 2009). Some scholars also questioned the educational value, noting that students may not understand the rationale of fitness tests or the meaning of the results they obtain (Pluim and Gard 2016). It has been submitted that sport-specific settings, such as youth sports clubs, rather than schools, represent a more appropriate context for fitness testing (Naughton et al. 2006). A recent study on the
relationship between fitness test performance and students attitudes towards physical education concluded that the authors remained pessimistic about the use of fitness tests in physical education because fitness tests were implemented in isolation of the broader curriculum (Simonton et al. 2019).

In contrast, proponents have highlighted the potential educational and health benefits of fitness testing in school-based physical education programmes, with many scholars noting the importance of students learning how to self-assess their own fitness levels (Castelli and Williams 2007; Mercier and Silverman 2014a). Mahar and Rowe (2008) highlighted the benefits of physical education teachers being able to provide individualised feedback to students about their fitness and make recommendations for increasing or maintaining current fitness levels. Welk (2008) also suggested that fitness testing can be used effectively to teach children about the components of health-related fitness and to motivate children to become more active. Similarly, from a health perspective, the increase in longitudinal data confirming the predictive capacity of HRPF in youth has led to calls for an increased focus on enhancing students’ ability to self-assess their HRPF levels (Ruiz et al. 2006b; Silverman et al. 2008). Indeed, Espana-Romero and colleagues (2010a) confirmed that, following familiarisation training, HRPF tests administered by physical education teachers are reliable, feasible and safe to be performed in the school setting. The interpretation and use of fitness tests in physical education involve important educational, pedagogical, and psychological consequences (Mahar and Rowe 2008). As Pate (2013) stated, fitness tests administered in an insensitive, punitive fashion, will inevitably have negative consequences, and could be de-motivating and counterproductive to the promotion of active lifestyles in young people who are most in need of guidance. Evidently, the debate on the place of fitness testing in schools remains as divisive as ever, however, there is an emerging majority consensus among prominent scholars in sport pedagogy, paediatric exercise science and related fields of
research that, if integrated appropriately and subjected to informed critique, there is no reason why fitness testing could not play a role in supporting healthy lifestyles and in educating young people about physical activity and fitness (Silverman et al. 2008; Cale et al. 2014; Cohen et al. 2015; Welk 2017).

2.6.2 Pedagogically sound recommendations for integrating fitness testing

At a school level, it is teachers that have the greatest impact on children’s educational experiences and achievements (Hattie 2012). Quality physical education programs play a unique role in developing young people, who have the physical competence and cognitive understanding about physical activity and fitness, to adopt healthy and active lifestyles (Phillips et al. 2017). Thus, the importance of administering concepts like fitness tests in a pedagogically sound manner is intensified given the aforementioned sensitivities associated with it. Many research articles have been published on best-practice approaches to integrating fitness tests in school-based physical education programmes (Corbin and Pangrazi 2008; Cale et al. 2014; Phillips et al. 2017; Zhu et al. 2018).

Recommendations included; to move away from command-style test administration and adopt a more reciprocal, student-centred approach (Graser et al. 2011); use criterion rather than norm referenced health standards to promote self-referenced comparison with attainable health standards (Mahar and Rowe 2008); not allow fitness monitoring to dominate or be conducted in isolation, but, ensure it is fully and appropriately integrated into the curriculum (Cale et al. 2014); and allow students an opportunity to familiarise themselves with tests prior to testing (Martin et al. 2010). If fitness testing is to contribute toward positive attitudes and promote lifelong physical activity, it needs to be used in educationally sound ways, otherwise it will not reap the benefits that are possible from a well-planned fitness education unit (Mercier and Silverman 2014a). Surprisingly, despite the abundance of information regarding effective methods to administer fitness tests in a
physical education context, many of these recommendations are based on the opinions of prominent scholars or anecdotal evidence, and have yet to be examined empirically.

2.6.3 Fitness test batteries

HRPF levels in youth are often assessed in the form of a test battery, which can be defined as a combination of two or more tests that measure one or more components of fitness (Bianco et al. 2015). In recent years, a great deal of attention has been devoted to reporting secular declines in fitness levels among youth. As a result, numerous field-based fitness test batteries have been developed to assess and monitor physical fitness in this population. Indeed, several states in the United States, and countries including Japan, China, Columbia, Slovenia, Hungary, and Finland, have mandated monitoring fitness through the medium of school-based physical education programs (Csányi et al. 2015; Miller et al. 2016; Salin and Huhtiniemi 2018; Shephard 2018). Table 2.1, modified and updated from Castro-Pinero et al. (2009), provides an overview of the 12 fitness test batteries currently used among adolescent youth in school settings internationally.
Table 2.1 Fitness test batteries used among adolescent youth in school settings internationally, modified and updated from Castro-Pinero et al. (2009).

<table>
<thead>
<tr>
<th>Test Battery (Acronym)</th>
<th>Full title</th>
<th>Organisation</th>
<th>Country/Region</th>
<th>Age</th>
<th>Admin-istrator</th>
<th>Software platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPHA-FTB</td>
<td>Assessing Levels of Physical Activity Fitness Test Battery</td>
<td>Council of Europe (formerly Eurofit)</td>
<td>Europe</td>
<td>6-18</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>Fitnessgram</td>
<td>-</td>
<td>The Cooper Institute</td>
<td>USA</td>
<td>5-17</td>
<td>Teacher</td>
<td>Yes</td>
</tr>
<tr>
<td>CNSFPS</td>
<td>Chinese National Student Physical Fitness Standard</td>
<td>Ministry of Education</td>
<td>China</td>
<td>6-18</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>FUPRECOL</td>
<td>-</td>
<td>Universidad del Rosario, Bogotá, D.C, Colombia</td>
<td>Columbia</td>
<td>9-17</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>AFEA</td>
<td>Australian Fitness Education Award</td>
<td>Australian Council for Health Physical Education and Recreation</td>
<td>Australia</td>
<td>9-18</td>
<td>Teacher</td>
<td>Yes</td>
</tr>
<tr>
<td>Net-fit</td>
<td>Hungarian National Student Fitness Test</td>
<td>Hungarian School Sport Federation</td>
<td>Hungary</td>
<td>11-19</td>
<td>Teacher</td>
<td>Yes</td>
</tr>
<tr>
<td>SLOfit</td>
<td>Slovenian National Surveillance System for physical and motor development</td>
<td>Ministry of Education Science and Sport</td>
<td>Slovenia</td>
<td>6-19</td>
<td>Teacher</td>
<td>Yes</td>
</tr>
<tr>
<td>PFAAT</td>
<td>Physical Fitness and Athletic Ability Test</td>
<td>Ministry of Education, Culture, Sports, Science and Technology</td>
<td>Japan</td>
<td>6-19</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>NAPFA</td>
<td>National Physical Fitness Assessment</td>
<td>Ministry of Education</td>
<td>Singapore</td>
<td>6-18</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>GTO/TRP</td>
<td>Ready for Labour &amp; Defence</td>
<td>Ministry for Sport of the Russian Federation</td>
<td>Russia</td>
<td>6-17</td>
<td>Teacher/Trained Assistant</td>
<td>No</td>
</tr>
<tr>
<td>GMT</td>
<td>German Motor Test</td>
<td>Karlsruhe Institute of Technology</td>
<td>Germany</td>
<td>6-18</td>
<td>Teacher</td>
<td>No</td>
</tr>
<tr>
<td>ASSO</td>
<td>Adolescents Surveillance System for the Obesity prevention</td>
<td>Ministry of Health</td>
<td>Italy</td>
<td>12-18</td>
<td>Teacher</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Of the test batteries listed in Table 2.1, Fitnessgram® and the ALPHA test battery have been identified as the most commonly administered school-based test batteries, internationally (Kolimechkov 2017). Fitnessgram® is used in approximately 20000 schools to assess over 10 million students each year in the United States alone, and the creators are actively involved in 20 international collaborations (Pluim and Gard 2016). The Fitnessgram® test battery is a comprehensive assessment of all components of HRPF including aerobic capacity, body composition, abdominal strength and endurance, trunk...
extensor strength and flexibility, upper body strength and endurance, and flexibility (Welk and Meredith 2013). Within these six categories, teachers have the options to select specific tests for each component of HRPF (Plowman and Meredith 2013). The ALPHA test battery, designed specifically for administration in school settings, was developed based on the results of three systematic reviews on the predictive validity (Ruiz et al. 2009a), criterion validity (Castro-Pinero et al. 2009) and reliability (Artero et al. 2011) of field-based fitness tests in youth. The developers aim was to provide a set of valid, reliable, feasible and safe field-based fitness tests for the assessment of HRPF in children and adolescents, in order to facilitate public health monitoring in a comparable way within the European Union. Since its original inception 2010, the ALPHA test battery has been used in several countries including Argentina (Secchi et al. 2014), Columbia (Ramírez-Vélez et al. 2015) and Spain (Moliner-Urdiales et al. 2010). The ALPHA test battery includes measures of CRE (20m shuttle run test, 20m SRT), musculoskeletal fitness (handgrip and standing broad jump,), motor fitness (4x10m shuttle run) and body composition (BMI) (Ruiz et al. 2011). As noted by Csányi and colleagues (2015) although validity, reliability, and comparability are important factors, tests that are administered in school-based physical education programmes must be simple to perform, require minimal equipment, and be motivational for students to complete. Furthermore, to ensure utility for national surveillance, the assessments should be sequenced in an easy-to-use battery (Csányi et al. 2015). Table 2.2 provides a breakdown of the field-based test items used in the 12 fitness test batteries currently administered to adolescent populations in school settings.
Table 2.2 Field-based fitness tests used to assess physical fitness among adolescent youth, by country.

<table>
<thead>
<tr>
<th>Component</th>
<th>Fitness Test Battery (country)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRE</td>
<td>Alpha (EU) • • • • • • • • • •</td>
</tr>
<tr>
<td>20m SRT (PACER)</td>
<td>• • • • • • • • • • •</td>
</tr>
<tr>
<td>Body Comp.</td>
<td>BMI • • • • • • • • • • •</td>
</tr>
<tr>
<td>Fitness Test Battery</td>
<td>Muscular Fitness</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>•</td>
</tr>
<tr>
<td>Standing broad jump</td>
<td>•</td>
</tr>
<tr>
<td>Push-up</td>
<td>•</td>
</tr>
<tr>
<td>Curl-up/sit-up</td>
<td>• • •</td>
</tr>
<tr>
<td>Pull-up/arm hang</td>
<td>• • •</td>
</tr>
<tr>
<td>4x10m shuttle</td>
<td>•</td>
</tr>
<tr>
<td>Timed rope Skip</td>
<td>•</td>
</tr>
<tr>
<td>Timed Sprint</td>
<td>•</td>
</tr>
<tr>
<td>Ball/Object throw</td>
<td>• • •</td>
</tr>
</tbody>
</table>

Fitness test battery abbreviated names provided in Table 2.1. Abbreviations; EU, European Union; US, United States; Aus, Australia; Col, Columbia; Hun, Hungary; Slov, Slovenia; Ger, Germany; Sing, Singapore; CRE, cardiorespiratory endurance; PACER, progressive aerobic cardiovascular endurance test; body comp, body composition; circ, circumference; BIA, bioelectrical impedance analysis. *Includes back-saver sit and reach test.
2.6.3.1 Cost, availability of instructional materials, and test administrators

HRPF test batteries developed for use in school settings need to be cost effective, include instructional materials and should be suitable for administration by non-expert populations (Espana-Romero et al. 2010a). A recent review of trends in youth fitness testing internationally by Keating et al. (2018) noted that, of the four most prominently used test batteries, namely Fitnessgram® (USA), CNPFT (China), ALPHA (Europe) and GTO (Russia), none included a total price for purchasing test kits. Fitnessgram®, the most popular test battery internationally, requires minimal equipment costs, however, an initial payment of $599 for the first year, and a $149 annual renewal fee, is required to use the software package to facilitate tracking students test scores. The ALPHA test battery similarly requires minimal equipment, with the exception of a handgrip dynamometer which can cost up to $350-450 (Keating et al. 2018). In terms of instructional material, both the ALPHA (Ruiz et al. 2011) and Fitnessgram® (Welk and Meredith 2013) test batteries have freely available user guidance manuals that detail the scientific underpinning and administration protocols for each test item. The Fitnessgram® user manual also contains criterion referenced values for adolescent age groups, while the ALPHA manual contains European normative values generated from a study by Ortega et al. (2011a). Of the test batteries listed in Table 2.1, all were designed specifically for administration in school settings by a physical education teacher, with the exception of Russia’s GTO test battery, which includes optional sport specific test items, such as shooting and skiing, and thus provides the option for a trained adult to administer test items outside of school time (Keating et al. 2018).

2.6.3.1 Student facilitators

Student-centred or peer-facilitated learning can be defined as a learning process whereby students learn from and with others. This can be with students of the same-age or across different age groups (Jenkinson et al. 2012). In light of adolescents’ preferences to
interact with and therefore be influenced by peers, the case for peers assisting peers in many roles including education is both feasible and compelling (Ellis et al. 2009). Interestingly, it has been reported that cross-age tutoring is more likely to enable the tutor to demonstrate greater knowledge, eliminate the competitive element between peers and protect the tutees' self-esteem (Cohen et al. 1982). Time constraints are frequently cited as among the biggest challenges by teachers when administering HRPF tests in school settings (Martin et al. 2010; Cale et al. 2014). Many prominent HRPF test batteries internationally including the Australian Fitness Education Award and Fitnessgram® recommend recruiting facilitators to assist the physical education teacher in both the set-up and delivery of fitness test batteries. It has been suggested that peer-facilitated learning in a physical education context may overcome some aspects that impede student learning by providing opportunities for increased levels of individualised feedback and less direct instruction from the teacher (Ward and Lee 2005), while simultaneously reducing the burden on teachers (Lubans et al. 2011b). A recent systematic review concluded that peer facilitated learning may be conducive to promoting a positive and engaging learning environment for both the facilitator and participant (Jenkinson et al. 2014).

There is a need for more research on best practice methods for integrating peer facilitated learning across various components of school-based physical education curricula. In the context of fitness testing, leading scholars have suggested that a student-centred or peer-facilitated approach affords participants the opportunity to develop a sense of personal control and fitness autonomy (Biddle and Fox 1998). Prusak and Vincent (2005) also suggested that students tested in an environment that supports their autonomy will be more motivated to participate and strive for self-improvement. However, to the authors’ knowledge, no research to date has quantified either the reliability or feasibility of a student-administered approach to fitness testing.
2.6.4 Teachers and students attitudes towards fitness testing

Attitude is something that influences every part of life, and understanding the attitudes of students and teachers towards HRPF testing, and physical education more broadly, is imperative to inform practice. In a recent review of attitude research in physical education, Silverman (2017) concluded that, as students get older, their attitudes become less positive, and this decline is more pronounced in girls. Much of the research in relation to students and teachers attitudes towards fitness testing has been conducted in the United States. Ferguson and colleagues (2007) reported that both preservice and in-service teachers (n= 323) had neutral to slightly positive attitudes toward fitness testing. It has also been suggested that these attitudes do not change during a teacher education program, and that they may be based mainly on previous experience with fitness tests (Keating 2003). Mercier and Silverman (2014b) developed an 18-item instrument comprising of four sub-factors (cognitive, affect-enjoyment, affect-feelings, and affect-teacher) to measure students’ attitudes towards fitness testing that was shown to produce valid and reliable scores with adolescent populations. In the only large-scale study to use this instrument and quantitatively examine students’ attitudes towards fitness testing to date, Mercier and Silverman (2014a) concluded that students (grades 9-12) had a slightly positive attitude toward fitness testing, and, on a five-point Likert scale ranging from one strongly disagree to five strongly agree, boys (M= 3.28, SD.74) had more positive attitudes than girls (M=2.97, SD.66). Several studies have reported on students and teachers attitudes towards and experiences of fitness tests using qualitative methods, including Alfrey and Gard (2014) who found that teachers’ (n=8) philosophies appeared to shift and range determinedly in favour of fitness testing to highly sceptical of their value in a school context. In an exploratory study which investigated the factors that influence high school girls’ enrolment in elective physical education, Davis et al. (2018) indicated that students’ (n=17) acknowledged the importance of HRPF, but desired less
of a focus on fitness testing. There is paucity of research examining teachers and students’ attitudes towards fitness testing outside of the United States.

2.7 Monitoring health-related physical fitness in youth

Monitoring or surveillance involves the systematic collection, analysis and interpretation of data from well-defined populations (Hallal et al. 2012). High quality data from population-based samples is a crucial resource that can inform policy makers and practitioners in the design and development of evidence-based and targeted interventions (Froberg 2014). Epidemiological studies suggest that scores corresponding to the different components of physical fitness are often better predictors of health status than levels of habitual physical activity in youth (Guedes et al. 2012). As previously discussed, Domone et al. (2016) emphasised that any large-scale fitness testing of children would need to be conducted in field settings as opposed to laboratory settings, as the provision of resources required for the latter would be prohibitive. Furthermore, given the difficulty and expense involved in objectively measuring physical activity in youth (Welk et al. 2000), it has been suggested that it could be more useful to measure and monitor physical fitness (Lang et al. 2018).

Leading international organisations, including the WHO, have recommended establishing comprehensive surveillance tools for monitoring both physical activity and fitness in youth in order to inform the development of non-communicable disease prevention programmes (WHO 2018). In light of this, and the accumulating evidence base confirming the predictive capacity of HRPF as a marker of health, many national (CSPPA, Growing Up in Ireland) and international (NHANES, HELENA) health surveillance surveys have been updated to include measures of physical fitness. Some countries have also mandated monitoring HRPF through the medium of school-based physical education programmes, which has resulted in the development of several
comprehensive school-based HRPF surveillance systems (Csányi et al. 2015; Ramírez-Vélez et al. 2015; Jurak et al. 2019). Monitoring HRPF in youth within a school context, specifically, is examined in the following paragraph.

2.7.1 Monitoring HRPF in youth in a school context

The ability to capture data through schools provides a unique opportunity to systematically evaluate educational, environmental and policy variables that may influence youth fitness (Kelly et al. 2010; Kim 2012; Sanchez-Vaznaugh et al. 2012). Despite the prevalence of fitness testing internationally (UNESCO 2014), surprisingly little research has been conducted on health monitoring practices in schools (Cale et al. 2014). As indicated in the previous section, if the purpose of HRPF testing was surveillance only, it would not be necessary or logical to test every child, as accurate estimates of youth fitness levels can be obtained through stratified sampling of much smaller sample sizes (Martin et al. 2010). However, if there is a strong educational rationale in addition to a health rationale underpinning HRPF testing, there is no reason why regular monitoring should not form part of a school-based physical education programme (Csányi et al. 2015).

Valid, reliable and safe large-scale fitness testing in schools will not occur unless those involved receive proper knowledge, preparation, motivation, and support (Martin et al. 2010). Martin and colleagues also highlighted some of the challenges associated with large-scale fitness testing from the perspective of teachers, and caution that bad or poor data are worse than no data. Recommendations to improve the quality of large-scale fitness monitoring included: professional development workshops for pre-service and in-service teachers (Silverman et al. 2008); provision of adequate equipment in all schools (Martin et al. 2010); getting financial, theoretical, oral, and written support from school management or relevant regional education boards (Martin et al. 2010); and administering
the test in a professional, organized manner (Cale et al. 2014). Furthermore, at an individual level, Martin et al. (2010) suggested that software platforms, that facilitate access to current and past student fitness data, would help improve the quality of teacher feedback on test results, which could lead to better information for students and their parents/guardians about lifetime health and fitness. Examples of software platforms used to monitor HRPF in schools are discussed in the next paragraph.

2.7.2 Software monitoring platforms

Software tracking technology that facilitates monitoring students’ health-related fitness is a key component of many test batteries internationally, including Fitnessgram® in the United States (Welk and Meredith 2013), SLOfit in Slovenia (Jurak et al. 2019) and Netfit in Hungary (Csányi et al. 2015). As previously mentioned, many researchers have highlighted the opportunity for the development of efficient systems for large-scale collection of HRPF data in schools, and the transfer of this data to centrally located databases (Ruiz et al. 2006b; Bianco et al. 2015). Examples of software platforms for monitoring physical fitness in youth currently in use internationally are detailed in the following paragraphs. An overview of some of the challenges associated with large-scale monitoring are also addressed.

The concept of using computers to store students’ fitness test results and print reports had its origin as far back as 1977, when Charles L. Sterling recognised school administrators and parents’ interest in a physical fitness report card (Plowman et al. 2006). This would ultimately lead to the creation of Fitnessgram®, which, as previously mentioned, is now the world’s most popular school-based fitness test battery and monitoring software platform (Pluim and Gard 2016). The Fitnessgram® software program is web-based, and is available in three versions; 1) For states and metropolitan districts wanting to conduct fitness data collection on a large-scale. 2) For two or more
schools in a district. 3) For one school in a district (Welk and Meredith 2013). Once the software package has been downloaded, it is up to the teacher or school IT staff to establish the data relationships of district, school, teacher, class, and student, before Fitnessgram® results can be inputted. A bulk import function also exists which can save time by importing teacher, class, or student information, as well as historical data from other Fitnessgram® programs. A key component of the Fitnessgram® software platform is individually tailored feedback reports for both students and their parents (Welk and Meredith 2013). Bai et al. (2015) noted that, although Fitnessgram® was not developed specifically as a surveillance tool, the large and distributed sample of schools who use the software to track results provided a useful benchmark for a national profile of health related fitness, in addition to population-level evaluations of fitness based on key demographic characteristics (Bai et al. 2016). Indeed, Welk (2017) noted that the publication of studies based on Fitnessgram® data gathered from schools in prominent medical journals emphasises the acceptance of this type of field-based data collection for research applications.

For more than 30 years, Slovenia has been a pioneer in the surveillance of physical fitness in school children. Every year all primary and secondary schools in Slovenia participate in the SLOfit test battery. Indeed, the test battery has also recently been administered to the university student population (Jurak et al. 2019). The Slovenian Ministry of Health developed a web-based application entitled My SLOfit, which allows students, parents, teachers and physicians web access to SLOfit results (Jurak et al. 2019). One of the unique components of the SLOfit software programme is the sharing of data with physicians, the only monitoring platform of its kind internationally to do so. Enrolment in the SLOfit system requires student and parental informed consent, which enables participant data to be processed centrally. Following test administration, data are sent from schools to the Faculty of Sport at the University of Ljubljana where they are
cleaned and analysed (http://en.slofit.org/, last accessed: 11/02/20). Tailored feedback reports, which include comparisons with the national average, are then sent back to schools for each student, class and school (Jurak et al. 2019). Declining levels of fitness and increasing rates of obesity, initially predicted to exceed 30% of the entire Slovenian adolescent population by 2020, were reported as part of the SLOfit data in the late 1990’s and early 2000’s. In light of these findings, program coordinators successfully lobbied the Ministry of Sport to provide two additional hours of physical education per week and a broader Healthy Lifestyle initiative for youth was established. Remarkably, trends from 2010 to 2015 now estimate a reduction in the prevalence of overweight to 22% by 2020 (Jurak et al. 2019).

Another eastern European country that has recently developed a standardised approach to tracking HRPF in schools using a centralised data management system is Hungary. The Hungarian Government, in collaboration with the Cooper Institute in the United States, developed a test battery and software monitoring platform, entitled Netfit, that has been administered to 1.2 million children in 4000 schools (Csányi et al. 2015). A comprehensive overview of the systematic 13-step plan involved in the development of the Netfit test battery and web-based monitoring platform is available in Csányi et al. (2015). The Hungarian School Sport Federation organized 30 hours of accredited and free of charge in-service training detailing test administration protocols and guidelines for inputting results to the web-based system for over 7100 teachers. HRPF test battery kits were also delivered to 3600 schools for free. Following in-service professional development training, physical education teachers were responsible for overseeing the administration of the Netfit test battery and uploading results to the web-based platform. The web-based platform was hosted by the Hungarian School Sport Federation and site administrators were available to assist teachers with any technical difficulties. Since its inception in 2015, research profiling the HRPF levels of Hungarian youth using data
generated from the Netfit test battery has been published in prominent research journals (Welk et al. 2015), further emphasizing the acceptance field-based data for research applications.

Examples of software monitoring platforms are less common in western European countries. The aforementioned ALPHA test battery (Ruiz et al. 2011) was created to facilitate monitoring in a comparable way in Europe, however, unlike Fitnessgram®, a software package enabling tracking of results was not developed as part of the project (Kolimechkov 2017). The Adolescent Surveillance System for Obesity prevention (ASSO) is a recent example of a project that has sought to introduce web-based tracking of multiple healthy lifestyle behaviours including activity, fitness and diet through schools in Italy (Tabacchi et al. 2016). The ASSO software package was developed to facilitate multi-site and standardised collection of data on obesity and its potential determinants such as diet, general health behaviours, physical activity, and fitness profiles among adolescents (Tabacchi et al. 2016). Following registration on the web-based platform, a username and password were automatically sent to teachers. Teachers participated in a 4-hour training session to standardize methodologies for data collection and a specially designed web-based tutorial detailing guidelines of the software platform was also provided. A unique component of the ASSO initiative was the inclusion of a science teacher who oversaw the administration of general health questionnaires, while the physical education teacher was responsible for administering and uploading data generated from the ASSO fitness test battery. The scalability of the ASSO programme is now being considered by the Italian Ministry following a successful pilot (Tabacchi et al. 2016). Some of the challenges associated with this and other web-based monitoring platforms, in the context of school-based physical education, are addressed in the following paragraph.
2.7.2.1 Challenges associated with multi-site monitoring

Martin and colleagues (2010) outlined some of the many challenges associated with large-scale fitness testing, concluding that bad or poor data are worse than no data. The authors noted that some students viewed testing as punishment, an opinion reinforced by a minority of teachers conducting the tests. Teachers also reported a lack of experience and knowledge of using the Fitnessgram® software platform as a significant challenge and time constraint (Martin et al. 2010). Morrow et al. (2010) similarly reported that large-scale, multi-site fitness testing can be fraught with problems unless properly planned and conducted. The authors’ emphasised the importance of administrators, politicians, educators, and local, state, or national researchers representing health agencies being able to trust the data, read reports, and make informed, evidenced-based decisions. Financial constraints associated with the purchase of test battery equipment and software were also reported (Martin et al. 2010). Some of the biggest challenges associated with the ASSO software platform were the lack of availability of computers and adequate internet connectivity in many schools (Tabacchi et al. 2016). Teachers also noted the time taken to input student data as a significant constraint. In terms of data processing, many of the open-ended style questions included in the health behaviour surveys were converted to closed-ended questions, and biologically plausible limits were included in result input fields to improve both the accuracy and efficiency of inputting students results (Tabacchi et al. 2016). Teachers and students losing or forgetting passwords and usernames was also noted as a regular issue on both the ASSO and SLOfit monitoring platforms. Interestingly, all of the fitness test batteries listed in Table 2.1 that include software monitoring platforms operate with full time system administrators to monitor data trends and provide system support for teachers. Furthermore, ASSO, Netfit and SLOfit were centrally funded by their respective government departments, minimising the cost burden on schools.
In summary, notwithstanding the many challenges presented in this section, the increasing number of countries that have implemented standardised HRPF test batteries and evaluation platforms through schools further illustrates the growing intersection between science and practice, and the potential for large-scale monitoring of key health indictors through schools (Welk 2017). It has been increasingly acknowledged that the systematic collection and tracking of physical fitness has emerged as a common, if not defining, characteristic within physical education, and its continued prevalence indicates that it will remain commonplace in schools into the future.

2.8 Summary

The aim of the current review was to provide a summary of health-related physical fitness in youth, its prevalence, historical use and application in school contexts. The review illustrates the predictive capacity of physical fitness as a powerful marker of health in youth, and provides a comprehensive summary of the current evidence base regarding the validity and reliability of field-based measures. This review confirmed the emerging prevalence of systematic tracking of physical fitness in school-based physical education programmes, while also highlighting many challenges and opportunities associated with field-based fitness testing. In summary, despite the prevalence of physical fitness monitoring internationally, and recommendations from national and international health promotion bodies, the Republic of Ireland lacks a clearly specified strategy for monitoring physical fitness in youth. Consequently, there is a dearth of research on the physical fitness levels of Irish adolescents and an absence of policy to support monitoring trends in order to inform interventions. As indicated during the course of the review, the collection of objective measures of health and physical fitness from population-based samples over pre-defined time periods is a crucial resource that can inform policy-makers, healthcare professionals and education authorities for timely planning of prevention
programs. In light of the findings from this review, and gaps in the current evidence-base, the overall aim of the current thesis is to develop a scientifically rigorous and pedagogically sound health-related fitness test battery and web-based platform to facilitate monitoring HRPF in secondary school settings in the Republic of Ireland.
Chapter Three: National survey of fitness monitoring practices in schools

This chapter has been published in the ‘Journal of Teaching Physical Education’:
3.1 Preface

Despite the prevalence of health-related physical fitness (HRPF) as a key curricular component of physical education programmes internationally (UNESCO 2014), there remains a paucity of research on HRPF monitoring practices in schools (Cale et al. 2014). This chapter presents the findings from a survey of physical fitness monitoring practices in secondary school-based physical education programmes in the Republic of Ireland. Prior to developing the Youth-fit test battery and software platform, detailed in Chapter Four, an examination of current monitoring practices was conducted in order to establish the prevalence of and approaches to fitness testing in secondary schools. The authors also sought to determine whether or not there was demand among key stakeholders for a standardised test battery and digital platform to facilitate monitoring HRPF. A total of 327 teachers from almost one third (N= 235, 33.1%) of secondary schools in the Republic of Ireland responded to the survey, with a demographic profile shown to be representative of the national sample. Over 95% of respondents indicated that they included HRPF testing as part of their physical education programme, confirming its prevalence. Just over half of teachers discarded results after a single use, less than 12% tracked students’ results from year to year, and only one third of teachers provided feedback on test results to the parents/guardians of their students’. Furthermore, teachers were overwhelmingly in favour of having access to a digital platform to facilitate tracking HRPF test scores. This survey provided a conclusive justification for the development of the Youth-fit HRPF test battery and web-based monitoring platform, as detailed in the remaining chapters of this thesis.
3.2 Abstract

**Purpose**: To examine the prevalence of and approaches to monitoring health-related physical fitness (HRPF) in secondary school-based physical education programmes. **Methods**: Physical education teachers (N= 327; 56.6% female) from 235 secondary schools (33.1% of national total) in the Republic of Ireland completed a survey designed specifically for the purposes of this study. **Results**: HRPF tests were used by 95.3% of teachers. A significant decline in testing frequency was observed from junior grades (13 to 15 years) to senior grades (16 to 18 years) (p < 0.001). Just over half (51.7%) of teachers discarded test results after a single use. Less than one third of teachers indicated that they provided feedback to parents/guardians on their students’ test results. The vast majority (87.0%) of teachers were in favour of the development of a digital platform to facilitate monitoring test results over time. **Conclusion**: HRPF testing is highly prevalent in secondary schools. More actions are needed to ensure teachers use pedagogically sound approaches towards monitoring HRPF, with a focus on learning that may lead to more positive testing experiences for students. Consideration should be given to the development of digital platforms to facilitate monitoring and reporting HRPF.

3.3 Introduction

The role of school-based physical education programmes in monitoring and promoting health has been extensively debated in recent years (Silverman et al. 2008; Alfrey and Gard 2014; Cale et al. 2014). The unique position of physical education as one of the primary vehicles to promote the importance of health and activity among young people (Pate et al. 2006) has been increasingly acknowledged by national (Department of Department of Health 2016) and international (Hallal et al. 2012) policy makers. Fitness testing has been part of school-based
physical education programmes for over half a century (J.R. Morrow, Jr. et al. 2009), and has been reported as the most common form of assessment used in physical education in the state of California, United States (US) (Ferguson et al. 2007). Despite the prominence of fitness testing in physical education programmes internationally (UNESCO 2014), calls for more extensive examinations of teachers’ use of fitness tests in school-based physical education programmes have mostly gone unanswered (Mercier et al. 2016). Therefore, little is known about teachers’ approaches to fitness testing in schools (Cale et al. 2014), particularly in countries where a standardised approach to HRPF monitoring does not exist.

Physical fitness is a complex and multi-faceted construct that includes performance related components and health-related components (Welk et al. 2000). In recent years, there has been a shift away from monitoring performance related components of fitness to health-related components (Pillsbury et al. 2013). Health-related components of fitness, including cardiorespiratory endurance (CRE), musculoskeletal fitness (muscular strength, endurance and power) and body composition, have been identified as powerful markers of future health among children and adolescents (Ortega et al. 2008b; Smith et al. 2014). Perhaps more importantly, positive changes to HRPF during adolescence can reduce the risk of negative health outcomes later in life (Ortega et al. 2012). In addition, high levels of HRPF have been associated with higher academic achievement (Bezold et al. 2014). HRPF is often assessed in the form of a fitness test battery in schools (Bianco et al. 2015). A fitness test battery is a group of two or more tests that measure one or more components of fitness. Some countries have developed test batteries in an effort to establish a standardised approach to fitness testing. International examples include Fitnessgram® (United States), CNPFT (China), ALPHA (European Union), GTO (Russia), SLOfit® (Slovenia), Netfit® (Hungary) and Move! (Finland). Indeed, several states in the US, and countries including Japan, China, Slovenia
Hungary and Finland have mandated monitoring physical fitness through the medium of school physical education programmes (Csányi et al. 2015; Salin and Huhtiniemi 2018; Shephard 2018). Assessments of physical literacy, such as the Canadian Assessment of Physical Literacy, also include measures of HRPF (Francis et al. 2016).

Despite its long history, the purpose of fitness testing in physical education remains a divisive topic (Lloyd et al. 2010). Proponents highlight the proposed educational and health benefits of HRPF monitoring (Csányi et al. 2015). Mahar and Rowe (2008) noted fitness tests can be used to provide individualised feedback to students about their fitness levels, promote goal setting and educate students about physical activity and fitness. Silverman and colleagues (2008) stated that, as with reading and mathematics instruction, it is important for students to monitor and improve their fitness test results. Many experts have also highlighted the importance of students being taught to self-assess their own fitness levels (Castelli et al. 2007; Mercier and Silverman 2014a). In a systematic review on the reliability of field-based fitness test batteries in youth, Artero et al. (2011) concluded that field-based testing was reliable in school settings and suggested schools presented a viable alternative to monitoring key markers of health in population-based studies. In contrast, many scholars have questioned the privileged position of fitness testing in physical education (Alfrey and Gard 2017). Cale and Harris (2009) suggested HRPF testing may well represent a misdirected effort in health promotion due to the lack of evidence supporting its role in promoting physical activity. In addition, it has been posited that fitness testing could be adding to the performative culture that many argue has enveloped education systems in recent years (Alfrey and Gard 2017). Wrench and Garrett (2008) have equally noted concerns over the unproblematic use of fitness testing, suggesting that many teachers incorporate it as a standalone component of a physical education programme. Naughton, Carlson and Greene
(2006) proposed that a more appropriate context for fitness testing may be in sports clubs rather than schools. Despite reservations regarding current implementation practices, Cale and colleagues (2014) concluded that, if integrated appropriately, there was no reason why fitness testing could not play a role in supporting healthy lifestyles and in educating young people about physical activity and fitness.

Over the past two decades, a wealth of research on pedagogically sound approaches to integrating fitness tests in school-based physical education programmes has been published (Cale et al. 2007; Liu 2008; Corbin et al. 2014). Recommendations included; moving away from command-style test administration, to a more reciprocal, peer–facilitated approach (Graser et al. 2011); using criterion rather than norm referenced health standards to promote self-referenced comparison with attainable health standards (Mahar and Rowe 2008); and allowing students an opportunity to familiarise themselves with tests prior to testing (Martin et al. 2010). In addition, it was advised that fitness tests should not be conducted in isolation, but included as part of a broader fitness education unit of learning (Wiersma and Sherman 2008). Although students are the primary focus when administering a HRPF test battery, it is teachers who determine whether fitness tests should be used, and how they are implemented (Silverman et al. 2008). A study by Mercier and Silverman (2014a) reported that teachers are a significant factor in shaping students’ attitudes towards fitness testing, and indeed, gaining teachers perspectives has become increasingly important for understanding pedagogical processes (Alfrey and Gard 2014). There has been, and continues to be, healthy debate on the place and purpose of fitness testing in school-based physical education programmes. However, there remains a dearth of empirical evidence on teachers’ uses of fitness tests in schools. Therefore, the aim of the current study was to
examine HRPF monitoring practices in secondary school-based physical education programmes in the Republic of Ireland.

3.4 Methods

3.4.1 Survey Development

A survey designed specifically for the purposes of this study was developed. Survey items were generated in part from the ‘Teachers Uses of Fitness Tests’ survey developed by Keating and Silverman (2004b), and a ‘Health, Activity and Fitness Monitoring’ survey administered by Cale, Harris and Chen (2007). The initial survey was categorised into three themes: *HRPF monitoring practices; Components and tests used; and Barriers to fitness testing*. Three response formats were utilised. (i) Closed-ended responses were used to obtain specific categories of response (ii) Open-ended questions were used where additional detail was required to explain a specific response and (iii) A seven-point Likert scale ranging from one (strongly disagree) to seven (strongly agree) was used for questions in relation to barriers to fitness testing (Keating and Silverman 2004b). In an effort to establish greater content validity, a review of the draft survey involving five experts in sport pedagogy was conducted. Experts were selected based on their knowledge and expertise in the area of health-related fitness and physical education. The lead author reviewed the survey with each expert individually. Using a five-point rating scale, the team of experts were asked to evaluate the relevance of the items in each theme (five = very relevant, one = not relevant). The expert review team were given the opportunity to record comments for each individual item and suggest new items or themes. The expert group were also asked to comment on the relevance of each theme. Using the thresholds as set out by Zhang and Chen (2017), it was determined that an item with a mean rating score below three out of five and/or with substantial revision
suggestions should not be accepted. The expert review panel provided specific recommendations regarding the inclusion of two additional themes, namely, test frequency and an open-ended question on the purpose of HRPF testing in physical education. A revised draft survey was circulated to the expert reviewers. All were satisfied with the revisions made and no additional comments were recorded.

The final amended survey (Appendix E) comprised of five themes. 1) *Frequency of test use*: This section sought to gather information regarding the time of year and frequency of HRPF testing. 2) *Monitoring practices*: Teachers were asked about the methods they used to record scores and provide feedback on test results. 3) *Components and tests*: This section contained questions in relation to the components of HRPF assessed and the tests used to assess these components. 4) *Barriers to HRPF testing*: Teachers were asked questions in relation to potential barriers to the implementation of HRPF tests in school settings, including gender differences, school facilities and equipment. 5) *HRPF testing in the physical education curriculum*: Finally, teachers were asked to provide a brief statement on whether or not fitness testing should be part of a physical education curriculum. To examine the internal consistency among the questionnaire items, a convenience sample of practising physical education teachers (n= 39; female= 24) were involved in a pilot of the questionnaire. Two approaches were used to examine internal consistency. Firstly, frequency counts of responses for similar ‘Yes’/‘No’ questions were reviewed and found to be consistent (Fowler 1995). In addition, correlations of responses between related and unrelated questions were computed for both the pilot and finalised survey. Low correlations were found between items that should not be strongly correlated. For example, the following two statements were not strongly correlated: “I find administering a fitness test lesson more challenging than a standard physical education lesson,” and “A HRPF test lesson is easy to deliver”, r(327)
= .24, p < 0.01. Moderate to high correlations were confirmed between items that should be related. For example, “I have the required knowledge to deliver a HRPF testing lesson”, and “My pre-service teacher education provided me with adequate knowledge to conduct HRPF fitness tests”, r (327) = .608, p < 0.01. Teachers were given the opportunity to note any questions that were unclear and make recommendations on how the survey could be improved. All participants agreed that the survey was clear and no additional comments were recorded.

3.4.2 Procedure

The current study utilized a cross-sectional survey design. For convenience and wide distribution, an online questionnaire was distributed via SurveyMonkey (SurveyMonkey, CA, US) cloud-based software. The Republic of Ireland education system is made up of three levels: primary (ages five to 12), post-primary or secondary (ages 13 to 18), and third level (i.e. Universities, Institutes of Technology). Specialist physical education teachers are only required at secondary level, which is comprised of junior cycle (age 13 to 15), a transition year (age 16) and senior cycle (age 17 to 18). In May 2017, 711 post-primary schools were registered in the Republic of Ireland on the Department of Education and Skills’ online database. An introductory email marked for the attention of the school’s physical education department was sent to the email address of all registered post-primary schools. The email outlined the purpose and objectives of the survey, as well as details regarding the time commitment and confidentiality of all data gathered. The email also provided a web link to access the survey. Informed consent was indicated by subsequent completion of the survey. Participants were informed that they may exit the survey at any time without implication. The timeframe for participation was set at five weeks, coinciding with the end of the school term in May 2017. To minimise non-response bias, a re-invitation to complete the survey
was circulated after two, four and five weeks. A unique school identifier code was used to track responses and target initial non-responders for the re-invitation process. After five weeks, all complete responses were downloaded from the SurveyMonkey platform and collated for statistical analysis.

### 3.4.3 Participants

Ethics committee approval for this study was granted by the Research Ethics Committee of the Faculty of Education and Health Sciences, University of Limerick (EHS_2017_02_12). Study protocols were approved by the lead author’s institute review board. Most physical education departments in Republic of Ireland schools contain more than one physical education teacher. Therefore, the project team agreed that all physical education teachers within each school could participate, as variations in programme design can exist within individual departments. A two year recall period was set for the questionnaire, as recommended by Keating and Silverman (2004). All elements of the questionnaire required an answer to minimise missing values. However, skip logic was used for some responses which accounts for the reduction in response numbers for some themes. For example, teachers who indicated that they did not use fitness tests were not required to complete questions in relation to HRPF monitoring practices.

### 3.4.4 Statistical Analysis

Complete responses \( (N = 327) \) were extracted from SurveyMonkey and converted for use in the Statistical Package for Social Sciences (SPSS version 24, Chicago IL) for analysis. The research team defined an incomplete response as having completed less than 80% of the overall survey or missing two or more items from one section. Incomplete responses \( (n = 34) \) were excluded from all analyses. The survey contained mostly closed-ended questions.
Therefore, responses were analysed descriptively which involved calculating and reporting percentages and frequencies. Means (M) and standard deviations (±) were calculated for data in section five, *Barriers to fitness testing*. Chi-square tests were used to assess differences among categorical variables. To check the normality of the scale scores, descriptive statistics, kurtosis, and skew were calculated. Mean, median, and mode were all approximated, and kurtosis and skew suggested normality was acceptable (George 2011). A z-test showed no significant differences between the components of HRPF assessed between year four (Transition year) and senior cycle (years five and six). Therefore, there was sufficient grounds to use the combined dataset of junior cycle (years one to three) and senior cycle (year four to six) when analysing differences in components assessed across year groups. The relationship between specific variables (e.g. teachers who track students’ results across school years and those who use computers to store results) were investigated using Pearson’s product-moment correlation coefficient. Responses to the only open-ended question regarding teachers’ views on whether or not HRPF testing should be part of the physical education curriculum were reviewed and organised thematically in line with the guidelines set out by Renner and Taylor-Powell (2003). This involved identifying themes and patterns from the responses. Once the key themes had been established and agreed upon by all members of the research team, responses were arranged into coherent categories and frequencies of responses within each category were calculated.

### 3.5 Results

#### 3.5.1 Demographics

The demographic profile of participants is provided in Table 3.1. Physical education teachers (*N* = 327; 56.6% female) from 235 secondary schools (33.1% of national total) completed the
survey. Responses by teachers in single sex and mixed sex schools (14.4% boys; 20.5% girls; 65.1% mixed) were shown to be representative of the national sample (14.2% boys; 18.5% girls; 67.3% mixed). There was an over representation of private fee-paying schools (9.8% survey; 7.1% national). However, a Chi-square test of independence indicated this did not have a significant effect on any of the key outcome variables (p ≥ 0.22). The regional spread of participants was consistent with state demographics (CSO 2016). Participants’ teaching experience ranged from one to 38 years (M = 12.8 ±9.2).

**Table 3.1** Demographic profile of participants.

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub Category</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender (Participants)</strong></td>
<td>Female</td>
<td>185(56.6%)</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>142(43.4%)</td>
</tr>
<tr>
<td><strong>Years Teaching</strong></td>
<td>1 (or less)</td>
<td>19 (5.8%)</td>
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<tr>
<td></td>
<td>2 to 5</td>
<td>62(21.2%)</td>
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<tr>
<td></td>
<td>6 to 10</td>
<td>69(18.8%)</td>
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<td></td>
<td>10 to 19</td>
<td>101(30.9%)</td>
</tr>
<tr>
<td></td>
<td>20 (or more)</td>
<td>76(23.3%)</td>
</tr>
<tr>
<td><strong>School Sex</strong></td>
<td>Boys</td>
<td>47(14.4%)</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>67(20.5%)</td>
</tr>
<tr>
<td></td>
<td>Mixed-sex</td>
<td>213(65.1%)</td>
</tr>
<tr>
<td><strong>School Type</strong></td>
<td>Public</td>
<td>203(90.2%)</td>
</tr>
<tr>
<td></td>
<td>Private (Fee Paying)</td>
<td>32(9.8%)</td>
</tr>
<tr>
<td><strong>No. of Students per class</strong></td>
<td>&lt;20</td>
<td>23(7.0%)</td>
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<tr>
<td></td>
<td>20-25</td>
<td>121(37.0%)</td>
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<tr>
<td></td>
<td>26-30</td>
<td>171(52.9%)</td>
</tr>
<tr>
<td></td>
<td>&gt;31</td>
<td>12(3.7%)</td>
</tr>
<tr>
<td><strong>Regional Breakdown of Schools</strong></td>
<td>Dublin (City + County)</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Connaught</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Leinster (ex. Dublin)</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Munster</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Ulster (Donegal, Cavan, Monaghan)</td>
<td>15</td>
</tr>
</tbody>
</table>

*The Republic of Ireland is divided into 4 provinces; Leinster, Munster, Connaught and 3 counties in Ulster. Dublin, Ireland’s largest city, comprises of almost 1/3 of the total population, is considered a separate region for the purpose of this demographic profile.*
3.5.2 Frequency of test use

The vast majority of the 327 respondents (95.3%) indicated that they used HRPF testing in their physical education programmes. Almost one third (29.9%) used HRPF tests with each class group on one occasion, 53.0% assessed twice and 12.4% of teachers assessed HRPF on three or more occasions per academic year. A Pearson product-moment correlation coefficient did not reveal a significant association between test frequency and (i) teacher gender ($r=0.06$, $p=0.48$), (ii) school type (boys, girls, mixed; $r=0.04$, $p=0.73$) (iii) or years’ teaching experience ($r=0.09$, $p=0.12$). A Chi-Square test of independence revealed a significant decline in monitoring frequencies from junior cycle (year one to three, ages 13 to 15) to senior cycle (year four to six, ages 16 to 18), $X^2 (1, n=327) = 137.20$, $p < 0.001$. The frequency of testing from year one to year six was not linear, with teachers of years two (ages 13 to 14) (96.6%) and three (ages 14 to 15) (97.2%) reporting highest frequencies of using HRPF tests.

3.5.3 Monitoring practices

Only 11.9% of teachers monitored students’ HRPF test scores from years one (13 years) to year six (18 years) and over half (51.7%) of teachers discarded test results after a single use. In addition, 27.7% ($n=91$) indicated that they tracked students’ results on a yearly basis but not across year groups. Hardcopy folders were the most commonly used method to store test results (69.2%). Computers or cloud-based software were used to store results by 17.8% of teachers. A weak but significant correlation was observed between teachers who tracked students’ results from year to year and those who used a computer to store results ($r=0.269$, $p<0.001$). A total of 85.9% of teachers indicated that they provided feedback to students on their results. However, only one third (33.1%) of teachers provided such feedback to students’
parents. The vast majority of teachers (87.2%) indicated that physical health was not monitored in school outside of physical education.

3.5.4 Components and tests used

Figure 3.1 and Figure 3.2 provide a breakdown of the components assessed in each year group and the tests used to assess these components. Cardiorespiratory endurance was the most commonly assessed component, with almost three quarters of teachers (71.2%) assessing it in all six year groups. Body composition was assessed least frequently, on average by 6.8% of teachers across all year groups. The PACER test (20m shuttle run test) was the most frequently administered test, used by 78.9% of teachers, followed by the sit and reach test (60.7%).

Figure 3.1 A breakdown of the HRPF components assessed in schools, by year group (grade).
3.5.5 Barriers to Fitness Testing

A chi-square test of independence revealed a significant difference between boys’ and girls’ reactions to fitness tests from their teachers’ perspective, $X^2 (2, n= 481) = 52.42, p < 0.001$.
A total of 65% of teachers indicated that boys respond positively to fitness tests, however, only 37% of teachers indicated that girls respond positively. With regard to school facilities, although 63.9% of teachers agreed or strongly agreed that their school had adequate physical education facilities, 69.4% of teachers indicated that they were required to share a sports hall on at least one occasion per week with another physical education class group. However, despite having to occasionally share PE facilities, teachers somewhat disagreed (M= 3.3 ±1.8) that administering a HRPF test lesson was more challenging than a standard PE lesson.

In terms of the selection of HRPF test measures, teachers indicated that they would be in favour of having a standardised test battery for monitoring HRPF in schools (M= 6.2 ±1.2). Teachers were also strongly in favour of having access to a digital platform that would facilitate tracking student scores and reporting results (M= 6.4 ±.94).

### 3.5.6 Reasons for fitness testing

Participants were asked to provide a brief statement as to why HRPF testing should or should not be part of a physical education programme. Of those who responded (n= 274), 252 (92.0%) were in support, while 22 teachers (8.0%) cautioned against the use of HRPF testing. No statistically significant differences were observed between male and female teachers’ responses. Educational benefits and student learning were the most commonly cited reasons for the inclusion of HRPF tests in a PE programme (17.3%, n= 48). One teacher stated, “Fitness testing is an educational tool and not an end in itself. Testing is used to give students an understanding of how components can be tested and to assist them in compiling their physical activity profile” (female teacher, mixed sex school). The importance of informing students of areas of strength and weakness across all the components of HRPF was the second most cited reason for its inclusion (13.4%, n= 37). For example, one teacher suggested it gives “students the opportunity for self-evaluation in relation to different aspects of health-
related fitness” (male teacher, single sex girls’ school). Many teachers cited the importance of HRPF in promoting physical health (12.3%, n = 34). One teacher described it as “essential for informing students about their physical health” (female teacher, single sex girls’ school). Teachers (n = 18) also noted the opportunity to compare students’ results against normative values, “it is great to see where a student is amongst their age range” (male teacher, mixed-sex school). Of the teachers who cautioned against the inclusion of HRPF testing (n = 22), many felt that it was the students who were least active that benefitted least. One participant argued that, “those students who achieve a good result are motivated to improve, but I find that those who perform poorly are embarrassed and display a negative attitude to testing” (male teacher, mixed-sex school).

3.6 Discussion

To date, examinations of HRPF monitoring practices in secondary schools have been generated from relatively small sample sizes that have not been representative at a national level (Keating and Silverman 2004b; Cale et al. 2014). This survey, shown to be representative of a national sample, and consistent with state demographics, is the first comprehensive review of HRPF monitoring practices to take place in the Republic of Ireland. The following discussions reflect on some of the key findings to emerge from the study.

3.6.1 Prevalence of HRPF testing

HRPF testing was a highly prevalent component of physical education programmes in secondary schools in the Republic of Ireland and was used by over 95% of teachers. This concurs with previous studies that have reported testing to be commonplace in school-based physical education programmes internationally. Cale et al. (2014) reported prevalence rates of 89% in the UK, while Keating and Silverman (2004b) reported slightly lower rates of 83%
in the US. Concerns have been expressed over HRPF testing often constituting an entire fitness education programme (Alfrey and Gard 2014). However, frequency rates reported in this study indicate that most teachers assessed HRPF on two occasions or less per academic year. Significant variations in the prominence of HRPF testing between junior cycle (year one to year three) and senior cycle (year four to year six) were observed. HRPF testing was far more prominent during students’ first three years of secondary education. There are several possible explanations for this, the most likely being the state leaving certificate examination which takes place in the final year of secondary education, leading to a subsequent reduction in the time allocated to physical education. Previous research at a national level by MacPhail et al. (2005) has highlighted the impact of the state Leaving Certificate examination on the time allocation for physical education, particularly during students’ final two years. They found that 88% of school principals were in support of physical education as a compulsory subject at junior cycle (ages 13 to 15), however, only 53% supported compulsory physical education at senior cycle (ages 16 to 18).

3.6.2 Monitoring practices

A logical reason for HRPF testing is to monitor students’ results over time. Yet, over half (51.7%) of teachers discarded test results after a single use, while less than 12% indicated that they tracked students results from year to year. There is a paucity of research internationally on HRPF monitoring trends in schools. Leading health experts have called for the development of efficient systems for large-scale monitoring of HRPF data, and the transfer of this data to centrally located databases (Ruiz et al. 2006b). Examples of such systems operated through school-based physical education programmes include SLOfit in Slovenia, Netfit in Hungary, and Fitnessgram® in the US. Participants in this study indicated that they were strongly in favour of developing a web-based solution to facilitate monitoring
HRPF. However, some scholars have expressed concern at the unprecedented levels of surveillance of young people (Webb and Quennerstedt 2010), suggesting it may be contributing to the performative culture that has dominated education discourse in recent times (Cale et al. 2014). Despite these concerns, we share the views expressed by Csányi and colleagues (2015) that HRPF monitoring should have a place in physical education programmes, both from an educational and public health viewpoint. As noted previously, HRPF in children and adolescents has proven to be a powerful predictor of health in later life (Ortega et al. 2008b) and physical education teachers are in a unique position to administer HRPF test batteries as a mechanism to educate students on the role of HRPF in leading a healthy lifestyle.

This investigation revealed many positive uses of HRPF tests in secondary school-based physical education programmes. These included, educating students on the importance of health and fitness, and providing a platform for students to self-evaluate their HRPF in the form of personal activity profiles. However, one of the more interesting findings was that less than one third of teachers shared test results with students’ parents. A recent study by Mercier, Phillips and Silverman (2016) revealed similar trends, with less than 30% of teachers indicating that they send students’ results home to parents/guardians. Communication between parents and teachers is a fundamental aspect of the education process (Jeynes 2007). Most of the existing HRPF web-based monitoring platforms, including Fitnessgram®, SLOfit and Netfit include an option that allows parents to view their child’s results. However, sharing HRPF results alone might be of little value in trying to promote engagement in physical activity. Such platforms for communicating HRPF results could also inform parents of their child’s physical activity levels and the current physical activity for health guidelines, in addition to the physical activity opportunities available in
schools and local communities. Cale and colleagues (2014) recommend complementing HRPF monitoring with physical activity monitoring via the use of simple questionnaires, activity diaries and pedometers which, they argue, represents a more holistic approach to monitoring.

3.6.3 Components assessed and tests used

Given that there is no standardised approach or recommended test battery for monitoring HRPF in the Republic of Ireland, a key objective of this survey was to examine the components of HRPF assessed and the fitness tests used by teachers. Cardiorespiratory endurance was the most commonly assessed component of HRPF in all year groups, almost twice as commonly assessed as any other component (see Figure 3.1). The prominence of some components including CRE at the expense of others, including musculoskeletal fitness, is a finding of potential concern. There is evidence to indicate that each HRPF component is independent, and we cannot compensate for a deficit in one component by excelling in another (Plowman et al. 2006). Similarly, studies which examine physical fitness in youth frequently select just one or two tests to represent the overall HRPF construct, which can be problematic if a true understanding of the relationship between HRPF and other variables is desired.

The 20m SRT, a measure of cardiorespiratory endurance, was the most commonly employed test, yet there has been some concern over the appropriateness and accuracy of such maximal tests in school settings (Wrench and Garrett 2008). However, an extensive review conducted by the Institute of Medicine concluded that the 20m shuttle run test is the most practical, valid and reliable test for assessing cardiorespiratory endurance in school settings (Pillsbury et al. 2013). That said, teachers should be given the scope to administer
tests that are most appropriate for the context in which they are teaching and submaximal alternatives such as a step test could therefore be considered (Buckley et al. 2004). Many researchers have also questioned the practice of monitoring body composition in school settings, suggesting that it is could lead to body shaming (Alfrey and Gard 2017). Although it was the least frequently assessed component, it was assessed by over one quarter (26.3%) of teachers with at least one year group. Several fitness test batteries internationally, including Fitnessgram® and ALPHA, among many others, include some form of body composition or anthropometric measure, as detailed in Table 2.2 in the previous chapter. The authors agree with Cale et al. (2014) who suggested that, any measurements of body composition should be dealt with sensitively, and not forced upon students.

### 3.6.4 Differences in boys’ and girls’ reactions

Another finding of interest was teachers’ perceptions of students’ reactions to HRPF testing. Almost twice as many teachers (65%) felt that boys had a more positive reaction to fitness testing compared to girls’ (37%). This corroborates the findings from a recent exploratory study by Davis, Zhu and Hagele (2018) which investigated the factors that influence high school girls’ enrolment in elective physical education. Participants (n= 17 girls) acknowledged the importance of HRPF, but desired less of a focus on fitness testing. Similarly, Zhu, Chen and Parrott (2014) found that boys reported significantly higher situational interest in the PACER (progressive aerobic cardiorespiratory endurance run) test in comparison to girls and that personal interest was a significant predictor of performance (Zhu et al. 2014). The prominence of the 20m shuttle run test in schools’ HRPF monitoring practices could be a significant factor in explaining the disparity between boys and girls experiences of HRPF tests. Students’ motivation to participate in HRPF testing could have a significant impact on their performance (Mercier and Silverman 2014b). Consequently,
further research is needed on how best to integrate such tests to ensure that girls in particular are comfortable performing fitness tests and motivated to try their best. Graser and colleagues (2011) suggested that students responded most positively to a self or peer-facilitated format. Moving away from command-style test administration, where the teacher controls everything, to a more reciprocal self-administered or peer-facilitated approach was strongly recommended by Silverman and colleagues (2008), who also suggested that insufficient attention had been given to promoting pedagogically sound approaches to HRPF testing in pre-service teacher education programmes.

**3.6.5 Should fitness testing be part of a physical education programme?**

An encouraging outcome of this study was the reasons provided by teachers for including HRPF testing as part of their physical education programme. The vast majority (91%) who were in support of HRPF testing most frequently cited the opportunity for student learning, enhancing students’ awareness of the importance of HRPF, and promoting self-evaluation through the creation of personal fitness profiles, as the reasons for using fitness tests. Claims of ‘fitness for performance’ discourse dominating the delivery of HRPF amongst physical education teachers in other studies (Harris and Cale 2007; Alfrey et al. 2012; Harris and Leggett 2015a) were not in evidence from the participants’ responses in this study. The most frequently cited reason for including HRPF monitoring as part of a physical education programme were the learning opportunities it presented for students. Of the less than 10% (n= 22) of teachers who cautioned against the use of HRPF testing, most identified the potentially serious consequences of misuse, particularly for the least active students. The importance of the process of engaging in and learning from the tests, rather than the product of the test results, was expressed by many teachers. Indeed, a process-orientated approach to monitoring has been identified as a key step for appropriately integrating HRPF tests in
school settings (Cale et al. 2014). When results are used as part of the learning process, it is suggested teachers should avoid inter-student comparisons, focusing instead on self-comparisons with criterion referenced health standards (Ernst et al. 2006). Consistent reinforcement of health-related fitness components, in addition to the purpose of each test, was also noted as critical to ensuring a process rather than product focused approach (Phillips et al. 2017). A process oriented approach better facilitates fitness testing to be incorporated as part of a broader fitness education unit of learning, and not implemented in isolation.

3.6.5 Limitations and strengths

Caution should be applied when interpreting the results of this study. Firstly, although the sample was shown to be nationally representative, it was not random. The survey was also sent to each school’s general e-mail address as opposed to directly to physical education teachers, which may have led to some non-response bias. The limited five week time scale, due to the end of school term, may have hindered the recruitment of a larger sample size. This survey was based on a single data source. Consequently, data were not verified a second time, potentially leading to a lack of depth in the interpretation of responses, for which qualitative methods may have provided further insights. In addition, the survey did not include information on the impact of key variables including age and ability level on engagement with fitness testing. However, this study had numerous strengths including: a nationally representative sample of almost one third of all secondary schools in the Republic of Ireland; a regional spread of participants that was consistent with state demographics; and the inclusion of participants with a wide range of teaching experience, as detailed in Table 3.1. In addition, the authors followed a comprehensive survey design protocol in an effort to maximise the content validity of all questions included in the survey.
3.7 Conclusion

This study confirms that HRPF testing is highly prevalent in secondary school-based physical education programmes in the Republic of Ireland. Statistically significant differences were identified in testing frequency between year groups, and in teachers’ perceptions of boys’ reactions to fitness testing in comparison to girls. Furthermore, the prominence of testing some components of HRPF including CRE in comparison to others, such as musculoskeletal fitness, is a finding of potential concern. Actions are needed to ensure that fitness tests are not implemented in isolation of the broader PE curriculum. Special attention needs to be paid to the uses and reporting of HRPF results to both students and their parents/guardians. Consideration should be given to the development of digital platforms to facilitate physical education teachers in tracking and reporting students’ HRPF and other important healthy lifestyle habits, including physical activity. Further research on students’ experiences of and attitudes towards fitness testing is also required. In conclusion, actions are needed from key stakeholders involved in the delivery of pre-service and in-service physical education, to promote consistency in the use of best practice approaches to HRPF monitoring in secondary schools.
Chapter Four: Methodology
4.1 Preface

The review of HRPF monitoring practices in school-based physical education programmes in the Republic of Ireland presented in Chapter Three, in addition to the latest research on the reliability and validity of field-based fitness testing in youth (Chapter Two), provided a strong theoretical underpinning and rationale for the development of Youth-fit test battery and web-based monitoring system. The following chapter describes this development process and is divided into two parts. Part one details the systematic process followed in the design, development and administration of the Youth-fit test battery. An overview of the Youth-fit project design is provided, before a justification outlining the scientific underpinning for each test item and administration protocol used, is outlined. The procedure for school and participant recruitment, in addition to the selection of senior student facilitators are also provided. Part two addresses the design and development of the Youth-fit software platform, which was developed following the guidelines of a well-established design science research methodology for information systems research (Peffers et al. 2007). This model identified six distinct phases in the development of large-scale information systems, including; identification, defining objectives of a solution, development, demonstration, evaluation and communication. Details of the web-based application, developed by project partners’ iMosphere, are also provided, in addition to links to video tutorials that provide an overview of the software infrastructure.
4.2 Part one: The design, development and administration of the Youth-fit test battery

4.3 Rationale

Physical fitness is a complex and multifaceted construct that includes performance-related components and health-related components (Welk et al. 2000). Health-related physical fitness (HRPF) is made up of multiple components including cardiorespiratory endurance (CRE), musculoskeletal fitness (muscular strength, local muscular endurance, and power), and body composition that have been identified as powerful markers of future health among children and adolescents (Ortega et al. 2008b; Smith et al. 2014). Higher levels of physical fitness in youth are associated with reduced risk of future cardio-metabolic related diseases (Schmidt et al. 2016), higher levels of academic achievement (Bezold et al. 2014) and better mental health (Ortega et al. 2008b). Furthermore, improvements to HRPF during childhood and adolescence have been shown to reduce the risk of negative health outcomes later in life (Silventoinen et al. 2009). In light of the emerging evidence-base highlighting the predictive capacity of HRPF, population-based surveys of health are increasingly including measures of physical fitness in the form of field-based measures (Pillsbury et al. 2013).

HRPF can be objectively and accurately measured in laboratory settings using sophisticated instruments, however, such tests are not feasible for administration on a large-scale (Ruiz et al. 2011). Field-based tests provide a suitable alternative since they are time-efficient, low in cost, and can be easily administered to a large group of participants simultaneously (Artero et al. 2011). Recently, calls have been made for the
development of efficient, user friendly, and low cost instruments to monitor HRPF levels in youth (Ruiz et al. 2006b; Tabacchi and Bianco 2011; Pillsbury et al. 2013). School-based physical education programmes, acknowledged by many as the most suitable vehicle to promote the importance of health and activity among young people (Pate et al. 2006), are often used to administer HRPF tests. However, despite World Health Organisation recommendations (Hallal et al. 2012), and unlike the US, Canada, Australia, New Zealand and several European countries (Cvejić et al. 2013), the Republic of Ireland lacks a clearly specified strategy for monitoring physical fitness in children and adolescents. Furthermore, a recent national survey of HPRF monitoring practices in secondary schools, conducted by our research team, reported that fitness tests were used by over 95% of physical education teachers, 87% of whom in favour of developing a web-based platform to facilitate monitoring HRPF over time (O’Keeffe et al. 2020c). Therefore, the aim of the Youth-fit research project was to develop a pedagogically sound and scientifically rigorous field-based fitness test battery and web-based solution to facilitate monitoring students’ health related physical fitness (HRPF) levels in school settings.

4.4 Overview of the Youth-fit project design

Guided by the framework of the Medical Research Council’s key elements for the development and evaluation of an intervention (Figure 4.1) (Craig et al. 2008), our research team developed a systematic eight step plan (Figure 1.1) comprised of three distinct phases. Phase One, ‘development’, involved conducting a national survey of current monitoring practices in secondary schools in the Republic of Ireland (O’Keeffe et al. 2020c). A review of literature was conducted to determine valid and reliable field-
based fitness tests of physical fitness that were suitable for administration in school settings. The design of the Youth-fit teachers’ and student administrators’ guidance manuals (Appendix A), were also completed during this phase. An examination of the intra-rater reliability of student-administered fitness tests was conducted at the conclusion of phase one (O’Keeffe et al. 2020, see Chapter Five). Phase Two (feasibility phase) involved the roll out of the test battery to a randomised and stratified sample of 20 schools in the south-west and mid-west regions of Ireland. This included delivering a workshop on test administration protocols to all cooperating teachers and student administrators in each of the 20 schools. Finally, Phase Three focused on a comprehensive evaluation the overall project, including an examination of both teachers and students’ experiences of the test battery. The authors categorised the final phase of the Medical Research Council’s model, ‘implementation’, as a national dissemination of the Youth-fit test battery, however, this was beyond the remit of the current project.
Figure 4.1 A framework for developing and evaluating complex interventions (adapted from Craig et al. 2008). The phases included in the current project are shaded black.

4.4.1 Fitness testing in schools

The assessment of physical fitness in school settings dates back to the 1950’s when published reports by Kraus and Hirschland (1953; 1954) indicated that American youth were much less fit than their European peers. During the early years of fitness testing in school contexts, the focus was very much on performance related fitness and preparation for military service (J.R. Morrow et al. 2009). However, since the mid to late seventies, there has been a shift away from monitoring performance-related to health-related components (Pillsbury et al. 2013). Health-related components of fitness, including cardiorespiratory endurance (CRE), musculoskeletal fitness (muscular strength,
endurance, and power), and body composition, have been identified as powerful markers of future health among children and adolescents (Ortega et al. 2008b; Ruiz et al. 2009a). HRPF is often assessed in the form of a fitness test battery, a group of two or more tests that measure one or more components of fitness. According to a recent systematic review by Bianco and colleagues (2015), there are currently over 15 fitness test batteries in use in schools internationally. Fitnessgram®, developed by the Cooper Institute in the United States, is the most widely utilised fitness test battery in schools globally, with over 20 active international collaborations and annual participation rates in excess of 10 million students in the United States alone (Pluim and Gard 2016).

4.4.2 ALPHA test battery

The ALPHA (Assessing Levels of Physical Activity in Europe) test battery was developed specifically for use in school settings to facilitate monitoring fitness in a comparable way within the European Union (Ruiz et al. 2011). The aim of this pan-European project was to provide a set of valid, reliable, feasible and safe field-based fitness tests for measuring physical fitness in youth throughout Europe, using a standardised approach (Ruiz et al. 2011). This comprehensive work package included systematic reviews of the predictive validity (Ruiz et al. 2009a), criterion validity (Ruiz et al. 2009b; Artero et al. 2012) and reliability (Artero et al. 2011) of field-based tests of HPPF. At the conclusion of the review process a seven item evidence-based HRPF test battery was developed. Test items included: the 20m shuttle run test to assess cardiorespiratory fitness; handgrip strength and standing broad jump as measures of musculoskeletal fitness; BMI, waist circumference, and skinfold thickness as estimates of body composition; and the 4x10m shuttle run as a measure of motor fitness (Ruiz et al. 2011). All test items from the
ALPHA test battery, with the exception of waist circumference and skinfolds, were included in the Youth-fit test battery. These two test items were omitted due to time constraints of administration during timetabled physical education class time, and potential body image related issues associated with invasive anthropometric measurements in school settings (Lodewyk and Sullivan 2016).

4.4.3 Additional test items

Four additional tests of physical fitness and health, commonly administered in school-based HRPF test batteries and population health surveys were also included in the Youth-fit test battery, namely; back-saver sit and reach; 90° push-up; isometric plank hold; and blood pressure. A detailed outline of the evidence underpinning each selected test item, and the protocol used to administer the test, is provided in the following section.

4.4.4 Hall layout and test sequencing diagrams

![Figure 4.2 Sports hall layout for testing day one.](image-url)
4.5 Justification for test item selection and protocols used

4.5.1 Cardiorespiratory endurance

4.5.1.1 Evidence for method
Cardiorespiratory endurance, also referred to as aerobic capacity and cardiovascular fitness, is the ability to perform large-muscle, whole-body exercise at moderate to high intensities for extended periods of time (Saltin 1973). Cardiorespiratory endurance is the most commonly assessed component of health related physical fitness in school settings (Pillsbury et al. 2013), and it has been consistently identified as a strong predictor of future health in youth (Ortega et al. 2008b; Ruiz et al. 2009a; Tan et al. 2015). The maximal oxygen consumption ($\dot{V}O_2$ max) attained during a graded maximal exercise test on a treadmill or bicycle ergometer is considered to be the gold standard measure of
cardiorespiratory endurance (Taylor et al. 1955). In field-based or school settings, cardiorespiratory endurance is often assessed in the form of a timed distance run, such as the 12 minute Cooper run (Cooper 1968), or a progressive shuttle run, such as the 20m SRT (Leger et al. 1988). Despite some recent debate regarding the validity of the 20m SRT in estimating \( \dot{V}O_2 \text{max} \) (Armstrong and Welsman 2019), given its well established relationship with health, as well as its reliability for administration in school settings (Espana-Romero et al. 2010a), criterion validity (Ruiz et al. 2009b), and feasibility, the 20m SRT, was selected as the most appropriate field-based test for measuring cardiorespiratory endurance.

4.5.1.2 Method used: 20m shuttle run test

The 20m SRT was performed according to the protocol described by Léger et al. (1988). Prior to commencing the test, the cooperating PE teacher divided students into pairs, and assigned one member of each pair as the recorder and the other as the performer. Recorders monitored their peers’ progress, tracking each 20m shuttle completed on the results sheet (Appendix B). Participants were required to run between two lines 20 metres apart, while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed was 8.5 km/h, and was increased by 0.5 km/h per minute (one minute equals one stage). Participants were instructed to run in a straight line, to pivot on completing a shuttle, and to pace themselves in accordance with the audio signals. The test was finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions, or when the participant stopped due to fatigue. Participants were encouraged to keep running as long as possible throughout the course of the test. The test was performed once and the last completed stage or half-stage at which the subject
dropped out was scored. Performers and recorders switched roles at the conclusion of the test, and the same procedure was repeated. An indoor sports hall large enough to mark out a 20 metre track was used to perform the test. Schools that did not have access to an indoor sports hall suitable to administer the 20m shuttle run test were not considered eligible for inclusion in the study.

4.5.2 Body composition

4.5.2.1 Evidence for method

Body composition, or morphological fitness, relates to the relative amount of muscle, fat, bone and other vital parts of the body (Artero et al. 2012). Although body composition is not a demonstrative action like other health-related components of fitness, it is a significant health marker and modifier of fitness in youth, and is one of many factors that influence performance in both laboratory and field-based tests of physical fitness (Pillsbury et al. 2013). While no single criterion measure of body composition is universally accepted as the gold standard, dual-energy x-ray absorptiometry is increasingly recognised as the most accurate lab-based technique (Ackland et al. 2012).

Commonly administered field-based tests of body composition include body mass index (BMI), waist circumference and skinfold measurements. High BMI levels in youth have been associated with a higher risk of developing type 2 diabetes and hypertension (Ekelund et al. 2007), while waist circumference has been linked to risk factors for cardiovascular disease and all-cause mortality (Moreno et al. 2002). Although not a direct measure of body composition, given its practicality and ease of administration, BMI was deemed as the most appropriate anthropometric measure for inclusion in the Youth-fit test battery, as recommended by the Institute of Medicine (Pillsbury et al. 2013).
4.5.2.2 Method used: Body mass index

Body mass index (BMI) is a measure of weight for height and is calculated by dividing total body mass in kilograms by stature in meters squared. Body mass was measured to the nearest 0.1kg using an electronic scale (SECA UK 875; range 0.05 to 200kg; precision 0.05kg) (Appendix D, p.280). Scales were calibrated using a known weight prior to testing. Stature was measured to the nearest 0.1cm in the Frankfort plane with the participant standing upright (SECA UK; range 20 to 205cm; precision 1mm). During the anthropometric measurements, students wore light clothing and were barefoot. Both measures were recorded twice. If a difference of greater than 0.2kg and/or 1cm was observed, participants were instructed to take a third measure. The mean of the two closest values was used.

4.5.3 Flexibility

4.5.3.1 Evidence for method

Flexibility is defined as the range of motion of muscle and connective tissues at a joint or group of joints (Pillsbury et al. 2013). In contrast to other components of HRPF, flexibility is highly specific to each joint of the body, therefore, linking it to one or more health outcomes is difficult. Although the evidence is inconclusive, poor hamstring flexibility in youth has been associated with higher risk of low-back pain later in life (Kujala et al. 1992). The Institute of Medicine’s report on fitness measures and health outcomes in youth (2013) recommended including a measure of flexibility in field-based fitness test batteries for educational purposes in school settings. Radiography has been cited as the best criterion measurement to assess flexibility, but due to the high cost, the need for qualified technicians, and time constraints, this method is not feasible in school settings.
or population-based studies (Castro-Piñero et al. 2009). Goniometry has been identified as an accurate field-based measure, however, significant training is required in order to improve the consistency of measures taken, limiting its use in educational settings (Castro-Piñero et al. 2009). The sit and reach test, and its multiple derivatives, has been a feature of field-based test batteries for over half century (Wells and Dillon 1952). Based on its reliability, validity and safety for administration in youth, the back-saver sit and reach was included in the Youth-fit test battery as a measure of hip and lumbar flexibility (Chillón et al. 2010).

4.5.3.2 Method used: Back-saver sit and reach
The back-saver sit and reach test was administered in line with the protocol as described by Welk and Meredith (2013) (Appendix D, p.281). Participants were asked to sit on the floor with one leg fully out-stretched and the sole of the non-extended leg resting beside the knee of the extended leg. The feet, with shoes off, were placed with the soles flat against the test device (Cartwrightfitness® sit and reach box). The knee of the participant’s extended leg was held flat against the floor by the peer facilitator. The participant’s hands were aligned one over the other, with their palms facing down. Once the starting position was assumed, the participant reached forward along the measuring line as far as possible. To avoid a jerking action, participants were required to hold their position at full extension for three seconds, before slowly returning to the starting position. The measurement device had a scale range of 70 cm and was marked in 0.5cm intervals. The zero mark was 15 cm before the feet of the participant. The result was recorded to the nearest 0.5cm and the average of the highest scores achieved from the left and right side was used in the analysis.
4.5.4 Cardiovascular health

4.5.4.1 Evidence for method
The relationship between blood pressure and physical fitness has not been examined in
great detail among large population samples, and the association between blood pressure
and negative health outcomes in youth is less understood. The practice of monitoring
blood pressure by non-expert populations using automated machines has been encouraged
(Graves and Althaf 2006; Stergiou et al. 2009). Technological advances have significantly
enhanced the validity and reliability of automated machine measures of blood pressure
(Christofaro et al. 2009). Although not commonly administered as part of school-based
fitness test batteries, many population based health surveys including the National Health
and Nutrition Examination Survey (NHANES) in the United States and the Children Sport
Participation and Physical Activity Survey (CSPPA) in the Republic of Ireland, include
blood pressure as a measure of cardiovascular health.

4.5.4.2 Method used: Automated blood pressure
Blood pressure (BP) was measured using an Omron M6 oscillometric automated blood
pressure monitor. BP was measured by the test administrator according to the protocol
outlined by the Centre for Disease Control (CDC 2008) (Appendix D, p.281). Participants
rested quietly for three to five minutes prior to the measurement. The test battery was
sequenced to ensure that the previous station, station one (BMI and flexibility), required
minimal physical exertion to ensure participants were well rested prior to having their BP
recorded. The participant was asked to sit all the way to the back of the chair so that the
spine was straight. The left arm and back were fully supported, and legs were uncrossed
with both feet flat on the floor. The left arm was placed on a table beside the participant,
unrestricted by clothing, with the palm of the hand turned upward and the elbow slightly
flexed. The left arm was positioned so that the midpoint of the upper arm was at the approximate level of the heart. The test was performed twice, with a three-minute rest interval between recordings.

4.5.5 Musculoskeletal fitness

4.5.5.1 Evidence for method
Musculoskeletal fitness is a multidimensional construct comprising the integrated function of muscle strength, muscle endurance, and muscle power (Pillsbury et al. 2013). No single measure of any of these dimensions adequately describes an individual’s overall level of musculoskeletal fitness, hence the importance of including measures of all three sub-categories. There is strong evidence of a positive association between musculoskeletal fitness and bone health, self-esteem and metabolic risk factors, although the associations are low to moderate (Smith et al. 2014). In a systematic review of criterion-related validity of field-based muscular fitness tests in youth, Artero and colleagues (2012) reported that handgrip strength and standing broad jump tests were the most valid field-based muscular fitness tests. The 90° push-up test was also included as a measure of musculoskeletal fitness. Performance in the 90° push-up has been shown to be less reliable than other measures of muscular strength including hand-grip strength and standing broad jump (Lubans et al. 2011a). However, not all schools have access to the necessary equipment to administer a handgrip or standing broad jump test, therefore, the 90° push-up was included. Furthermore, a recent longitudinal analysis found that push-up capacity was associated with a lower incidence of cardiovascular disease among young male adults (Yang et al. 2019). Unlike most field-based test batteries internationally, the ALPHA test battery does not include a measure of muscular endurance, an important
component of musculoskeletal fitness. The isometric plank hold, a measure of torso muscular endurance, is a no cost test that is increasingly being included in fitness test batteries internationally (Francis et al. 2016). Boyer and colleagues (2013) concluded that the isometric plank hold was a feasible, reliable and valid measure of torso muscular endurance among children 8 to 12 years of age.

4.5.5.2 Method used: Handgrip strength
Handgrip strength was measured using a digital hand dynamometer with an adjustable grip (Model: 5401, Takei Scientific, Japan). This dynamometer presents a high validity and reliability when calibrated with known weights (Espana-Romero et al. 2010a). The grip span of the dynamometer was adjusted according to the hand size of the participant using an equation developed for adolescents (Ruiz et al. 2006a). Participants were instructed to squeeze the handle as hard as possible for three seconds, keeping the arm fully extended by the side of the body at all times (Appendix D, p.282). The test was performed twice and the maximum score for each hand was recorded in kilograms. The average of the scores achieved by left and right hands was used in the analysis.

4.5.5.3 Method used: Standing broad jump
Lower body explosive strength was measured using the standing broad jump test (Appendix D, p.282). The participant stood on an Atreq® jump mat behind the starting line, and was instructed to push off vigorously and jump forward as far as possible. Following three sub-maximal practice trials, the test was repeated twice, and the best score was retained to the nearest centimetre as the distance between toes at take-off and heels at landing.

4.5.5.4 Method used: 90° push-up
The 90° push-up test was performed in line with the Fitnessgram® protocol as outlined by Welk and Meredith (2013) (Appendix D, p.283). Participants started in the push-up
position, with their hands and toes touching the floor and arms shoulder width or slightly wider apart. Ensuring shoulder to ankle alignment, participants then lowered themselves towards the ground until a 90° angle was achieved at the elbows, with the upper arm parallel to the floor. A foam block was positioned under the participant to ensure a depth of 90° was reached before returning to the starting position. Push-ups were completed in time to a metronome set at 40 beats per minute, with one complete push-up every 3 seconds. One form correction (e.g. lowering of hips) was permitted. The test concluded on the second form correction or when the participant stopped due to fatigue.

4.5.5 Method used: Isometric plank hold
Muscular endurance of the torso was measured using the isometric plank hold test (Appendix D, p.283). This test required participants to maintain a static prone position, with only forearms and toes touching the ground. Correct alignment required feet together with toes curled under the feet, elbows shoulder width apart, and forearms against the floor or mat. Participants maintained eye contact with their hands, a neutral spine, and alignment from shoulders to ankles. The participant was given a five second practice trial, during which the peer facilitator instructed the participant into the correct position, followed by a brief period of rest. The timer started when the participant assumed the correct position. Participants were allowed to deviate from the correct position once, and could continue the test if they immediately resumed the correct starting position. The test was terminated on the second deviation from the correct position, or if the participant did not return to the correct position after the first correction. The score was recorded to the closest second using a stopwatch.
4.5.6 Motor fitness

4.5.6.1 Evidence for method
Although not a component of health related fitness, the important role of motor fitness in establishing and maintaining engagement in physical activity has been increasingly acknowledged (Ruiz et al. 2009a; Britton et al. 2018). Motor fitness consists of those components of physical fitness that have a relationship with enhanced performance in sports and motor skills including speed, agility, coordination and balance (Artero et al. 2011). In a review of the reliability of health-related fitness tests in European adolescents, Ortega and colleagues (2008a) identified the 4x10m shuttle run test as a reliable measure of speed of movement and change of direction that was suitable for administration in school settings.

4.5.6.2 Method used: 4x10m shuttle run
The test was performed in line with the ALPHA test battery protocol (Ruiz et al. 2011) (Appendix D, p.284). Two parallel lines were drawn on the floor 10 metres apart. The participant ran as fast as possible from the starting line to the opposite line and returned to the starting line, touching the line with either the hand or foot every time. This was performed twice, covering a distance of 40m (4x10 m). Every time the participant touched either of the lines, they were required to pick up (first time) or exchange (second and third time) a sponge that was placed on both 10m lines prior to each trial. The timer was stopped when the participant crossed the finishing line with one foot. The time taken to complete the test was recorded to the nearest tenth of a second. The procedure for uploading results to the Youth-fit software platform is outlined in part two of this chapter.
4.6 Administration of the Youth-fit test battery

The Youth-fit test battery administration procedure was developed in line with published recommendations that represented a pedagogically sound (Cale et al. 2014), student-centred (Graser et al. 2011) and scientifically rigorous approach (Ruiz et al. 2011; Welk and Meredith 2013) to fitness testing in a school context. This research project focused specifically on students in year one of secondary school (ages 13 to 14), and was open to all students in the selected year group in each participating school, who fulfilled the physical activity readiness questionnaire (PAR-Q) pre-test requirements (Warburton et al. 2011). A minimum participation rate threshold of 70%, as used in other similar studies (Moreno et al. 2008), was set for a school to be considered eligible. The test battery was administered over two days during timetabled physical education lessons, lasting 80 minutes. On day one, students completed the 20m SRT, and spent the remainder of their physical education class period completing familiarisation trials of the remaining test items. The 20m SRT is a measure of maximal aerobic endurance, and thus, was completed on a separate day to the other tests. The remaining test items were delivered on day two using a station format, in which students were divided in to groups of six or less, and assigned to one of five stations (Figure 4.3). Once students had completed each test item within their assigned station, they then rotated in a clockwise direction between stations after approximately eight to ten minutes. Large laminated printouts of the test protocols were displayed beside each testing station to serve as a visual aids for participants and peer facilitators (Appendix D).
4.6.1 Pre-feasibility pilot trial

Following the completion of development phase, and prior to the randomized expansion phase, the Youth-fit test battery and software platform was trialed with 151 students (Age $= 13.05 \pm 0.47$; girls, $n=92$) and 12 physical education teachers, from a convenience sample of four schools. The aim of this pre-feasibility trial was to determine the acceptability of the study protocols and procedures in advance of the 20 school expansion study. Although HRPF data were inputted to the Youth-fit software platform, they were not analysed as part of this trial. Teachers completed a brief process evaluation questionnaire, developed specifically for this study. Some minor adjustments to test protocols and the software platform were made based on the feedback from teachers. The single biggest development to emerge from this trial phase was the introduction of senior student facilitators, based on the recommendations of teachers in three of the four schools from the convenience sample. In addition, due to the time taken to administer the blood pressure test, it was recommended to include two automated monitors in an effort to reduce the time taken to complete this station. Updates to the software platform including the introduction of biologically plausible value limits, the creation of a bulk import function to enable all students in a school to be imported with one click, and automatically saving students’ results upon entry. A comprehensive overview of the development of the software platform is provided in the part two of this chapter.

4.6.2 Student assistant administrators

A unique component of the Youth-fit test battery was the inclusion of senior student facilitators. The estimated time to perform the ALPHA test battery with 20 students was approximately 2 hours and 30 minutes (Ruiz et al. 2011). Therefore, due to the significant
challenge of limited time and space, particularly in school contexts (Ortega et al. 2011c; De Moraes et al. 2019), it was decided following a pre-feasibility pilot trial of the project to include eight senior student facilitators to assist the physical education teacher in the organisation and delivery of the test battery. Following approval from the school principal, the cooperating physical education teacher in each school was responsible for selecting eight senior students (final two years of secondary school, ages 16 to 18). A detailed standard operating procedure for each test item was designed for and read by student facilitators one week before data collection started. Subsequently, student facilitators participated in a three hour training workshop delivered by the lead author during which each facilitator was assigned one test, and trained in the assigned test only. Student facilitators conducted several familiarisation trials, and examples of correct and incorrect trials were demonstrated by the lead investigator (BO’K). Cooperating teachers and student facilitators each received a hard copy of the Youth-fit Guidance Manual (Appendix A). Reliability indices for student administered HRPF tests in school settings have recently been published (O’Keeffe et al. 2020), as detailed in Chapter Five. On day two of testing, each facilitator was responsible for setting up their assigned station and test item. Student facilitators provided an overview of the test protocol and demonstrated examples of correct and incorrect trials to each group of students following a rotation (Figure 4.2). The cooperating PE teacher was responsible for tracking the duration of station rotations, with each rotation lasting between eight to ten minutes.

4.7 School and participant recruitment

A randomised sample of 20 schools, stratified for sex (single-sex boys, single-sex girls and mixed-sex), location (categorised by population density: urban, the cities of Cork and
Limerick; rural, all other areas of the mid-west and south-west of the Republic of Ireland), and educational (dis)advantage, participated in the study. Designated disadvantaged schools were categorised based on the ‘Small Area Deprivation Index’ scale developed by Haase (2012) and centrally held Department of Education and Skills pupil data as part of the Government of Ireland’s Delivering Equality of opportunity in Schools (DEIS) scheme. There are currently 185 DEIS secondary schools in Ireland, representing just over 25% of all schools (Department of Education and Skills 2017).

The procedure for generating a randomised sample was completed using a computer generated randomisation list, in which all secondary schools in the mid-west and south-west regions of Ireland were assigned a code and categorised according to the predefined strata. Due to the geographical spread of schools, and the need to visit each school individually, 20 schools was considered to be the maximum sample size achievable from a logistical viewpoint, and the minimum required to obtain a sufficient number of schools in each of the chosen strata. If a school declined to participate, the next school on the computer-generated randomised reserve list, in the same predefined category, was recruited. Approval from the principal and cooperating physical education (PE) teacher in each school was granted following an initial email and telephone conversation. Written informed consent was obtained from the parents of the students, and the students themselves (Appendix G).
4.8 Part two: The design and development of the Youth-fit software platform

4.9 Rationale

To implement effective non-communicable disease prevention programmes, policy makers need data on the physical activity and physical fitness levels of youth (Hallal et al. 2012). The development of efficient systems for large-scale collection of health related fitness data, and the transfer of data to centrally located databases, has been cited by leading experts as the next step in monitoring HRPF in youth (Ruiz et al. 2006b; Tabacchi et al. 2016). The inclusion of physical fitness in health surveillance systems has been recommended (Tomkinson and Olds 2007), and schools have been identified as a suitable setting for monitoring youth fitness (Espana-Romero et al. 2010a; Ramírez-Vélez et al. 2015). In recent years, many countries including Slovenia (Jurak et al. 2019), Hungary (Csányi et al. 2015) and several regions in the United States (Welk 2017) have introduced software platforms to facilitate monitoring HRPF in schools. Furthermore, a recent survey on HRPF monitoring practices from a nationally representative sample of secondary schools in the Republic of Ireland reported that 87% of physical education teachers would be in favour of the development of a web-based platform to facilitate tracking students’ HRPF (O’Keeffe et al. 2020c). This survey also reported that over half (51.7%) of respondents indicated that they discarded test results after a single use, while less than 12% of teachers tracked their students’ HRPF results from year to year. Therefore, another primary aim of the current study was to develop a low-cost, user-friendly, and efficient web-based solution that would facilitate monitoring key measures of HRPF and the transfer of this data to a centrally hosted anonymised database, enabling trends to be viewed in real-time. In order to achieve this, the research team reviewed existing technologies that could potentially facilitate the development of a web-based HRPF
tracking platform. Leading edge multi-site data capture technology developed by software analytics firm iMosphere, was identified as the most suitable platform to pursue the development of the web-based solution. Following a pitch of the project to the company, iMosphere agreed to collaborate in the development and design of the Youth-fit software platform.

4.10 Design science research methodology for information systems

Peffers and colleagues (2007) design science research methodology for information systems research (DSRM) was used to guide the development of the Youth-fit software platform (Figure 4.4). The DSRM model identifies six distinct phases in the development of large-scale information systems. The DSRM approach has been used successfully in similar projects, including ‘CATCH’ (Comprehensive Assessment for Tracking Community Health) in the United States (Studnicki et al. 1997), as well as in the development of some of iMosphere’s unique disruptive technology applications. The steps taken to develop the Youth-fit software platform, within each of the six phases of the model, are detailed in the following sections.
**4.10.1 Phase 1: Problem identification and motivation**

Health related physical fitness (HRPF) in childhood and adolescence is a powerful marker of future health (Ortega *et al.* 2008b). However, despite WHO recommendations (Hallal *et al.* 2012), and unlike the US, Canada, Australia, New Zealand and several European countries (Cvejić *et al.* 2013), the Republic of Ireland lacks a clearly specified strategy for monitoring physical fitness in children and adolescents. Although almost 95% of physical education teachers in secondary schools in the Republic of Ireland assess HRPF, over half (51.7%) discard the test results after a single use, while less than 12% of teachers track their students’ HRPF results from year to year (O’Keeffe *et al.* 2020c). The vast majority of physical education teachers (87%) in this study also indicated that they would be in favour of developing a web-based system to facilitate monitoring their students HRPF levels.

**4.10.2 Phase 2: Define objectives of a solution**

The objective of the Youth-fit software platform was to develop a web-based application for recording and monitoring the measures generated from the Youth-fit fitness test battery, and to transfer this data to an anonymised database, hosted at the University of Limerick. Physical education teachers were responsible for overseeing the administration of the Youth-fit test battery and inputting results to the web-based platform. The aim of this novel project was to serve as a feasibility trial for a national, open-access database, which would make the Republic of Ireland one of the first countries to report data on key predictors of adolescent health in real-time, showing trends, and aiding interventions to improve current and future health among school-going populations.
4.10.3 Phase 3: Design and development

4.10.3.1 Carepartner
Two software applications, developed by project partner’s iMosphere, were used to gather HRPF results, and transfer data to a centrally hosted anonymised database. Firstly, results were inputted through the Carepartner application, which was hosted on an internally facing server at the University of Limerick. This user-friendly application enabled data from all participating schools to be captured through an easily navigable interface (Figure 4.5), and stored on a secured database. Individual log-in accounts for each cooperating physical education teacher were created by a member of the research team. Teachers were required to reset their assigned password following their first log-in. Passwords needed to be seven characters long, contain at least one letter, one figure and one special character. Only participating school principals, PE teachers, the three members of the research team and a designated iMosphere software support administrator had access to the Carepartner application. School profiles (name), cooperating teacher profiles (name) and consented student profiles (name, gender, month of birth, school, and class group) were created by the system administrator (BO’K) using a bulk import function on the Carepartner application. An anonymized alphanumeric coding system was used to associate each school, cooperating teacher, and their students. The Carepartner application also enabled teachers to download summary reports of an individual’s HRPF test results. A comprehensive guide on the Carepartner application is provided in the Youth-fit software guidance manual (Appendix C). A video tutorial, developed to assist cooperating teachers inputting results, was also developed (available here).
4.10.3.2 Atmolytics

Following input to the Carepartner application, data automatically transferred in anonymised form to the Atmolytics application, which was also hosted on a server at the University of Limerick. The Atmolytics platform enabled more detailed statistical analysis at a school or regional level, but not at an individual level. All identifiable information from the Carepartner system was redacted when transferred to the Atmolytics application. The Atmolytics application included a variety of functions that facilitated the generation of school-level reports, which enabled the school principal or cooperating teacher to compare their schools results with established criterion or normative values that had been saved to the system by the lead investigator. Unidentifiable numeric tags were assigned to all sensitive data, and the school and participant coding procedure was stored in a password protected folder on the lead investigators PC. A comprehensive step-by-step guide explaining the Atmolytics application, as well as sample report outputs, were provided in Youth-fit software guidance manual (Appendix C). A video tutorial detailing the procedure for generating reports on the Atmolytics platform was also developed for cooperating teachers (available here).
4.10.4 Phase 4: Demonstration

Following the completion of design and development phase, and prior to the randomized expansion phase, the Youth-fit test battery and software platform was trialed with 151 students and six physical education teachers, from a convenience sample of four schools. Minor system improvements were made to the software platform based on the feedback from cooperating physical education teachers. Recommended edits predominantly focused on the result input screen (Figure 4.7). Recommendations included, the introduction of biologically plausible value limits to minimize input error, creating a one click summary results sheet report for an individual student, and automatically saving results upon inputting data to a student’s profile. A randomized sample of 20 schools, stratified for sex, location and socioeconomic status were recruited for the demonstration phase. The lead investigator travelled to each of the 20 schools and delivered a tutorial on the Youth-fit software platform to all cooperating teachers. School and teacher login codes were provided during the workshop, and cooperating teachers performed software familiarisation trials using a fake school account.
4.10.5 Phase 5: Evaluation

At the conclusion of the expansion phase, a feasibility evaluation framework, developed by Orsmond and Cohn (2015), was used to conduct a systematic evaluation of the Youth-fit test battery and software platform. Guiding questions for the evaluation of feasibility trials developed by Orsmond and Cohn (2015) were used to evaluate each of the aforementioned objectives of the framework (Appendix J). A comprehensive evaluation of the Youth-fit test battery and software platform is provided in Chapter Eight.

4.10.6 Phase 6: Communication

Manuscripts relating to the Youth-fit test battery and software platform have been published in academic journals (Appendix L), and academic conference proceedings (Appendix M and Appendix N). The Youth-fit project was also featured on a TV documentary during primetime viewing hours on the national broadcaster (RTÉ) in the Republic of Ireland, as well as local and national newspaper outlets. It is hoped that the
current feasibility project will serve as a template for a future national system, enabling data on key predictors of adolescent health to be available for analysis, showing trends in real time, and informing interventions to improve current and future health among school-going populations.
Chapter Five: Test-retest reliability of student administered health-related fitness tests in school settings

This chapter has been published in the journal of ‘Paediatric Exercise Science’:

5.1 Preface

The previous chapter provided details of the design and development of the Youth-fit test battery and web-based platform. The focus of the following chapter was to determine the test-retest reliability of the student administered approach to delivering the Youth-fit test battery. Although a student or peer facilitated approach has often been recommended by scholars as a pedagogically sound approach to fitness testing, this was the first study of its kind to examine the test-retest reliability of such data, and represented a crucial step in determining the scientific rigour of the data gathered. A two group study design was utilised in which participants were assigned to a student administered group or research-assistant administered group. Tests were administered twice by both groups of testers, one week apart. Following this, absolute and relative reliability indices were compared between both groups. Positive intra-rater reliability indices demonstrated that, following familiarisation training, student-assessed measures of anthropometric (BMI), musculoskeletal (hand-grip strength and standing broad jump) and performance-related (4x10m shuttle run) components of fitness can be considered just as reliable as those taken by experienced research assistants.
5.2 Abstract

**Purpose:** The purpose of this study was to establish the test-retest reliability of student administered health-related fitness tests in school settings, and to compare indices of reliability with those taken by trained research assistants. **Methods:** Participants (N= 86; age: 13.43 ±33) were randomly assigned in to a student administered (SA) (n= 45; girls n= 26) or research-assistant administered (RA) (n= 41, girls n= 21) group. Both groups received test familiarisation training. The following tests were performed twice by both groups, one week apart: body mass, height, back-saver sit and reach, hand-grip strength, standing broad jump, isometric plank-hold, 90° push-up, 4x10m shuttle run and blood pressure. **Results:** With the exception of SA systolic blood pressure (M= 3.73 ±7.35, p <.05, t-test) and RA 90° push-up (M= 1.14±1.98, p <.05), no statistically significant inter-test differences were found in either group (p >.05). Intra-class correlation coefficients (ICC) for SA (ICC ≥ 0.797) and RA (ICC ≥ 0.866) groups were very high for all tests. Mean test-retest percentage error values were less than 10% for BMI, standing broad jump, handgrip strength, and 4x10m shuttle run tests in both groups, and the observed systematic error (Bland-Altman Plot) for all tests was nearly zero. **Conclusion:** This study demonstrates that, following familiarisation training, student administered health-related fitness tests in school-based physical education programmes can be considered reliable.

5.3 Introduction

Physical fitness is a complex and multi-faceted construct integrating a wide range of bodily functions including morphological, muscular, motor, cardiorespiratory, and metabolic (Bouchard et al. 1994). Physical fitness is composed of performance-related components and health-related components. In recent years, there has been a shift away from monitoring performance-related components of fitness to health-related components.
Health-related components of fitness, including cardiorespiratory endurance (CRE), muscular fitness (muscular strength, local muscular endurance and power) and body composition, have been identified as important markers of current and future health among children and adolescents (Hurtig-Wennlöf et al. 2007; Ortega et al. 2008b; Smith et al. 2014). Higher levels of CRE are associated with reduced risk of future cardio-metabolic related diseases (Schmidt et al. 2016), potentially higher levels of academic achievement (Bezold et al. 2014), and better mental health (Ortega et al. 2008b). In addition, positive changes to HRPF during adolescence can reduce the risk of negative health outcomes later in life (Ortega et al. 2011b; Ortega et al. 2012). There is also mounting evidence that has associated higher levels of muscular fitness in youth with lower levels of cardiovascular risk factors in young adulthood, independent of CRE and adiposity (Grøntved et al. 2015). In a systematic review of the health benefits of muscular fitness for children and adolescents, Smith and colleagues (2014) concluded that there was strong evidence of an inverse association between muscular fitness, central adiposity and metabolic risk factors. The growing evidence base supporting the predictive capacity of physical fitness as a marker of current and future health has important implications for health promotion practices, and has resulted in calls for the development of population wide monitoring of fitness (Ruiz et al. 2009a; Kaminsky et al. 2013).

HRPF can be objectively and accurately measured in laboratory settings by qualified technicians using sophisticated instruments. However, as indicated by Espana-Romero and colleagues (2010a), such tests are not feasible for administration at a population level. Field-based tests provide a suitable alternative since they are time-efficient, low in cost, and can be easily administered to a large number of people simultaneously (Ruiz et al. 2009a). Indeed, there have been increasing calls for the development of simple, accurate, and inexpensive methods to measure fitness in youth (Tabacchi and Bianco 2011). In any testing situation, it is important that the results are
derived from high quality measurement techniques. Reliability and validity are essential for meaningful interpretation and inference of results (Morrow et al. 2010). Validity refers to the ability of a test to reflect what it is designed to measure. Reliability refers to the reproducibility of a test result in repeated tests on the same individual under the same conditions. Extensive research has been conducted on the validity and reliability of field-based measures of physical fitness. However, the majority of research to date has used an intra- or inter-tester reliability methodological design, in which reliability is established by experienced and highly trained test administrators in standardised and controlled settings (Espana-Romero et al. 2010a). Different models of administration exist in secondary school-based fitness testing, including; trained experts visiting the school to collect HRPF data; the PE teacher coordinates and administers the test battery to students following training; the teacher co-ordinates the test battery and fitness tests are conducted by trained senior student administrators; or peer testing, where students measure each other’s fitness. Given the greater degree of variability in secondary school settings, and the concurrent need for efficient test administration within a specified time period, maximising validity and reliability represents a significant challenge.

Recently, a fitness test battery entitled ALPHA (Assessing Levels of Physical Activity in Europe) was developed specifically for use in school settings to facilitate monitoring fitness in a comparable way within the European Union (Ruiz et al. 2011). The ALPHA test battery was shown to be both valid and reliable when administered by Physical Education (PE) teachers in school settings (Espana-Romero et al. 2010a). Other studies have also examined the reliability of teacher assessed measures of HRPF in school settings with positive results (Morrow et al. 2010). Fitness tests are often administered in the form of a test battery, a set of two or more tests used to assess a component(s) of physical fitness. International examples currently in use in school settings include Fitnessgram® (US), CNPFT (China), ALPHA (EU), Move! (Finland), GTO (Russia),
SLOfit (Slovenia) and Netfit (Hungary). Several states in the US, and many countries including Japan, Finland, Slovenia and Hungary have mandated monitoring physical fitness in school PE programmes (Csányi et al. 2015; Salin and Huhtiniemi 2018; Shephard 2018). In such contexts, as noted in a recent review of HRPF monitoring practices in school-based physical education programmes by O’Keeffe et al. (2020b), it is often not feasible for one teacher to administer a test battery to a large group of students within the allocated PE lesson time. The estimated time to perform the ALPHA priority test battery with 20 students was approximately 2 hours and 30 minutes (Ruiz et al. 2011). Therefore, limited time and space present a significant challenge to test administrators, particularly in school contexts (Ortega et al. 2011c; De Moraes et al. 2019).

A student administered format, where, following test protocol familiarisation, senior student test facilitators are responsible for the measurement of test items, could represent a feasible alternative (Morrow and Ede 2009; Graser et al. 2011). In a recent global review of youth fitness testing practices, Keating and colleagues (2018) reported that, of the four most prominent test batteries in use internationally, ALPHA (Europe), CNPFT (China), Fitnessgram® (US) and GTO (Russia), only Russia’s GTO test battery supported a self-administration approach. Research has indicated that students prefer to have fitness tests administered by fellow students, as opposed to having their measurements taken by teachers or trained research assistants (Graser et al. 2011). However, no research has been conducted to date on the reliability of student administered measures of HRPF in school settings. Just as objective data are needed to answer key questions about the accuracy and repeatability of teacher-administered tests (Mahar and Rowe 2008), so too are data on the reliability of student-administered measures. Therefore, the aim of this study was to examine the test-retest reliability of student-administered measures of HRPF in secondary school-based physical education programmes.
5.4 Methods

5.4.1 Participants

Research ethics approval for this study and the associated protocols was granted by the Research Ethics Committee of the Faculty of Education and Health Sciences, University of Limerick, Ireland (EHS_2017_02_12). The study was administered in a mixed-sex secondary school in the mid-west region of Ireland. All students (N=96) in year 1 of secondary education in the school were invited to participate. Informed consent to participate was received from school principals, participants and parents/guardians (Appendix F). The participation rate was 92.4% (N=86). The reliability of student administered health-related fitness tests was assessed using a multi-group design. Participants were randomly assigned in to a student-assistant administered (SA) group (n=45; age: 13.44 ±.35; girls n= 26) or research-assistant administered (RA) group (n= 41; age: 13.42 ±.32; girls n= 21). All participants (N=86) completed a self-report physical activity survey (PACE+) and the International Fitness Scale for youth (Ortega et al. 2011c). Age and gender were evenly distributed, and an independent sample t-test indicated no significant differences between self-reported activity or fitness levels between both groups (p >.05).

5.4.2 Procedures

Both the SA and RA groups comprised of eight test administrators. Cooperating physical education teachers’ selected eight senior students (final two years of second level education) (age: 15.59 ±.56; girls n=4) from the participating school to administer the test battery to the SA group. In addition, eight research assistants with a minimum of two years’ experience in field-based testing (age: 21.21 ±1.38; girls n=5) were recruited from the lead authors’ institution to administer the test battery to the RA group. Each
administrator was responsible for one test item on the test battery. A detailed standard operating procedure for each test item was designed for and read by both student and research assistant administrators, one week in advance of data collection. Subsequently, test administrators from both groups participated in a three hour training workshop delivered by the lead author. During this workshop, each administrator was assigned one test, and trained in the assigned test only. Test administrators conducted several familiarisation trials, and examples of correct and incorrect trials were demonstrated.

Tests were administered during a double period of physical education lasting 80 minutes. Tests were performed in small groups of five or less using a station format. Participants were provided with a minimum of three minutes rest between stations and one minute rest between trials. Participants performed the HRPF tests on two occasions (hereafter T1 and T2), on the same day at the same time, one week apart. Participant groupings and the order of test completion were the same on both test days for all participants. A period of one week for functional tests has been reported as sufficient to minimise learning effect, without introducing additional error due to maturation (Lubans et al. 2014).

5.4.3 Measures

The tests included in this study were selected because they (i) have high validity (Ruiz et al. 2009b; Artero et al. 2012; Chen et al. 2017) (ii) are safe (Espana-Romero et al. 2010a) (iii) involve minimal equipment at low cost (iv) and are feasible for administration in school settings among adolescent youth (Espana-Romero et al. 2010a; Welk and Meredith 2010). Test items included, handgrip strength, standing broad jump, height, body mass, and a 4x10m shuttle run. The scientific rationale for the selection of the tests was based on their predictive (Ruiz et al. 2009a) and criterion-related validity (Artero et al. 2012). Four additional tests of physical fitness and health, commonly administered in
school-based HRPF test batteries and population health surveys, were included, namely, 90° Push-up, isometric plank hold, back-saver sit and reach, and blood pressure. The administration protocol for each test is detailed below, and can also be found in the Youth-fit guidance manual (Appendix A).

**Anthropometry:** Although not a direct measure of body composition, body mass index (BMI) represents a feasible alternative for use in school settings (Pillsbury *et al.* 2013). BMI is a measure of weight for height and is calculated by dividing total body mass in kilograms by stature in metres squared. Body mass was measured to the nearest 0.1kg using an electronic scale (SECA UK 875; range 0.05 to 200kg; precision 0.05kg). Scales were calibrated using a known weight prior to testing. Stature was measured to the nearest 0.1cm in the Frankfort plane, with the participant standing upright (SECA UK 218; range 20 to 205cm; precision 1mm). During the anthropometric measurements, students wore light clothing and were barefoot. Both height and body mass were recorded twice. If a difference of greater than 0.2kg and/or 1cm was recorded, participants were instructed to take a third measure. The mean of the two closest values was used for analysis.

**Muscular strength:** Handgrip strength was measured using a digital hand dynamometer with adjustable grip (Model: 5401, Takei Scientific, Japan). This dynamometer presents a high validity and reliability when calibrated with known weights (Espana-Romero *et al.* 2010a). The grip span of the dynamometer was adjusted according to the hand size of the participant using an equation developed specifically for adolescents (Ruiz *et al.* 2006b). Participants were instructed to squeeze the handle as hard as possible for three seconds, keeping the arm fully extended by the side of the body at all times. The test was performed twice and the maximum score for each hand was recorded in kilograms. The mean of the maximum score achieved by both hands was used in the analysis. Lower body explosive strength was measured using the standing broad jump
test. The participant stood on an Atreq® Jump Mat behind the starting line, and was instructed to push off vigorously and jump as far as possible. Following three sub-maximal practice trials, the test was repeated twice, and the best score was retained to the nearest centimetre as the distance between toes at take-off and heels at landing.

Muscular endurance: Muscular endurance of the torso was measured using the isometric plank hold test. This test required participants to maintain a static prone position, with only forearms and toes touching the ground. Correct alignment required feet together with toes curled under the feet, elbows shoulder width distance apart, and forearms against the floor mat. Participants maintained eye contact with their hands, a neutral spine, and alignment from shoulders to ankles. The participant was given one 5 second practice trial, during which the test administrator instructed the participant into the correct position, followed by a brief period of rest. The timer started when the participant assumed the correct position. Participants were allowed to deviate from the correct position once, and could continue the test if they immediately resumed the correct starting position. The test was terminated on the second deviation from the correct position, or if the participant did not return to the correct position after the first warning. The score was recorded to the nearest second using a stopwatch. Upper body muscular strength was measured using a 90° push-up test. The test was performed in line with the Fitnessgram® protocol as outlined by Welk and Meredith (2010). Participants started in the push-up position, with their hands and toes touching the floor, and arms shoulder width or slightly wider apart. Ensuring shoulder to ankle alignment, participants then lowered themselves towards the ground until there was a 90° angle at the elbows, with upper arms parallel to the floor. A foam block was positioned under the participant to ensure a depth of 90° was reached before returning to the starting position. Push-ups were completed in time to a metronome, set at 40 beats per minute, with one complete push-up every 3 seconds. One form
correction (e.g. lowering of hips) was permitted. The test concluded on the second form correction or when the participant stopped due to fatigue.

Motor Component: Speed of movement and coordination were assessed using the 4x10m shuttle run test. The test was performed in line with the ALPHA test battery protocol (Ruiz et al. 2011). Two parallel lines were drawn on the floor 10 metres apart. The participant ran as fast as possible from the starting line to the opposite line and returned to the starting line, touching the line with either the hand or foot every time. This was performed twice, covering a distance of 40m (4x10 m). Every time the participant touched any of the lines, they were required to pick up (first time) or exchange (second and third time) a sponge that was placed on either line prior to each trial. The timer was stopped when the adolescent crossed the finishing line with one foot. The time taken to complete the test was recorded to the nearest tenth of a second.

Flexibility: Hamstring and lumbar extensibility was measured using the back-saver sit and reach test, following the protocols detailed by Welk and Meredith (2010). Participants were asked to sit on the floor with legs fully out-stretched. Feet, with shoes off, were placed with the soles flat against the test device (Cartwrightfitness® sit and reach box). The knee of the participants extended leg was held flat against the floor by the test administrator, hands aligned one over the other, and palms facing down. Once the starting position was assumed, the participant reached forward along the measuring line as far as possible. To avoid a jerking action, participants were asked to hold their position at full extension for three seconds, before slowly returning to the starting position. The measurement device had a scale range of 70cm and was marked in 0.5cm intervals. The zero mark was 15cm before the feet of the participant. The result was recorded to the nearest 0.5cm, and the average of the highest scores achieved from the left and right side was used in the analysis.
**Cardiovascular Health:** Blood pressure (BP) was recorded using an Omron M6 oscillometric automated BP monitor. BP was measured by the test administrator according to the protocol outlined by the Centre for Disease Control (2008). Participants rested quietly for three to five minutes prior to the measurement. The participant was asked to sit all the way to the back of the chair so that the spine assumed an anatomically sound resting position. The left arm and back were fully supported, and legs were uncrossed with both feet flat on the floor. The left arm was unrestricted by clothing, with the palm of the hand turned upward and the elbow slightly flexed. The left arm was positioned so that the midpoint of the upper arm was at the approximate level of the heart.

### 5.4.4 Statistical analyses

A Shapiro-Wilk’s test ($p > .05$) (Razali and Wah 2011) and a visual inspection of their histograms showed that data were normally distributed, with the exception of SA BMI, handgrip strength and isometric plank hold, and RA BMI and BSR ($p < 0.05$). Non-parametric alternatives were used to analyse these data where necessary. Sex specific effects on reliability were only found in SA diastolic blood pressure ($p = .023$, $t$-test). Therefore, analyses were performed for both boys and girls together. A Pitman-Morgan test (Gardner 2001) indicated homogeneity of variance for SA and RA groups across all measures between T1 and T2 ($p > .05$). In addition, the presence of heteroscedasticity was examined in line with the procedure as set out by Brehm and colleagues (2012). Firstly, Bland-Altman plots were used to visually inspect the presence of heteroscedasticity by plotting the measurement differences (T2-T1) against the respective means. Following this, the degree of heteroscedasticity was then measured by calculating Kendall’s tau ($\tau_b$) correlation between the absolute inter-test difference and the corresponding means. When a positive correlation of $>0.1$ was found, the data were denoted heteroscedastic.
heteroscedasticity was present, the data were transformed by logarithms to the base 10, if \( \tau_b \) decreased, reliability was analysed on the log transformed scale (Brehm et al. 2012).

The level of test-retest reliability was explored using both relative and absolute indices: paired samples t-tests (Wilcoxin Signed Rank tests for non-parametric data) were used to determine systematic bias in mean values, intra-class correlation coefficient (ICC) was used to provide an estimate of rank order repeatability, and within-participant inter-test variation was graphically illustrated using Bland-Altman plots. 95% limits of agreement for all the physical fitness variables were calculated as the inter-test mean difference ±1.96 SD of the inter-test differences. The Bland-Altman procedure considers the proportion between the magnitude of measurements and the error graphically, but not quantitatively. In order to solve this problem, the authors calculated the percentage error by dividing the limits of agreement by the mean value of the measurements obtained (Hanneman 2008). In an examination of the reliability of a battery of field-based fitness measures among adolescents, Lubans and colleagues (2011a) suggested 20% variability was an acceptable degree of error. However, the decision as to what is acceptable agreement is a scientific judgement and one that statistics alone cannot answer (Ortega et al. 2008a). The threshold for acceptable percentage error should be specific to the variable being measured (Hanneman 2008). Therefore, a specific figure within which all tests might be considered reliable was not set. All calculations were performed using SPSS v.24.0 software for Windows (SPSS, Chicago, Illinois, USA). For all analyses, the significance level was set at 5%. 

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5.5 Results

A total of 86 participants were randomly assigned in to a student administered (SA) group (n= 45; age: 13.44 ±35; girls n= 26) or a research-assistant administered (RA) group (n= 41; age: 13.42 ±32; girls n= 21). Mean (M) and standard deviation (±) values for T1 and T2, as well as mean inter-test differences (T2-T1) are reported in Table 5.1. It can be observed that inter-test differences in the SA and RA groups are close to zero for nearly all measurements. Highest mean inter-test differences were observed in SA systolic blood pressure (M= 3.73mmhg ±7.4), and RA standing broad jump (M= -1.7cm ±0.1).

Intra-class correlation coefficients (ICC), paired sample t-tests, 95% limits of agreement (±1.96 SD) and mean percentage error for both RA and SA groups are reported in Table 5.2. ICC values for all tests in both SA (ICC ≥0.797) and RA groups (ICC ≥0.866) were very high. An examination of systematic bias between T1 and T2 indicated no statistically significant inter-test differences in either group (p >0.05), aside from SA systolic blood pressure (3.73 ±7.35, p =.002) and RA 90° push-up (1.14±1.98, p = .003). The average percentage error for all tests combined, calculated by dividing the 95% upper limit of agreement by the mean multiplied by 100, was 5.6% and 5.8% for SA and RA groups respectively. The BSR, isometric plank hold and 90° push-up tests had mean percentage error values of greater than 20% in both groups. SA and RA BMI had the lowest mean percentage error scores, 2.6% (SA) and 2.0% (RA) respectively. Measures of muscular strength (hand-grip strength and standing broad jump) and motor fitness (4x10m shuttle run) had mean percentage error scores of less than 10% in both groups.
Table 5.1 Test and retest measurements (mean ±SD) of student administered (n=45) and research assistant administered (n=41) groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Student administered (SA)</th>
<th>Research assistant administered (RA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n=45; age: 13.44 ±.35; girls n= 26)</td>
<td>(n=41; age: 13.42 ±.32; girls n= 21)</td>
</tr>
<tr>
<td><strong>Test 1 Mean</strong></td>
<td><strong>Test 2 Mean</strong></td>
<td><strong>Inter-test difference</strong></td>
</tr>
<tr>
<td><strong>(SD)</strong></td>
<td><strong>(SD)</strong></td>
<td><strong>(T2-T1, SD)</strong></td>
</tr>
<tr>
<td>B.M.I (kg/m$^2$)</td>
<td>20.3±3.6</td>
<td>20.2±3.7</td>
</tr>
<tr>
<td>BSR (cm)</td>
<td>12.9±5.9</td>
<td>12.9±5.9</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>101.5±11.0</td>
<td>104.9±10.7</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>72.3±7.2</td>
<td>71.2±8.6</td>
</tr>
<tr>
<td>SBJ (cm)</td>
<td>145.0±20.6</td>
<td>144.3±20.8</td>
</tr>
<tr>
<td>Handgrip (kg)</td>
<td>21.5±4.1</td>
<td>21.5±4.5</td>
</tr>
<tr>
<td>90° Push Up (repetitions)</td>
<td>10.1±6.6</td>
<td>10.3±6.3</td>
</tr>
<tr>
<td>Isometric Plank Hold (s)</td>
<td>84.0±39.6</td>
<td>86.0±41.1</td>
</tr>
<tr>
<td>4x10m Shuttle Run (s)</td>
<td>12.2±0.9</td>
<td>12.2±1.0</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; BSR, back saver sit and reach; SD, standard deviation; BP, blood pressure; aThe average of right and left side scores is shown in the table and was used for the analyses *Significant differences (*P <.05) were found between trial 1 and trial 2, paired samples T-test.
Table 5.2 Reliability indices for health and physical fitness tests in student administered (n=45) and research-assistant administered (n=41) groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Student assistant measured (n=45)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Research assistant measured (n=41)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC (95% CI)</td>
<td>p</td>
<td>LOA (±1.96 SD)</td>
<td>CV (%)</td>
<td>ICC (95% CI)</td>
<td>p</td>
<td>LOA (±1.96 SD)</td>
<td>CV (%)</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>0.998 (0.996 to 0.999)</td>
<td>0.075^</td>
<td>0.52 to -0.42</td>
<td>0.7%</td>
<td>0.999 (0.998 to 1.00)</td>
<td>0.925^+</td>
<td>0.41 to -0.41</td>
<td>0.6%</td>
<td></td>
</tr>
<tr>
<td>BSR (cm)</td>
<td>0.984 (0.971 to 0.991)</td>
<td>0.887</td>
<td>2.89 to -2.95</td>
<td>8.4%</td>
<td>0.980 (0.962 to 0.989)</td>
<td>0.324^</td>
<td>4.37 to -5.15</td>
<td>15.5%</td>
<td></td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>0.848 (0.680 to 0.922)</td>
<td>0.002*</td>
<td>10.84 to -17.96</td>
<td>4.3%</td>
<td>0.900 (0.812 to 0.947)</td>
<td>0.444</td>
<td>14.74 to -15.22</td>
<td>3.9%</td>
<td></td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>0.797 (0.632 to 0.888)</td>
<td>0.291</td>
<td>13.60 to -11.55</td>
<td>5.3%</td>
<td>0.866 (0.747 to 0.928)</td>
<td>0.394</td>
<td>12.08 to -12.61</td>
<td>5.1%</td>
<td></td>
</tr>
<tr>
<td>SBJ (cm)</td>
<td>0.979 (0.962 to 0.988)</td>
<td>0.452</td>
<td>0.12 to -0.11</td>
<td>2.0%</td>
<td>0.974 (0.951 to 0.986)</td>
<td>0.234</td>
<td>0.19 to -0.16</td>
<td>3.2%</td>
<td></td>
</tr>
<tr>
<td>Handgrip (kg)</td>
<td>0.984 (0.970 to 0.991)</td>
<td>0.608^*</td>
<td>1.63 to -2.70</td>
<td>3.0%</td>
<td>0.992 (0.985 to 0.996)</td>
<td>0.128</td>
<td>2.05 to -1.57</td>
<td>2.2%</td>
<td></td>
</tr>
<tr>
<td>90 Push Up (repetitions)</td>
<td>0.964 (0.935 to 0.980)</td>
<td>0.420</td>
<td>4.35 to -5.02</td>
<td>24.3%</td>
<td>0.971 (0.930 to 0.986)</td>
<td>0.003*</td>
<td>2.90 to -4.86</td>
<td>18.9%</td>
<td></td>
</tr>
<tr>
<td>Isometric Plank Hold (s)</td>
<td>0.979 (0.962 to 0.989)</td>
<td>0.455^</td>
<td>24.55 to -20.51</td>
<td>9.8%</td>
<td>0.978 (0.958 to 0.989)</td>
<td>0.768</td>
<td>24.23 to -25.86</td>
<td>10.4%</td>
<td></td>
</tr>
<tr>
<td>4x10m Shuttle Run (s)</td>
<td>0.985 (0.973 to 0.992)</td>
<td>0.758</td>
<td>0.49 to -0.47</td>
<td>1.2%</td>
<td>0.943 (0.891 to 0.970)</td>
<td>0.419</td>
<td>0.83 to -0.73</td>
<td>1.8%</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ICC, intra-class correlation coefficient; CI, confidence interval; LOA, limits of agreement (mean differences ±1.96SD); CV, coefficient of variation; BMI, body mass index; BSR, back saver sit and reach. *Significant differences (*p <.05) were found between trial 1 and trial 2, paired samples T-test. ^Wilcoxon Signed Rank Test used for non-normally distributed data. ^LOA: *If heteroscedasticity was present, the data were transformed by logarithms to the base 10.
Bland-Altman plots (Figure 5.1 and Figure 5.2) were used to graphically depict the reliability patterns in terms of systematic error (bias or mean inter-test difference) and random error (95% limits of agreement) of the fitness tests studied. The systematic error, represented by the red line, was close to zero for all tests in both groups. A visual inspection of the plots indicated the presence of heteroscedasticity for SA handgrip strength and RA BMI. This was confirmed by Kendall’s tau ($\tau_b$) correlation coefficients, which were .264 and .259 respectively. Log transformations to the base 10 did not remove the heteroscedasticity for either measure ($p = .011$, SA handgrip strength; $p = .019$, RA BMI). Heteroscedasticity was not observed for any other measure in both groups ($p > .05$).
Figure 5.1 Bland-Altman plots for SA BMI, back-saver sit and reach, standing broad jump, handgrip strength, 90° push-up, isometric plank hold, and 4x10m shuttle run. The central line represents the mean differences between the second test (T2) and the first test (T1); the upper and lower black lines represent the upper and lower 95% limits of agreement (means differences ±1.96 SD of the differences), respectively.
Figure 5.2 Bland-Altman plots for RA BMI, back-saver sit and reach, standing broad jump, handgrip strength, isometric plank hold, and 4x10m shuttle run test. The central line represents the mean differences between the second test (T2) and the first test (T1); the upper and lower black lines represent the upper and lower 95% limits of agreement (means differences ±1.96 SD of the differences), respectively.
5.6 Discussion

The results from this study offer insights about the quality of student administered fitness tests in school settings. The practicality and feasibility of field-based tests for administration in school settings are crucial, however, students, parents and policy makers need to have confidence in the validity and reliability of the data gathered. With the aim of making data gathered as close to the reality of a school context as possible, tests were performed during timetabled PE lessons, and senior student facilitators only received one day of training. The main findings suggest that, following training on test administration protocols, student administered fitness tests including BMI, standing broad jump, handgrip strength and the 4x10m shuttle run, can be considered reliable. These results concur with previous research that examined the reliability of teacher administered fitness tests in youth (Espana-Romero et al. 2010a; Ramírez-Vélez et al. 2015; Vanhelst et al. 2016). Further research is needed to confirm the reliability of the isometric plank hold, 90° push-up, blood pressure, and BSR in light of the large test-retest mean percentage error scores found in both student administered and research administered groups.

To the authors’ knowledge, this is the first study of its kind to examine the test-retest reliability of student administered physical fitness in an adolescent population, and to compare these reliability indices with those taken by experienced research assistants. Aside from SA blood pressure, no sex specific differences were observed between T1 and T2 in either group, corroborating the findings of other similar studies that examined the reliability teacher administered tests in school settings (Espana-Romero et al. 2010a; Lubans et al. 2011a). Relative reliability indices were very good, with high ICCs across all tests in both the SA (ICC, ≥0.797) and RA (ICC, ≥0.866) groups. Systematic bias was only found in SA
systolic blood pressure and RA 90° push-up. Surprisingly, the mean percentage error for all tests combined was marginally lower in the SA group (5.5%) in comparison to the RA group (5.8%), potential reasons for which are explored later in the discussion. A significant disparity between the ICC and mean percentage error values could be observed for the BSR, 90° push-up and isometric plank hold tests in both the SA and RA groups. The disparity might be explained by a wide range of scores in each group. This can lead to higher ICC values despite the high percentage error, indicating that individuals were inconsistent in their test-retest results from T1 to T2 for these particular tests. This further emphasises the importance of using both relative and absolute reliability indices (Atkinson and Nevill 1998).

Although not strictly a measure of body composition, the Institute of Medicine recommends BMI as the most appropriate anthropometric measure for use in schools (Pillsbury et al. 2013). The reliability of BMI measures taken in school-based physical education programmes has been shown to be higher when compared to other measures of body composition (2010a). Reliability statistics were very high for measures of BMI in both the SA (ICC ≥0.797) and RA (ICC ≥0.866) groups. These findings concur with those in previous studies, who reported similar levels of agreement for teacher administered BMI tests in children and adolescents (Espana-Romero et al. 2010a; Ramírez-Vélez et al. 2015). High inter-rater reliability of BMI measures taken by a school nurse and trained research staff among boys and girls aged 5 to 12 years has also been reported (2008). The reliability of BMI measures may be enhanced when two or more measures are obtained and averaged (2003), as was the protocol used in this study. While some scholars have highlighted the benefits of systematic monitoring of anthropometric measures in school settings (Thompson et al. 2019), physical education teachers need to be mindful of the influence of body image concerns and elevated levels of anxiety on self-efficacy in fitness test performance (Lodewyk
and Sullivan 2016). Therefore, particular care needs to be given to preparing student facilitators for the appropriate administration of such measures in school settings, and should only be used in contexts in which the physical education teacher deems it appropriate.

Reliability patterns for tests measuring musculoskeletal fitness varied considerably. The 90° push-up and isometric plank hold tests had very high mean percentage errors in both groups (≥ 24.3%), despite having excellent ICC values of ≥0.964 and ≥0.971 for SA and RA groups respectively. As indicated previously, the wide range of scores observed in each group could explain this discrepancy. Lubans et al. (2011a) and Morrow et al. (2010) similarly found poor reliability for the 90° degree push-up test. Interestingly, a significant inter-test difference was found for RA 90° push-up test (p = .003) that was not observed in the SA group. This suggests that reliability declined with experience, however, it has been reported that more experienced testers may not count as many repetitions that meet the criteria for a full repetition, hence the greater degree of variability (McManis et al. 2000). A similar finding of reduced reliability with experience for the trunk-lift test was reported by Morrow and colleagues (2010). Acceptable reliability of the isometric plank hold test among children aged 8 to 12 years has been reported elsewhere (2013), however, this study only reported ICC values, the limitations of which have previously been outlined. Test-retest reliability for the handgrip strength test and standing broad jump was very high in SA and RA groups. This corroborates the findings of previous studies that examined the reliability of both test items delivered by physical education specialists in school settings (Ortega et al. 2008a; Espana-Romero et al. 2010a; Ramírez-Vélez et al. 2015). Similarly, in a systematic review on the reliability of field-based tests in youth, Artero and colleagues (Artero et al. 2011) indicated that neither learning nor fatigue effects were found for either measure in the studies they identified.
The BSR test produced high relative reliability scores in both the SA (ICC 0.984) group and RA (ICC 0.980) group. Hartman and Looney (2003) found similarly high ICC levels for the BSR test in a study involving 87 boys and 62 girls aged 6 to 12 years. However, the mean percentage error was high for both groups (≥22.4%). In line with existing research (Espana-Romero et al. 2010a; Ramírez-Vélez et al. 2015), the 4x10m shuttle produced very good relative and absolute reliability indices in both groups. The 4x10m shuttle test thus represents a very practical and reliable approach to assessing components of motor fitness in paediatric populations. Automated blood pressure recordings, although within a moderate range, had the lowest ICC values for both groups when compared to the other test items (RA; systolic = 0.677, diastolic = 0.761; SA; systolic = 0.742, diastolic = 0.668). Mean percentage error values for blood pressure were less than 20% for both groups, however, a significant inter test difference (p=.002) was observed for SA systolic values. Previous studies have highlighted the multiple advantages of automated BP recordings (Graves and Althaf 2006). Although home BP measurement in children and adolescents has been shown to be reliable (Stergiou et al. 2006), further research on the reliability of its application in a school context is needed.

A significant association between the magnitude of the measure and the difference between test and retest values (heteroscedasticity) was observed for SA handgrip strength and RA BMI. In both cases, higher values produced significantly more variability in test-retest scores (p = <.05), indicating the presence of heteroscedasticity. All other tests analysed were homoscedastic. In an examination of the reliability of fitness tests administered by teachers in schools, Espana-Romero and colleagues (2010a) did not find the presence of heteroscedasticity in any physical fitness test they analysed. The presence of
heteroscedasticity for the BSR measure identified by Ramiréz-Vélez et al. (2015), was not observed in the current study.

This study had some limitations which should be noted. Given the relatively small sample size, and tight age range of participants drawn from only one school, our findings cannot be generalized to all field-based testing settings at this time. A larger sample size, involving a more diverse age-range, and the inclusion of an additional trial, could have improved the precision of the reliability estimates, while also allowing for a more detailed examination of results by age group. Furthermore, the experience level of the eight research assistants varied from one to five years. However, the two group study design (SA and RA) and the wide variety fitness tests examined, in addition to the authenticity of the environment in which testing took place, are notable strengths of this study.

5.7 Conclusion

In conclusion, although a student-assessed approach to fitness testing has been recommended by several researchers, this is the first study to examine the reliability of such data. No testing situation can be perfect, particularly in a field-based or school context, however, this study presents various steps that can be taken to minimize potential sources of error and optimize reliability, while simultaneously contributing to student learning when measuring fitness in a school context. The results suggest that, following training on test administration protocols, the accuracy of student-assessed measures of anthropometric (BMI), musculoskeletal (hand-grip strength and standing broad jump) and performance-related (4x10m shuttle run) components of fitness can be considered reliable. Further research is needed to examine the high test-retest mean percentage error for the isometric plank hold, 90° push-up, and back-saver sit and reach tests.
Chapter Six: Profiling the fitness levels of Irish adolescents

This chapter has been accepted for publication in ‘PLOS One’.
6.1 Preface

The feasibility phase of this thesis included the delivery of the Youth-fit test battery to a randomised sample of 20 schools, stratified for sex, location and socioeconomic status. This represented the most comprehensive examination of all components of health-related physical fitness (HRPF) among adolescents ever undertaken in the Republic of Ireland. The focus of Chapter Six was to profile the results obtained from this phase of the project, and examine trends across key demographic variables, including, gender, location and socioeconomic status. This chapter also included a comparison of HRPF levels between participants in the current study and European normative values, established as part of the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study (Ortega et al. 2011a). Consistent with existing research, boys outperformed girls across all components of HRPF, with the exception of flexibility. In addition to overweight and obesity, school level socioeconomic status was a strong determinant of performance in both sexes. Age-matched comparisons of HRPF levels with European normative values were broadly positive for all components, aside from muscular fitness in which European norms were significantly higher. This study illustrates the capacity of large-scale systems for monitoring key predictors of adolescent health to inform policy and interventions aiming to improve the current and future health of school going populations.
6.2 Abstract

Purpose: The purpose of this study was twofold; 1) to examine the influence of school level characteristics on fitness test performance; 2) to compare Irish adolescents’ physical fitness to European norms. Methods: Adolescents (N= 1215, girls = 609) aged 13.4 years (SD.41) from a randomised sample of 20 secondary schools, stratified for sex, location and educational (dis)advantage, completed a series of field-based fitness tests. Tests included; body mass index, 20m shuttle run test (20m SRT), hand-grip strength, standing broad jump (SBJ), 4x10m shuttle run and back-saver sit and reach (BSR). Results: Overall, boys outperformed girls in all measured variables, aside from flexibility (BSR) (p < 0.005, t-test, Bonferroni correction). Participants in designated disadvantaged schools had significantly higher body mass index levels, and significantly lower cardiorespiratory endurance (20m SRT) and muscular strength (handgrip strength) levels compared to participants in non-disadvantaged schools (p < 0.005). When compared to European norms, girls in this study scored significantly higher in the 20m SRT, 4x10m shuttle run and SBJ tests, while boys scored significantly higher in the BSR test (Cohen’s d 0.2 to 0.6, p < 0.01). However, European adolescents had significantly higher handgrip strength scores (Cohen’s d 0.6 to 0.8, p < 0.01). Conclusion: Irish adolescents compared favourably to European normative values across most components of HRPF, with the exception of muscular strength. School socioeconomic status was a strong determinant of performance among Irish adolescents. The contrasting findings for different fitness components reiterate the need for multi-component test batteries for monitoring fitness in youth.
6.3 Introduction

Physical fitness is a multifaceted construct that can be described as an integrated measure of most, if not all, body functions that are involved in daily physical activity (Ortega et al. 2008b). Health-related physical fitness (HRPF) is made up of multiple components including, cardiorespiratory endurance (CRE), musculoskeletal fitness (muscular strength, endurance, and power) and body composition. These components have been identified as powerful markers of future health among children and adolescents (Ortega et al. 2008b; Ruiz et al. 2009a). There is a consistent body of evidence supporting the favourable effects of moderate-to-high levels of physical fitness to health-related outcomes, including cardio-metabolic risk factors (Schmidt et al. 2016), musculoskeletal (Smith et al. 2014), and cognitive (Bezold et al. 2014) traits in childhood and adolescence. It has also been reported that positive changes to HRPF during childhood and adolescence can mitigate the impact of negative health outcomes later in life (Ortega et al. 2011b).

Declining HRPF levels among youth internationally have been reported. For example, an international analysis of secular trends of CRE among adolescents, involving 11 countries from 1980 to 2000, noted a sample-weighted mean decline of 0.43% per year in mean values, and the decline was most prevalent in older adolescent age groups (Tomkinson et al. 2003). A meta-analysis of 20m shuttle run test scores among a sample of 1,142,026 children and youth from 50 countries reported that 67% of boys (CI 95% ±14%) and 54% (CI 95% ±17%) of girls had healthy CRE according to Fitnessgram® criterion referenced standards, and the numbers achieving healthy standards decreased systematically with age (Tomkinson et al. 2017). In contrast, Moliner-Urdiales (Moliner-Urdiales et al. 2010) and colleagues reported significant increases in CRE among Spanish adolescents between 2001 and 2007 (Cohens d 0.2 to 0.4, p <0.05). In terms of muscular fitness, Cohen et al. (2011) reported that English schoolchildren have shown a decrease
in upper body muscular strength, measured by hand-grip dynamometer over the past decade, a trend also reported in Spain (Moliner-Urdiales et al. 2010), Canada (Tremblay et al. 2010) and China (Ao et al. 2019). However, Huotari et al. (2010) reported that muscular fitness was higher in a cross sectional cohort of Danish adolescents in 2001 than an age-matched cohort from 1976.

Variations in physical fitness are caused by a network of social, behavioural, physical, psychosocial and physiological factors (Tomkinson and Olds 2007). Well established determinants of physical fitness among youth include age, gender and physical activity levels (Zaqout et al. 2016). Inverse associations between physical fitness, particularly CRE, and overweight in adolescents, have also been reported (Dumith et al. 2010; Zaqout et al. 2016). The relationship between socioeconomic status and physical fitness has been less examined, with much of the research to date producing inconsistent results (Jiménez Pavón et al. 2010). In addition, despite the prominence of fitness testing in schools (O’Keeffe et al. 2020c), the influence of school level demographic characteristics including location and sociodemographic status on HRPF are scantily represented in the current literature. In one of the few studies to examine school sociodemographic characteristics and health nationally, Bel-Serrat and colleagues (2018) reported that school socioeconomic status was a strong determinant of overweight and obesity in schoolchildren. Bai et al. (2016) also concluded that there was clear evidence showing that school SES was the most influential contextual factor for explaining disparities in school fitness outcomes among 157971 schoolchildren from 675 schools in the US.

It has been projected that the Republic of Ireland is on course to become the most obese nation in Europe by the year 2030 (Keaver et al. 2013). Despite World Health Organisation recommendations (Hallal et al. 2012), the Republic of Ireland lacks a clearly
specified strategy for monitoring HRPF in youth. Consequently, there is a paucity of data on objectively measured fitness levels of Irish youth, with much of the health and activity surveillance surveys to date utilising self-reported measures (Callaghan et al. 2015). To the authors’ knowledge, the Children Sport Participation and Physical Activity study (Woods et al. 2010; Woods et al. 2019) is the only study to measure a component of HRPF among a nationally representative sample of adolescents in the Republic of Ireland. Woods and colleagues (2019) reported no significant changes in CRE levels between 2010 and 2018, with 76% and 77% of participants, respectively, meeting established criterion referenced standards (Lobelo et al. 2009). The collection of objective measures of health and physical fitness from population-based samples over pre-defined time periods is a crucial resource that can inform policy-makers and the public, and is vital for healthcare and education authorities for timely planning of prevention programs (Froberg 2014). In light of the scarcity of research specific to the Irish context, the aim of the current study was twofold. Firstly, to profile the HRPF of Irish adolescents from a randomised and stratified sample of schools, and secondly, to compare these data to established European normative values published by Ortega and colleagues (2011a).

6.4 Methods

6.4.1 Sampling and recruitment

Research ethics approval for this study and the associated protocols was granted by the Institution Review Board of the Faculty of Education and Health Sciences, University of Limerick, Ireland (EHS_2017_02_12). A randomised sample of 20 schools, stratified for sex (single-sex boys, single-sex girls and mixed-sex), location (urban and rural categorised by population density), and educational (dis)advantage, participated in the study. Designated disadvantaged schools were selected based on Department of
Education and Skills categorisations as part of the Government of Ireland’s Delivering Equality of Opportunity in Schools (DEIS) scheme (Department of Education and Skills 2017). This classification is based on a ‘Deprivation Index Scale’ which accounts for demographic growth, social class composition, and employment status, in addition to centrally held Department of Education and Skills pupil data. There are currently 185 designated disadvantaged secondary schools in Ireland, representing just over one quarter of all secondary schools (Department of Education and Skills 2017). The procedure for generating a randomised sample was conducted using a specialised computerized code system in which all secondary schools in the mid-west and south-west region of Ireland were assigned a code and categorised according to the aforementioned strata. Due to the geographical spread of schools, and the need to visit each school individually, 20 schools was considered to be the maximum sample size achievable from a logistical viewpoint, and the minimum required to obtain a sufficient number of schools in each of the chosen strata.

6.4.2 School and participant recruitment

Approval from the principal and cooperating physical education teacher in each school was granted following an initial email and telephone conversation. Written informed consent was obtained from parents and student participants (Appendix G). Of the initial sample of 20 schools, four schools declined to participate, in which case the next school on a randomised reserve list was recruited. This study focused specifically on students in year one of secondary school education (ages 13 to 14), and was open to all students in the selected year group in each participating school who provided informed consent to participate, and fulfilled the physical activity readiness questionnaire (PAR-Q) pre-test requirements (Warburton et al. 2011). A minimum participation rate threshold of 70%, as used in other similar studies (Moreno et al. 2008), was set for a school to be considered
eligible. Reasons for non-participation were recorded on a non-participant form. The most commonly cited reasons were absenteeism, injury/sickness, and/or the students or parents deciding not to provide consent to participate in the study. Participation rates in the final sample were $\geq 75\%$ in each school.

6.4.3 Testing procedures

The cooperating physical education teacher in each school selected eight senior students (final two years of second level education) to facilitate the administration of the test battery. Tests were delivered in a station format to small groups of five students or less, and each administrator was responsible for one test item on the test battery. A manual detailing standard operating procedures for each test item was designed for and read by both cooperating teachers and senior student administrators. Cooperating teachers and student facilitators participated in a three hour workshop in which each administrator was assigned one test, and trained in the assigned test only. Test administrators conducted several familiarisation trials, and examples of correct and incorrect trials were demonstrated. Test items included; body mass index (BMI); 20m shuttle run test (20m SRT); handgrip strength; standing broad jump (SBJ); 4x10m shuttle run.

The scientific rationale for the selection of the tests was based on their feasibility and reliability for administration in a school setting (Espana-Romero et al. 2010a), and their established criterion-related validity (Artero et al. 2012). Four additional tests of physical fitness and health commonly administered in school-based HRPF test batteries and large-scale health surveys, were also included namely; 90˚ push-up; isometric plank-hold; back-saver sit and reach (BSR); and blood pressure. O’Keeffe and colleagues (2020b) confirmed the test-retest reliability of the administration protocol outlined above for each test item, reporting intra-class correlation coefficients of $\geq 0.797$ and mean coefficient of variation values of 6.5% across all test items. Detailed test administration
protocols for each test item are available in this study (O’Keeffe et al. 2020b). All tests, with the exception of the 20m shuttle run test (20m SRT), were conducted during timetabled physical education lessons (≥80 minutes). As the 20m SRT is a maximal aerobic capacity test, it was conducted on a separate day to all other tests using the Léger et al. protocol (1988). Participants were required to run between two lines 20 metres apart, while keeping pace with audio signals emitted from a pre-recorded CD. The initial speed was 8.5 km/h, and was increased by 0.5 km/h per minute. The test finished when the participant failed to reach the end lines concurrent with the audio signals on two consecutive occasions, or when the subject stopped because of fatigue.

6.4.4 Data collection and quality control

A software platform was developed specifically for the purpose of this study to enable efficient multi-site capture of data from participating schools. Following test administration, cooperating physical education teachers uploaded test results to a web-based application hosted on a secured internally facing server at the lead authors’ institution. Cooperating teachers received a tutorial on using the software platform from the lead author. A comprehensive user manual outlining the procedure for inputting results (Appendix C), in addition to a video tutorial demonstration (available here) were also provided. Biologically plausible value limits were assigned to each result input field to minimise potential inaccuracies when inputting data. An additional quality control feature included collecting test battery results sheets from participating schools, from which the lead author randomly selected half of the completed results sheets, and cross-referenced each to ensure the accuracy of results inputted. Thus, an additional objective of the current study was to determine the capacity for large-scale collection of objective measures of health and physical fitness from population-based samples, and the transfer of this data in anonymised form to a centrally hosted database.
6.4.5 Statistical Analysis

Complete cases ($N = 1215$; designated disadvantaged, $n = 221$) were extracted from the software platform and transferred to Statistical Package for Social Sciences (SPSS version 25, Chicago IL) for analysis. The research team defined an incomplete case as missing the body mass index (BMI) recording, or two or more fitness test items. Incomplete responses ($n = 66$) were excluded from all analyses. A visual inspection of histograms and box plots for key outcome variables showed that data were normally distributed, with skewness of $\leq 1.2$ and kurtosis of $\leq 1.6$. Means ($M$) and standard deviations ($SD$) were calculated for all scale scores, with $t$-tests testing for differences by selected demographics. A linear mixed model analysis was conducted to examine the differences between designated disadvantaged and non-disadvantaged schools for key health-related fitness outcome variables, controlling for age and gender as fixed effects, and school as a random effect. Results from this analysis were then graphically depicted using clustered error bar graphs. Following a request to the authors, access was provided to the original dataset from the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study (Ortega et al. 2011a), containing sex and age-specific physical fitness normative values among European adolescents. Cohen’s $d$ was used to compare differences between participants in this study and age-matched European normative values by calculating the mean difference between the two groups, and dividing the result by the pooled standard deviation (Ortega et al. 2011a). Cohen suggested that 0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size (Cohen 1988). Correction for multiple comparisons was made via the Bonferroni Correction. Participants physical fitness scores were also expressed using a quintile classification framework based on European normative values (Ortega et al. 2011a),
corresponding to “very low,” “low,” “moderate,” “high,” and “very high” levels, as recommended by Tomkinson et al. (2018)

6.5 Results

Anthropometric characteristics and HRPF levels of the study sample are shown in Table 6.1. Overall, boys had significantly higher cardiorespiratory endurance (20m shuttle run test), muscular fitness (handgrip strength, standing broad jump (SBJ), 90° push-up and isometric plank hold) levels compared to girls, while girls had significantly higher flexibility (back-saver sit and reach (BSR)) \((p < 0.005, t\text{-test, with Bonferroni correction for multiple comparisons})\). Girls also had significantly lower mean systolic blood pressure in comparison to boys, however, despite reaching statistical significance, the total difference in mean values was small (< 1.5 mmHg). The prevalence of overweight and obesity was estimated as per the criteria published by Cole et al. (2000). Over one quarter (25.8%) of girls and 23.9% of boys were overweight, of which 12.2% of girls and 9.2% of boys were obese. An inverse relationship between performance in both the 20m SRT \((r = -0.32, p=.001)\) and standing broad jump \((r= -0.29, p=.001)\) tests and overweight and/or obesity was observed. Boys and girls categorised as overweight or obese ran an average of 17 fewer shuttles (20m SRT) and jumped (SBJ), on average, 14cm less than their peers.
Table 6.1 Descriptive characteristics of the study sample by sex.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Mean (SD)</th>
<th>Boys Mean (SD)</th>
<th>Girls Mean (SD)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1215 (0.4)</td>
<td>606 (0.4)</td>
<td>609 (0.4)</td>
<td>NS</td>
</tr>
<tr>
<td>BMI</td>
<td>1215 (3.6)</td>
<td>606 (3.6)</td>
<td>609 (3.7)</td>
<td>NS</td>
</tr>
<tr>
<td>BSR (cm) a</td>
<td>1177 (9.3)</td>
<td>591 (8.7)</td>
<td>586 (9.7)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>1189 (13.3)</td>
<td>595 (13.3)</td>
<td>594 (13.1)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>1189 (11.4)</td>
<td>595 (11.3)</td>
<td>594 (11.5)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>SBJ (cm)</td>
<td>1206 (26.1)</td>
<td>601 (27.3)</td>
<td>605 (23.7)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Handgrip strength (kg) a</td>
<td>1201 (5.1)</td>
<td>598 (5.7)</td>
<td>603 (4.3)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>90° Push Up (repetitions)</td>
<td>1177 (8.6)</td>
<td>583 (8.6)</td>
<td>594 (8.0)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Isometric Plankhold (s)</td>
<td>1177 (49.5)</td>
<td>581 (54)</td>
<td>596 (42.8)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>4x10m Shuttle Run (s)</td>
<td>1174 (1.4)</td>
<td>588 (1.1)</td>
<td>586 (1.7)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>20m SRT (# shuttles) b</td>
<td>1138 (22.4)</td>
<td>570 (22.8)</td>
<td>568 (20.3)</td>
<td>&lt;.005</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; BSR, back-saver sit and reach; SBJ, standing broad jump; SD, standard deviation; BP, blood pressure; 20m SRT, 20m shuttle run test. aThe average of right and left side scores is shown in the table. Significant differences (p <0.005, with Bonferroni correction) were found between boys and girls, independent samples t-test. bIndicates a more favourable HRPF score for boys. cIndicates a more favourable HRPF score for girls. Due to school absences and/or injury, not all totals amount to 609 (girls) and 606 (boys).

Descriptive characteristics of boys and girls in non-disadvantaged versus designated disadvantaged schools are presented in Table 6.2. A mixed model analysis of the differences between designated disadvantaged and non-disadvantaged schools for key health-related fitness outcome variables, controlling for age, gender and school (as a random effect) is presented in Table 6.3. Mean values were significantly higher in designated disadvantaged schools for BMI and significantly lower for the 20m SRT, 90° push-up, handgrip strength (p < 0.005, t-test with Bonferroni correction). Differences were particularly large for the 20m SRT, with mean values for designated disadvantaged
schools over 19 shuttles (380 metres) fewer than non-disadvantaged schools. Boys and girls in designated disadvantaged schools also scored significantly lower in both the 90° push-up and isometric plank-hold tests \((p < 0.005, t\text{-test})\). Clustered error bar graphs, with 95% confidence intervals, were used to graphically depict the differences in performance at a school level across key HRPF fitness variables, as displayed in Figure 6.1. It can be observed that four of the five lowest 20m shuttle run test mean scores, and three of the five lowest handgrip and standing broad jump mean scores, were observed in designated disadvantaged schools. Furthermore, the four schools with the highest mean BMI values were designated disadvantaged schools.

**Table 6.2** Descriptive characteristics of students in non-disadvantaged versus designated disadvantaged schools, by sex.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Boys Non-Disadvantaged (n=472)</th>
<th>Boys Disadvantaged (n=134)</th>
<th>Girls Non-Disadvantaged (n=522)</th>
<th>Girls Disadvantaged (n=87)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td></td>
<td>19.8 (3.4)</td>
<td>21.3 (4.0)</td>
<td>20.2 (3.5)</td>
<td>21.8 (4.2)</td>
</tr>
<tr>
<td>BSR (cm) (^a)</td>
<td>22.1 (8.5)</td>
<td>21.6 (9.4)</td>
<td>25.5 (9.4)</td>
<td>21.4 (10.6)</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>110.8 (13.4)</td>
<td>110.1 (13.1)</td>
<td>108.2 (13.1)</td>
<td>108.4 (13.5)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>72.8 (11.3)</td>
<td>73.6 (11.5)</td>
<td>75.1 (11.6)</td>
<td>74.3 (10.6)</td>
</tr>
<tr>
<td>SBJ (cm)</td>
<td>161.8 (26.7)</td>
<td>148.0 (26.5)</td>
<td>147.6 (23.3)</td>
<td>139.9 (23.5)</td>
</tr>
<tr>
<td>Handgrip (kg) (^a)</td>
<td>24.6 (5.5)</td>
<td>22.6 (5.9)</td>
<td>22 (4.1)</td>
<td>21.9 (5.0)</td>
</tr>
<tr>
<td>90° Push Up (reps)</td>
<td>14.2 (8.4)</td>
<td>10.2 (8.2)</td>
<td>8.9 (8.2)</td>
<td>6.3 (5.8)</td>
</tr>
<tr>
<td>Isometric Plank (s)</td>
<td>92.2 (54.6)</td>
<td>67.5 (47.4)</td>
<td>70.8 (43.5)</td>
<td>57.5 (36.9)</td>
</tr>
<tr>
<td>4x10m Shuttle (s)</td>
<td>11.9 (1.0)</td>
<td>12.3 (1.3)</td>
<td>12.3 (1.7)</td>
<td>12.7 (1.3)</td>
</tr>
<tr>
<td>20m SRT (# shuttles)</td>
<td>57.8 (21.3)</td>
<td>38.0 (21.3)</td>
<td>43.9 (20.3)</td>
<td>26.3 (12.2)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; BSR, back-saver sit and reach; SBJ, standing broad jump; SD, standard deviation; BP, blood pressure; 20m SRT, 20m shuttle run test \(^a\) The average of right and left side score is shown in the table and was used for all analyses.
Table 6.3 Adjusted mean differences in non-disadvantaged versus designated disadvantaged schools, controlling for age and gender as fixed effects, and school as a random effect.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Non-Disadvantaged (n=994)</th>
<th>Disadvantaged (n=221)</th>
<th>Mean difference (CI)b</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>20.0</td>
<td>21.6</td>
<td>-1.6 (-2.2 to -0.97)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>BSR (cm)¹</td>
<td>24.3</td>
<td>20.7</td>
<td>3.5 (-3.6 to 10.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>109.4</td>
<td>108.9</td>
<td>0.5 (-2.4 to 3.4)</td>
<td>NS</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>73.9</td>
<td>73.3</td>
<td>0.6 (-2.5 to 3.7)</td>
<td>NS</td>
</tr>
<tr>
<td>SBJ (cm)</td>
<td>154.3</td>
<td>142.0</td>
<td>12.3 (2.9 to 21.9)</td>
<td>NS</td>
</tr>
<tr>
<td>Handgrip (kg)¹</td>
<td>23.4</td>
<td>22.0</td>
<td>1.4 (0.0 to 2.7)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>90° Push Up (reps)</td>
<td>11.5</td>
<td>8.4</td>
<td>3.1 (0.7 to 5.6)</td>
<td>&lt;.005</td>
</tr>
<tr>
<td>Isometric Plank (s)</td>
<td>79.4</td>
<td>60.7</td>
<td>18.7 (-0.5 to 38.0)</td>
<td>NS</td>
</tr>
<tr>
<td>4x10m Shuttle (s)</td>
<td>12.1</td>
<td>12.7</td>
<td>-0.6 (-1.3 to -0.0)</td>
<td>&lt;NS</td>
</tr>
<tr>
<td>20m SRT (# shuttles)</td>
<td>51.3</td>
<td>32.2</td>
<td>19.1 (12.3 to 25.9)</td>
<td>&lt;.005</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; BSR, back-saver sit and reach; SBJ, standing broad jump; SD, standard deviation; BP, blood pressure; 20m SRT, 20m shuttle run test. ¹ The average of right and left side score is shown in the table and was used for all analyses. bMean difference (95% CI) from linear mixed models, controlling for age and gender as fixed effects, and school as a random effect.
Figure 6.1 Clustered error bar mean graphs 20m shuttle run test, body mass index, standing broad jump and handgrip strength with 95% confidence intervals, by school. Designated disadvantaged schools are highlighted red, non-disadvantaged schools are highlighted blue.
When compared to European normative values (Ortega et al. 2011a), girls in this study scored significantly better in the 20m SRT, 4x10m shuttle run and SBJ tests, while boys scored significantly higher in the BSR test (Cohen’s d ranging from 0.2 to 0.6, \( p < 0.01 \), Bonferroni correction). However, European adolescents had significantly higher handgrip strength scores (Cohen’s d 0.6 to 0.8, \( p < 0.01 \)). European boys also had significantly higher SBJ scores (Cohen’s d = 0.5, \( p < 0.01 \)). Using a quintile classification framework, the authors established the percentage of Irish adolescents from the current study that fell within each quintile of European normative values (Ortega et al. 2011a) (Figures 6.2 and 6.3). Only 11.1% of boys and 10.0% of girls achieved a very high score (>80\(^{\text{th}}\) centile) for handgrip strength, with 34.0% of boys and 31.2% of girls classified in the very low quintile (<20\%). SBJ scores were more evenly spread, 19.5% and 9.9% scoring in the very low category, and 17.6% and 17.1% scoring in the very high category, for boys and girls, respectively. With regard to back-saver sit and reach, 39.1% of boys and 29.2% of girls achieved a very high score based on European norms. While boys’ scores for the 4x10m shuttle run were relatively evenly distributed in each quintile, 41.1% of girls achieved a score \( \geq 80^{\text{th}} \) percentile. Finally, the most significant differences with European normative data were found in the 20m SRT. Almost two thirds of girls (61.4%) and 41.1% of boys in the current study were ranked in the highest quintile (\( \geq 80^{\text{th}} \) percentile), with only 5.6% of boys and 0.9% of girls categorised in the very low category (\( \leq 20^{\text{th}} \) percentile).
Figure 6.2 Quintile classification framework of physical fitness components for girls, based on European normative values (Ortega et al. 2011a).

Figure 6.3 Quintile classification framework of physical fitness components for boys, based on European normative values (Ortega et al. 2011a).
6.6 Discussion

The aim of the current study was to examine the influence of school level characteristics on fitness test performance, and to compare Irish adolescents’ physical fitness to European norms. Overall, boys had significantly higher HRPF levels in comparison to girls, participants in designated disadvantaged schools had significantly poorer HRPF levels in comparison to those in non-disadvantaged schools, and although participants in this study had significantly higher cardiorespiratory endurance levels, European adolescents had significantly higher muscular strength levels. This study represents the first analysis of all components of HRPF among adolescents from the Republic of Ireland, which it is hoped will form the basis of further examinations of physical fitness variables among youth across a broader range of age groups. In addition, the multi-site data capture application (Figure 4.6) used to input HRPF results and transfer anonymised data to a secured, centrally hosted database, confirmed the capacity for the collection of objective measures of health and physical fitness from population-based samples.

Perhaps unsurprisingly, boys scored higher than girls across all measured components of HRPF, aside from flexibility. This corroborates the findings of a recent meta-analysis of physical fitness among adolescents internationally (Catley and Tomkinson 2013), which reported that boys consistently scored higher than girls on fitness tests, except on the sit-and-reach test of flexibility, in which girls scored higher. Furthermore, in line with research to date, an inverse relationship between performance in the 20m SRT and standing broad jump tests and overweight and/or obesity was found in the current sample. In an investigation of the determinant factors of physical fitness among 13,622 European children, Zaqout and colleagues (2016) highlighted the significance of BMI as a physical fitness determinant,
independent of physical activity. In an examination of overweight/obesity and physical fitness among 519 Brazilian children and adolescents aged 7 to 15 years, Dumith et al. (2010) also reported that higher BMI values were associated with declines in physical fitness, independent of age.

Contrasting findings emerged from comparisons between the current study sample and age-matched European normative values generated from the HELENA study (Ortega et al. 2011a). Girls in this study had significantly higher mean scores in the SBJ, 4x10m shuttle run and 20m SRT in comparison to their European peers, while boys in this study scored significantly higher in the back-saver sit and reach test. However, as illustrated in Figures 6.2 and 6.3, over three quarters of Irish boys and girls were classified as moderate or below average for handgrip strength when compared to European norms using a quintile classification framework. This is a finding of particular concern given the emerging evidence-base linking poor musculoskeletal fitness in adolescence with negative health outcomes later in life (Ortega et al. 2012; Smith et al. 2014). In contrast, 84.3% of girls and 66.5% of boys scored above the 60th percentile in the 20m SRT when compared to European normative values. Mean 20m SRT values were similar to those from the most recent nationally representative data (Woods et al. 2019). Nationally, research shows a significant drop off in sports participation and physical activity rates among young adolescents girls from the age 14 (Lunn et al. 2013). Although beyond the scope of the current study, an examination of fitness variables across all school-going adolescent age groups is needed to confirm if the reported differences between Irish and European adolescents track across all adolescent age groups.
An important finding to emerge from this study was the disparity in fitness levels between participants in designated disadvantaged and non-disadvantaged schools. Participants in designated disadvantaged schools had significantly higher BMI levels, and significantly lower 20m SRT and standing broad jump scores in comparison to those in non-disadvantaged schools. A comprehensive analysis on the influence of SES on physical fitness among European adolescents concluded that SES was positively associated with physical fitness, independently of total body fat and habitual physical activity (Jiménez Pavón et al. 2010). In one of the few empirical studies to investigate the impact of school sociodemographic characteristics on physical fitness variables, Welk et al. (2010) reported that physical fitness was consistently higher among students in schools categorized as low diversity and high socioeconomic status. Bai and colleagues (2016) similarly reported clear evidence that school SES was the most influential contextual factor for explaining disparities in school fitness outcomes. It has also reported that school socioeconomic status was a strong determinant of overweight and obesity in Irish schoolchildren (Bel-Serrat et al. 2018). This suggests that government funding utilised for the promotion of healthy lifestyle behaviours among youth should provide additional support for designated disadvantaged schools.

This study had some limitations which should be noted. Firstly, although the current study sample represents the largest examination of multiple components of HRPF in the Republic of Ireland to date, participants were only generated from year one of secondary school education, precluding an analysis of fitness variables across all adolescent age groups. Additionally, the sample size of 20 schools is small for the linear mixed model analysis of non-disadvantaged (n=14) versus designated disadvantaged (n=6) schools. However, the randomised and stratified nature of the sample, the variety of fitness tests used, and the
provision of the original HELENA dataset to facilitate more detailed comparisons with the dataset generated from this study, were important strengths.

6.7 Conclusion

This study represents the first comprehensive review of multiple components of health-related fitness among a stratified sample of adolescents in the Republic of Ireland. The contrasting findings for different fitness components within our sample reiterate the need for multi-component HRPF test batteries for monitoring physical fitness in youth. Overall, age-matched normative comparisons of HRPF levels with European data were broadly positive for all components, aside from muscular fitness in which European adolescents scored significantly higher. Therefore, interventions aimed at improving the physical fitness and activity levels of Irish youth should include a focus on muscular fitness. Furthermore, the extent of the disparity in fitness levels between participants in designated disadvantaged and non-disadvantaged schools was a finding of particular concern. This study also underscores the capacity for the collection of objective measures of health and physical fitness from large-scale samples, and the transfer of this data, in anonymised form, to a centrally hosted database, facilitating live tracking of data in real-time. Future interventions designed to promote healthy lifestyle behaviours among school-going populations should give special consideration to students in designated disadvantaged schools. The provision of additional support funds to promote healthy lifestyle behaviours could represent an efficient model of funding, targeting those who are most in need.
Chapter Seven: Students’ attitudes towards and experiences of the Youth-fit peer facilitated health-related fitness test battery

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7.1 Preface

Students’ experiences of fitness tests using best practice recommendations have yet to be analysed in order to determine whether or not they actually work, and calls for more empirical work in this area have mostly gone unanswered (Alfrey and Gard 2017). Evaluating the experiences of key stakeholders is a critical step in developing evidence-based pedagogical approaches. The following chapter addresses this gap by focusing specifically on students’ experiences of the Youth-fit peer facilitated test battery. Following participation in the Youth-fit test battery, students completed an 18-item attitude towards fitness testing questionnaire developed by Mercier and Silverman (2014b). Additional questions in relation to students’ experiences of each fitness test item were also included. In summary, students had positive attitudes towards the Youth-fit test battery, boys had a significantly more positive attitude than girls, and boys and girls in this study produced significantly more positive mean scores when compared to age-matched scores of students from the United States (Mercier and Silverman 2014a).
7.2 Abstract

Aim: The aim of this study was to examine secondary school students’ attitudes towards and experiences of a peer facilitated health-related fitness test battery. Methods: A total of 795 adolescents (403 boys, 50.7%) aged 13.2 years (SD = 0.39) from 20 secondary schools in the Republic of Ireland participated in the study. Schools were stratified for sex, location and educational (dis)advantage. Students completed the test battery in small groups (n = ≤ 6), and each test item was administered by a trained senior peer facilitator. Testing took place during physical education lessons. Test items included; BMI, back-saver sit and reach, hand-grip strength, standing broad jump, isometric plank-hold, 90˚ push-up, 4x10m shuttle run and blood pressure. Following participation in the test battery, students completed an instrument with valid scores for measuring attitudes towards fitness tests (Mercier and Silverman 2014b). Students’ experiences of each test item were also analysed. Results: Overall, students had a positive attitude towards fitness testing (M = 3.9, SD .59) on a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree). Although both positive, the mean attitude score for boys (M = 4.05, SD .59) was significantly higher than girls (M = 3.79, SD .59; p < 0.01, t-test). Most students (n = 690, 86.8%) agreed or strongly agreed that the senior student peer facilitator made it easier for them to perform the tests. Conclusion: Students had a positive experiences of the Youth-fit test battery. Physical education teachers should consider implementing a small group and senior student facilitated approach when administering fitness tests.

7.3 Introduction

Schools, and specifically physical education programmes have been identified as the most suitable vehicle to promote active and healthy lifestyles among young people (Pate et al. 2006). In recent years, the unique position of physical education, as a key stakeholder in the promotion of healthy lifestyle behaviours among youth, has been increasingly
acknowledged by global (WHO 2018) and national (Department of Health 2016) policy makers. Rising obesity and inactivity levels among youth have stimulated a continued push for health-related fitness outcomes to be a focal point of physical education (Garn and Sun 2009). In a worldwide survey of physical education programmes, health-related physical fitness (HRPF) was ranked the number one most significant curriculum theme in school-based physical education (UNESCO 2014). Fitness testing, a component of fitness education programmes, has been part of physical education for over half a century (J.R. Morrow et al. 2009), and has been reported as one of the most practical ways to teach the components of HRPF in physical education settings (Garn and Sun 2009). Indeed, several states in the United States (US), and countries including Japan, China, Slovenia, Hungary and Finland, have mandated monitoring HRPF in school physical education programmes in the form of health-related physical fitness test batteries (O’Keeffe et al. 2020c).

Although fitness testing continues to be a component of most physical education programmes (Cooper et al. 2010), its role in physical education remains a divisive topic. Critics claim the prominence of fitness testing could be contributing to the growing performative culture that has enveloped education systems in recent years (Alfrey and Gard 2014), and its inclusion in physical education programmes may well represent a misdirected effort at health promotion (Cale and Harris 2009). In one of the few empirical studies of students’ attitudes towards fitness testing, Hopple and Graham (1995) suggested that students are often unclear about what they actually learn from the process. In contrast, proponents highlight the potential educational (Pate et al. 2013), motivational (Graser et al. 2011) and health (Ruiz et al. 2009a) benefits of HRPF testing. Many scholars have cited the importance of teaching students how to self-assess their fitness levels as a core element of promoting lifelong physical activity (Castelli and Williams 2007). Artero and colleagues (2011) suggested that fitness testing in school settings
coordinated by qualified physical education professionals could represent a viable alternative to monitoring key indicators of health among youth in epidemiological studies. Despite these contrasting views, there is an emerging consensus that, if appropriately employed, and incorporated as just one component of a broad and balanced programme, there is no reason why HRPF testing cannot make a valuable contribution to a physical education programme (Wiersma and Sherman 2008; Cale et al. 2014).

There has been a wealth of research on HRPF test items that produce valid scores (Ruiz et al. 2009a; Lubans et al. 2011a; Ramírez-Vélez et al. 2015). Similarly, pedagogically sound approaches for integrating fitness tests in school-based physical education programmes have been widely reported (Harris and Cale 2007; Liu 2008; Wiersma and Sherman 2008; Corbin et al. 2014; Zhu et al. 2018). Recently, the ALPHA (Assessing Levels of Physical Activity) fitness test battery was developed to facilitate monitoring HRPF in a comparable way in the European Union (Ruiz et al. 2011). The ALPHA test battery was shown to produce valid and reliable scores, and was found to be safe for use in school settings when administered by a physical education teacher (Espana-Romero et al. 2010a). Recommendations for integrating fitness tests in a pedagogically sound manner included; moving away from command-style test administration, to a more reciprocal and student-centred approach (Graser et al. 2011); using criterion rather than norm referenced health standards to promote self-referenced comparison with attainable health standards (Mahar and Rowe 2008); and allowing students an opportunity to familiarise themselves with tests prior to testing (Martin et al. 2010). However, a recent review of HRPF monitoring practices from a nationally representative sample of schools in the Republic of Ireland indicated that many teachers were not implementing best practice recommendations, instead integrating tests in isolation of the broader physical education curriculum, and thus minimising learning opportunities for students (O’Keeffe et al. 2020c).
There is a dearth of research on student voice regarding their attitudes towards and experiences of fitness testing. Much of the research that is commonly cited when debating the role of fitness testing in physical education is based on a very small number of empirical research studies, some of which were conducted over a quarter of a century ago (Luke and Sinclair 1991; Hopple and Graham 1995; Cale and Harris 2009). Students’ experiences of fitness tests using the aforementioned pedagogically sound recommendations have yet to be analysed in order to determine whether or not they actually work. Indeed, calls for more empirical work on the views of young people on fitness testing have mostly gone unanswered (Alfrey and Gard 2017). Furthermore, given the prominence of testing in fitness education units (O’Keeffe et al. 2020c), what students think and feel about fitness testing, and how these attitudes could affect participation in life-long physical activity, are important to identify (Mercier and Silverman 2014b). Vazou, Mischo and Ladwig (2019) similarly highlighted the scarcity of pragmatic experimental investigations examining the effects of specific changes to how physical education, and more specifically fitness testing, is delivered, on the quality of the experience that students derive.

In an effort to address the paucity of empirical research, Mercier and Silverman (2014b) developed an instrument to measure students’ attitudes towards fitness testing. The 18 item instrument, which was shown to produce valid and reliable scores with adolescent populations, comprises of four sub-factors namely; cognitive, affect-enjoyment, affect-feelings, and affect-teacher (Mercier and Silverman 2014a). The instrument was informed by Ajzen’s (1991) Theory of Planned Behaviour, which posits that attitudes are a significant predictor of human behaviour, in addition to subjective norms and perceived behavioural control. Researching attitudes is important as decisions, such as whether to remain physically active, can be strongly influenced by attitudes (Solmon 2003). In the only large-scale study to use the instrument to date, Mercier and
Silverman (2014a) found that students’ had a slightly positive attitude toward fitness testing, with boys reporting significantly higher mean values in comparison to girls. However, this instrument has not been used to examine students’ attitudes towards fitness tests outside of the United States. In addition, to the authors’ knowledge, no study has examined students’ experiences of multiple commonly administered HRPF test items when delivered in the form of a test battery in a physical education context. Therefore, the aim of the current study was to examine students’ attitudes towards and experiences of a student-centred health-related fitness test battery in secondary school-based physical education programmes.

7.4 Methods

The methodological design of this study included four steps: 1) instrumentation 2) school and participant recruitment, 3) Youth-fit test battery administration and evaluation 4) data analysis. Ethics committee approval was granted by the Research Ethics Committee of the Faculty of Education and Health Sciences at the University of Limerick (EHS_2017_02_12).

7.4.1 Instrumentation

Data were collected using the Students’ Attitudes towards Fitness Testing instrument, developed by Mercier and Silverman (2014b). This is an 18 item instrument, made up of four sub factors: cognitive (6 items), affect-enjoyment (3 items), affect-feelings (4 items) and affect-teacher (5 items). Scores from this instrument were shown to be valid and reliable for measuring adolescents’ attitudes towards fitness testing. The development of this instrument has been described elsewhere (Mercier and Silverman 2014b). Questions specifically in relation to students’ experiences of the Youth-fit test battery were also included in the evaluation. Students were asked to rate their experience of completing each test item on a scale of 1 (very poor) to 5 (very good). Students also indicated if they
preferred a peer, teacher or external expert approach to administering the test battery, and if they shared their HRPF results with a parent or guardian. Finally, students were asked two open ended questions in which they were required to identify the most and least enjoyable part of the test battery. The final version of the survey is available in the appendices of this thesis (Appendix H).

A confirmatory factor analysis (CFA) was used to examine data fit to the model proposed by Mercier and Silverman (2014b) for the current study sample using SPSS Amos (v26, Chicago IL). The CFA confirmed an overall good fit of the data to the four factor model, all indicator variables loaded significantly ($p < .001$) on the associated latent factor. Model fit indices including the comparative fit index, the Tucker-Lewis Index and root mean square error of approximation, were 0.897, 0.877 and 0.085, respectively, indicating a good fit of the data to the model. Cronbach’s alpha internal consistency coefficients were also determined and represented good to excellent levels of reliability for each sub factor and for the overall model. The alpha reliability coefficient for the entire model was 0.892, and the four factors and their reliability scores were cognitive ($\alpha$ 0.887), affective-enjoyment ($\alpha$ 0.808), affective-feelings ($\alpha$ 0.834), and affective-teacher ($\alpha$ 0.732). Furthermore, a Cronbach’s alpha measure of 0.851 was established for the 10 item test experience scale developed specifically for this study, representing excellent reliability.

7.4.2 School and participant recruitment

A randomised sample of 20 schools, stratified for sex (single-sex boys, single-sex girls and mixed-sex), location (categorised by population density: urban, the cities of Cork and Limerick; rural, all other areas of the mid and south west of the Republic of Ireland) and educational (dis)advantage (designated disadvantaged and non-disadvantaged schools), classified by the Department of Education and Skills, Government of Ireland (2017),
participated in the study. If a school in the initial sample declined to participate, a replacement list of schools for each strata was generated to provide an alternative school with similar demographics. Due to the geographical spread of schools, and the need to visit each school individually, 20 schools was considered to be the maximum sample size achievable from a logistical viewpoint, and the minimum required to give a sufficient number of schools in each of the chosen strata. Approval from the principal and cooperating physical education teacher in each school was granted following an initial email and telephone conversation. Written informed consent was obtained from the parents of the students, and the students themselves. The Republic of Ireland education system comprises three levels including, primary, post-primary (secondary) and third level. Post primary or secondary education is made up of junior cycle (Years 1 to 3, ages 13 to 15), a transition year (Year 4, age 16) and senior cycle (Years 5 and 6, ages 17 to 18). This study focused specifically on students in year one of secondary school education (ages 13 to 14), and was open to all students in the selected year group in each participating school.

7.4.3 **Youth-fit test battery administration and evaluation**

Cooperating physical education teachers in each school selected eight senior students (year’s four to six, ages 16 to 18) as test facilitators. A detailed standard operating procedure was designed for and read by both the senior student facilitators and cooperating teachers (Appendix A). Teachers and student facilitators also participated in a three hour workshop delivered by the lead author one week in advance of testing. Administration protocols for each test item have been outlined elsewhere (O’Keeffe et al. 2020b). One week after participating in the test battery, students completed the evaluation survey during physical education class time. For convenience and wide distribution, an online questionnaire, via SurveyMonkey (Palo Alto, CA) cloud-based software, was
utilised to administer the evaluation survey. All student participants received an email that outlined the purpose of the survey, details regarding the time commitment and confidentiality, and a web link to complete the survey. Participants were informed that they may exit the survey at any time without implication. Cooperating physical education teachers clarified any questions students had on specific items in the survey.

7.4.4 Data analysis

Complete responses ($N = 795$) were extracted from SurveyMonkey and transferred to SPSS (version 25; IBM Corp. Chicago, IL) for analysis. The research team defined an incomplete response as missing one or more items from the attitude instrument. Incomplete responses ($n = 74$) were excluded from all analyses. A visual inspection of histograms for key outcome variables showed that data were normally distributed, with skewness of $\leq -1.3$ ($SE = 0.087$) and kurtosis of $\leq 1.9$ ($SE = 0.173$). Descriptive statistics including means (M), standard deviations (SD) and 95% confidence intervals were determined for gender and school type for factor and overall attitude scores. Independent samples $t$-tests were used to compare differences between boys and girls, and school level socioeconomic status. Effect size was determined by calculating the mean difference between the two groups, and dividing the result by the pooled standard deviation (Cohen’s d).

A factorial multivariate analysis of variance (MANOVA) using gender and school type as independent variables and the four factor variables as dependent variables was performed. The absence of multicollinearity was confirmed by examining correlations among the four sub-factor dependent variables. The dependent variables were moderately related, ranging from $r = 0.27$ to $r = 0.58$, and thus did not exceed the 0.80 threshold (Dormann et al. 2013). A separate ANOVA was conducted for each factor. Effect sizes for ANOVAs were calculated using the $\eta^2$ (Eta squared) method, by dividing the treatment
sum of squares by the total sum of squares. A one sample $t$-test, was used to compare total and factor mean values of students in this study with age-matched values reported in a study that used the same instrument to measure students attitudes towards fitness tests in the United States (Mercier and Silverman 2014a). The rationale for this comparison was to determine if there was a significant difference in students’ responses to contrasting approaches to administering fitness test batteries in school contexts. Correction for multiple comparisons was via the Bonferroni correction (Abdi 2007).

Responses to the two open-ended questions regarding the most and least enjoyable aspect of the test battery were reviewed and organised thematically in line with the guidelines set out by Renner and Taylor-Powell (2003) for analysing qualitative data. This involved identifying themes and patterns from the responses. Once the key themes had been established and agreed upon by each author, responses were arranged into coherent categories, and frequencies of responses within each category were calculated.

### 7.5 Results

Overall, students had a positive attitude towards fitness testing ($M = 3.92, \ SD = .59$) on a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree). The cognitive (perceived usefulness) factor had the highest mean score ($M = 4.19, \ SD = .66$), while the affect-feelings factor produced the lowest mean score ($M = 3.58, \ SD = 1.05$). Although both positive, boys ($M = 4.05, \ SD = .55$) had significantly higher overall attitude scores in comparison to girls ($M = 3.79, \ SD = .59$) ($t(793) = 6.34, \ p = 0.001$, Cohen’s $d = 0.44$). Boys produced significantly higher scores across all factors in comparison to girls, with the exception of affect-teacher, in which there was no significant difference. The cognitive factor produced the highest mean scores for boys and girls, however, as illustrated in Table 7.1, the lowest mean scores differed between sexes, affect-teacher for boys and affect-feelings among girls.
Table 7.1 A comparison of overall and factor level descriptive statistics of boys’ and girls’ attitudes towards fitness testing.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total Mean (SD) (N=795)</th>
<th>Boys Mean (SD) (N=403)</th>
<th>Girls Mean (SD) (N=392)</th>
<th>95% CI of Difference (lower)</th>
<th>95% CI of Difference (higher)</th>
<th>p value</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>3.92 (0.59)</td>
<td>4.05 (0.55)</td>
<td>3.79 (0.59)</td>
<td>0.18</td>
<td>0.34</td>
<td>&lt;0.01*</td>
<td>0.44</td>
</tr>
<tr>
<td>Cognitive</td>
<td>4.19 (0.66)</td>
<td>4.27 (0.66)</td>
<td>4.12 (0.64)</td>
<td>0.05</td>
<td>0.24</td>
<td>&lt;0.01*</td>
<td>0.22</td>
</tr>
<tr>
<td>Affect Enjoyment</td>
<td>3.90 (0.83)</td>
<td>4.08 (0.77)</td>
<td>3.71 (0.86)</td>
<td>0.26</td>
<td>0.49</td>
<td>&lt;0.01*</td>
<td>0.45</td>
</tr>
<tr>
<td>Affect Teacher</td>
<td>3.82 (0.68)</td>
<td>3.86 (0.67)</td>
<td>3.78 (0.69)</td>
<td>-0.01</td>
<td>0.18</td>
<td>NS</td>
<td>0.12</td>
</tr>
<tr>
<td>Affect Feelings</td>
<td>3.58 (1.05)</td>
<td>3.88 (0.95)</td>
<td>3.27 (1.05)</td>
<td>0.47</td>
<td>0.75</td>
<td>&lt;0.01*</td>
<td>0.58</td>
</tr>
</tbody>
</table>

Abbreviations; SD, standard deviation; CI, confidence interval. Data are shown as means with standard deviation in brackets. * Significant at Bonferroni adjusted p-value < 0.01.

In terms of differences by selected demographics, total and factor attitude scores for students in designated disadvantaged and non-disadvantaged schools did not differ significantly, with the exception of the cognitive factor which produced a significantly higher mean score for students in non-disadvantaged schools (M= 4.22, SD= .65) in comparison to those in designated disadvantaged schools (M= 4.08, SD= .65) (t (793) = 2.58, p = 0.01, Bonferroni correction). Furthermore, total and factor attitude scores did not differ significantly between students from urban or rural schools.

A MANOVA with follow up, using gender and school type as independent variables, and the four factor variables as dependent variables, indicated that there was a significant difference in total attitude between participants in single sex boys, single sex girls and mixed sex schools, Wilk’s Λ = 0.970, F(8, 1578) = 3.07, p =.002, partial η2 = 0.15. A separate ANOVA was conducted for each factor using a Bonferroni adjusted p value of .01. Post-hoc comparisons using the Tukey HSD test indicated that the total attitude mean scores for single-sex boys’ schools and mixed-sex schools were significantly higher than single-sex girls’ schools, specifically within the cognitive,
affect-enjoyment and affect-feeling factors. However, despite reaching statistical significance, the actual differences in mean values between school types was quite small, as evidenced by the low effect size values in Table 7.2. Although relatively small, the largest differences were produced in the affect feelings factor $F(2, 792) = 10.00, p = .001, \eta^2 = 0.03$. A significant difference was not found between school types in the affect teacher domain, $F(2,792) = 2.91, p = .06, \eta^2 = 0.001$. 
Table 7.2 Overall and factor mean (SD) scores for students’ attitudes towards fitness testing, by school type.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>School Type</th>
<th>Mean (SD)</th>
<th>Lower (95% CI)</th>
<th>Upper (95% CI)</th>
<th>p value</th>
<th>Effect Size (η²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive</td>
<td>Boys (n = 100)</td>
<td>4.27 (0.51)</td>
<td>4.14</td>
<td>4.40</td>
<td>&lt;0.01*</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Girls (n = 101)</td>
<td>4.02 (0.75)</td>
<td>3.89</td>
<td>4.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed (n = 594)</td>
<td>4.21 (0.66)</td>
<td>4.16</td>
<td>4.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affect Enjoyment</td>
<td>Boys</td>
<td>3.98 (0.82)</td>
<td>3.82</td>
<td>4.14</td>
<td>&lt;0.01*</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>3.63 (0.90)</td>
<td>3.46</td>
<td>3.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>3.93 (0.82)</td>
<td>3.87</td>
<td>4.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affect Teacher</td>
<td>Boys</td>
<td>3.85 (0.66)</td>
<td>3.72</td>
<td>3.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>3.67 (0.77)</td>
<td>3.54</td>
<td>3.80</td>
<td>NS</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>3.84 (0.66)</td>
<td>3.79</td>
<td>3.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affect Feelings</td>
<td>Boys</td>
<td>3.81 (0.95)</td>
<td>3.61</td>
<td>4.02</td>
<td>&lt;0.01*</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>3.19 (1.1)</td>
<td>2.99</td>
<td>3.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>3.61 (1.0)</td>
<td>3.53</td>
<td>3.69</td>
<td></td>
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<tr>
<td>Overall</td>
<td>Boys</td>
<td>4.01 (0.48)</td>
<td>3.92</td>
<td>4.11</td>
<td>&lt;0.01*</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>3.76 (0.67)</td>
<td>3.56</td>
<td>3.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>3.95 (0.58)</td>
<td>3.90</td>
<td>3.99</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: SD, standard deviation; CI, confidence interval. Data are shown as means with standard deviation in brackets. * Significant at Bonferroni adjusted p-value < 0.01.

When compared with single value age-matched mean scores from United States, as reported in Mercier and Silverman (2014a), boys (Figure 7.1) and girls (Figure 7.2) in the Youth-fit study produced significantly higher overall mean attitude scores ($t(793) = 2.58, p = 0.01$). Participants in this study scored significantly higher across three of the four factors, with the largest difference recorded in the affect-enjoyment factor for both boys ($t(403) = 25.8, p < .001$) and girls ($t(392) = 14.0, p < .001$).
Figure 7.1 A comparison of mean total and sub-factor attitude scores between boys in the Youth-fit study (Ireland) and single value age-matched mean scores from Mercier and Silverman (2014a). *Significant at Bonferroni adjusted $p$-value < 0.01. NS = not significant.

Figure 7.2 A comparison of mean total and sub-factor attitude scores between girls in the Youth-fit study (Ireland) and single value age-matched mean scores from Mercier and Silverman (2014a). *Significant at Bonferroni adjusted $p$-value < 0.01. NS = not significant.
Responses to survey items examining students’ experiences of the Youth-fit test battery specifically were encouraging. Overall, 78% (n = 618) students agreed or strongly agreed that completing the Youth-fit test battery was a worthwhile experience, with a further 16% undecided. The vast majority of students (n = 636, 81.3%) agreed or strongly agreed that they would like to track their HRPF while in secondary school. When asked to rank who they would like to administer fitness tests from most preferred to least preferred, students (n = 413, 52.8%) indicated that they would be in favour of the peer-facilitated format used in the Youth-fit test battery, in comparison to an external expert (27.0%) or their teacher (20.2%) recording test scores. In addition, 86.8% (n = 690) of students agreed or strongly agreed that the senior student facilitator made it easier for them to perform each test item. Students reported fair to good experiences of each test item on a Likert scale ranging from one (very poor) to five (very good) (M = 3.78 SD = 1.0). The 90° push-up for girls (M = 3.24 SD = 1.27) and sit and reach for boys (M = 3.52 SD = 1.16) had the lowest mean scores, while the 4x10m shuttle run had the highest mean scores for both groups (Girls, M = 3.91 SD = 0.9; Boys, M = 4.19 SD = 0.89). Overall, boys (M = 3.45 SD = 0.62) reported significantly more positive test experiences in comparison to girls (M = 3.33 SD = 0.58) on all items combined (t(766) = 2.73, p = .007). It was also interesting to note that students who indicated they shared their test results with a parent or guardian had a significantly higher mean score on the attitude towards fitness tests instrument (M = 4.02 SD = 0.49) in comparison to those who did not (M = 3.69 SD = 0.62) (t(218) = 4.4, p = 0.001).
Figure 7.3 A comparison of boys and girls experiences of test items on the Youth-fit test battery. *Note: *Denotes a significant difference, *p* <0.01.

The final part of the evaluation survey comprised of two open ended questions in which students were requested to identify the most and least enjoyable part of the test battery. Participating with friends and having fun was the most commonly cited enjoyable aspect of the test battery (*n*=196). For example, one student stated, (I enjoyed) “doing it with a small group of my closest friends and motivating each other to get a good score” (male, boys school). The muscular endurance test items (plank and push-up) were cited more than twice as many times (*n*=210) compared to the second most cited item as the least enjoyable aspect. Although not in the top five most frequently cited least enjoyable aspects of the test battery, 83 students noted having their height/weight measured. One student stated “if someone is a bit heavier than another then they could get bullied for their weight” (male, mixed school).
7.6 Discussion

The aim of this study was to examine secondary school students’ attitudes towards and experiences of a student-centred health-related fitness test battery. Much of the research on students’ perceptions of fitness testing to date have been generated from relatively small sample sizes (Garn and Sun 2009; Graser et al. 2011; Davis et al. 2018), and participants in these studies often experienced different test items and administration protocols (Mercier and Silverman 2014a). This investigation, the first outside of the United States to use the students’ attitudes towards fitness testing instrument (Mercier and Silverman 2014b), included a stratified sample of students from a randomised sample of 20 secondary schools. In summary, students had a positive attitude towards fitness testing, boys had a significantly more positive attitude than girls, and students in this study produced significantly higher mean scores when compared to age-matched scores of students from the United States.

Students had a positive attitude towards fitness tests, with the cognitive, or perceived usefulness, factor scoring highest across all demographic groupings, indicating that students perceived fitness testing to be a useful component of their physical education programme. This corroborates the findings of Mercier and Silverman (2014a), in which the same instrument was administered to 1199 students from 9th to 12th grade in the United States. Unlike Mercier and Silverman’s study, in which affect-enjoyment was the factor with the lowest mean score, the affect-feelings factor had the lowest mean score among students in the current study, indicating that students may have been nervous about performing the tests. However, relatively large standard deviations for each factor reported by Mercier and Silverman, likely composed of students with highly positive or highly negative attitudes, were not as extreme in this investigation, indicating less variation in students’ attitudes. Indeed, students in this study had significantly higher mean attitude scores when compared
to age-matched data from the United States in three of the four factor variables (Mercier and Silverman 2014a), namely, cognitive, affect-feelings, and affect-enjoyment.

An interesting finding to emerge from the current study was the disparity between boys’ and girls’ attitudes towards fitness testing. Boys reported significantly more positive attitudes across all factors in comparison to girls, with the exception of affect-teacher, which did not differ significantly. Furthermore, mean scores for students in single-sex boys’ schools and mixed-sex schools were significantly higher than single-sex girls’ schools. An exploratory study which investigated the factors that influence high school girls’ enrolment in elective physical education (Davis et al. 2018) indicated that students’ (n= 17) acknowledged the importance of HRPF, but desired less of a focus on fitness testing. Similarly, Zhu, Chen and Parrott (2014) found that boys reported significantly higher situational interest in the PACER test in comparison to girls. Engaging girls in physical education has been reported as a challenge for teachers across most aspects of a curriculum (Enright and O'Sullivan 2010), however, these gender differences appear to be augmented when it comes to fitness testing (Davis et al. 2018). It should be noted that, although girls reported significantly lower attitudes in comparison to boys, their mean scores were positive, and significantly higher than those reported by Mercier and Silverman (2014a). This suggests that physical education teachers should consider adopting the peer facilitate, small group design used in this study. However, despite the positive attitudes’ reported, further research is needed on how best to integrate fitness tests to ensure that girls in particular are comfortable participating and motivated to try their best.

Although fitness testing is highly prevalent in physical education programmes internationally, to the authors’ knowledge, this is the first study of its kind to quantitatively analyse students’ experience of multiple HRPF test items. Students reported fair to good
experiences of each test, with lowest mean scores recorded in the 90° push-up for girls and sit and reach test for boys. It has been suggested that the maximal and physically challenging nature of aerobic tests, such as the PACER, may lead to more negative motivation among students, and the appropriateness of such tests in a physical education context has been questioned (Wrench and Garrett 2008; Cale et al. 2014; Ladwig et al. 2018). Armstrong and Welsman (2019, p.2) recently questioned the validity of the 20mSRT suggesting it is “not a measure of CRE, but a function of willingness and ability to run between two lines 20 metres apart.” Interestingly, students in this study reported fair to good experiences of the PACER test, and it was frequently highlighted as the most enjoyable aspect of the test battery in the open ended part of the survey. Simonton and colleagues (2019) recently reported that PACER performance predicted lower reports of future anger toward PE for both girls and boys. Further research is needed to examine mechanisms to best motivate students to participate in the PACER test in order to ensure maximum effort and get a true estimation of CRE.

It should also be noted that the body mass test item had the joint second lowest mean score among students, and having body mass and height recorded was cited by 83 students as the least enjoyable aspect of the test battery. While some scholars have highlighted the benefits of systematic monitoring of anthropometric measures in school settings (Thompson et al. 2019), physical education teachers need to be mindful that body image concerns and elevated levels of anxiety appear to undergird the influence of self-efficacy in fitness test performance, particularly so in girls (Lodewyk and Sullivan 2016). Lodewyk and Sullivan (2016) provide some suggestions to assist physical education teachers in structuring fitness education units to better minimise this vulnerability. Recommendations included, reducing social and normative comparisons, making accommodations for attire and providing the option of gender-segregated health-related fitness units in coeducational settings. However,
the recommendation to offer gender-segregated HRPF units could be questioned based on the findings of this study, which indicated that girls in coeducational or mixed sex schools had significantly more positive attitudes towards fitness testing than girls in single sex schools. Providing students in coeducational settings with the opportunity to complete fitness test batteries in small groups of their closest peers, regardless of sex, could potentially enhance their motivation to participate.

Much of the existing research regarding students’ attitudes towards fitness education, and physical education more broadly, has highlighted the importance of enjoyment (Prochaska et al. 2003; Garn and Sun 2009). Participating with friends and having fun was the most commonly cited enjoyable aspect of the HRPF test battery. Similar studies that have investigated experiences of fitness tests to date reported that students’ enjoy a peer-assessed testing format in small groups (Mercier and Silverman 2014a; Phillips et al. 2017). The student-centred approach affords participants the opportunity to develop a sense of personal control and fitness autonomy (Biddle and Fox 1998). Indeed, Prusak and Vincent (2005) noted that students tested in an environment that supports their autonomy will be more motivated to participate and strive for self-improvement. Research by O’Keeffe et al. (2020b) demonstrated that, following a period of familiarisation, student administered fitness tests in physical education settings were as reliable as those taken by experienced research assistants. The vast majority of students in the current study agreed that the senior student facilitator at each test station made it easier for them to complete each test. The student-centred approach also offers cooperating physical education teachers the opportunity to move throughout the learning space, without being restricted to delivering a single test item. Therefore, both the process of engaging in the test battery, and the validity of the scores obtained, can be simultaneously enhanced.
Students who shared their fitness test results with a parent or guardian had significantly more positive attitudes towards fitness testing in comparison to those who did not share their results. A recent review of HRPF monitoring practices involving a nationally representative sample of schools in the Republic of Ireland revealed that less than one third of physical education teachers shared HRPF test results with their students’ parents (O’Keefe et al. 2020c). Mercier et al. (2016) also reported that less than 30% of teachers surveyed in their study sent HRPF test results home. The importance of integrating parents in a child’s education has been well established (Jeynes 2007), and sharing fitness test results could represent a useful avenue to keep parents informed of their child’s HRPF levels. Furthermore, many school-based fitness test batteries, including Fitnessgram® (Welk and Meredith 2013), have been updated to include a greater focus on physical activity promotion, in addition to physical fitness, further emphasising the opportunity to integrate fitness testing as just one element of a broader HRPF education unit.

This study had some limitations which should be noted. Participants in the current study were in year one of secondary school education, and research consistently indicates that students’ attitudes towards physical education decline as they get older (Silverman 2017). Furthermore, comparisons with data that used the same measurement instrument in the US (Mercier and Silverman 2014a) were generated from age-matched fixed means as opposed to the original dataset. Future research should analyse how attitudes towards fitness testing change as students’ progress through secondary school. In addition, although students in each of the 20 schools involved in the study were represented, response rates within schools varied between 60 and 100 percent, which could have resulted in some response bias. Finally, this survey was based on a single data source, therefore, data were not verified a second time,
potentially resulting in a lack of depth in the interpretation of responses for which qualitative methods may have provided further insights.

7.7 Conclusion

Analysing students’ attitudes and experiences is a critical step in developing evidence-based pedagogical approaches. Overall, students had a positive attitude towards fitness testing and participants clearly perceived fitness testing to be a useful component of a fitness education unit. This study illustrates the potential of a student-centred approach to administering fitness tests in a physical education context. Teachers should strongly consider educating students to facilitate in both the set-up and administration of a fitness test battery as a mechanism to enhance participants understanding of each test item, while simultaneously improving the accuracy of the measures obtained. Further research is needed to determine if positive responses to the student-centred approach presented in the current study maintain as students’ progress through secondary school.
Chapter Eight: The feasibility of the Youth-fit test battery and software platform for monitoring health-related fitness in secondary schools

To be submitted for consideration in ‘BMC Public Health’ in April 2020.
8.1 Preface

The aim of this penultimate chapter was to examine the feasibility of the Youth-fit test battery and software platform. A comprehensive framework developed by Orsmond and Cohn (2015), designed specifically to evaluate feasibility studies, was used to conduct this evaluation. The feasibility framework is comprised of five overarching objectives, namely: recruitment capability; data collection procedures and outcome measures; acceptability of study procedures; resources; and preliminary evaluation of participant responses. For each objective, a detailed list of follow-up questions developed by Orsmond and Cohn (Appendix J) was used to facilitate a deeper understanding of the barriers to the ultimate success of the Youth-fit test battery and software platform. Elements of data gathered throughout the course of the project were used to operationalise Orsmond and Cohn’s (2015) feasibility framework including, test-retest reliability indices (Chapter Five), HRPF data from the 20 school feasibility phase (Chapter Six), and the student and teacher evaluations surveys (Chapters Seven and Eight). Overall, positive feasibility benchmarks indicated that the Youth-fit test battery and software platform represents a feasible, pedagogically sound and scientifically rigorous approach for monitoring health-related fitness in secondary school settings.
8.2 Abstract

**Aim:** The aim of the Youth-fit project was to develop a pedagogically sound and scientifically rigorous health-related physical fitness (HRPF) test battery and software platform to facilitate monitoring key indicators of adolescent health in secondary schools. This study examines the feasibility of the project. **Methods:** An evaluation framework for feasibility studies, developed by Orsmond and Cohn (2015), was applied to the Youth-fit test battery and software platform. Five feasibility benchmarks were examined, including: assessment of recruitment capability and resulting sample characteristics, data collection procedures and outcome measures, acceptability and suitability of study procedures, resources and ability to manage and implement the study, and evaluation of participant responses. Various sources were used to operationalise the feasibility framework including, student (n=795) and teacher (n=20) evaluation surveys, test-retest reliability indices (O’Keeffe *et al.* 2020b), and HRPF data from the 20 school expansion phase. **Results:** Student participation rates exceeded 75% in all schools. The vast majority of teachers (95%) and students (87%) surveyed agreed or strongly agreed that the senior student facilitators made the administration and performance of the test battery easier. Teachers (25%) did raise concerns over the feasibility of the time allocated to deliver the test battery, and the inclusion of the blood pressure test item was also questioned by 25% of teachers. Half of teachers surveyed were undecided or disagreed that the quality of the student report generated from the software platform was high. Overall, 95% of teachers (n=19) and 79% of students (n=618) surveyed agreed or strongly agreed that completing the Youth-fit test battery was a worthwhile experience. **Conclusion:** Positive feasibility benchmarks, including, recruitment capability, data collection procedures, resources, and participant responses, indicate that the Youth-fit test battery and software platform represents a feasible, pedagogically sound and
scientifically rigorous approach for monitoring health-related fitness in secondary school settings.

**8.3 Introduction**

Lack of physical activity and low levels of health-related physical fitness (HRPF) threaten both the current and future health of children (Strong *et al.* 2005; Welk *et al.* 2016). Schools are recognised as key settings for promoting healthy lifestyle behaviours (Ekelund *et al.* 2012), and physical education programmes are commonly acknowledged as the most powerful opportunity to systematically influence the health of children and adolescents (Pate *et al.* 2006). Fitness testing has been part of school based physical education programmes for over half a century (J.R. Morrow *et al.* 2009) and systematic tracking of physical fitness has been described as a common, if not defining, characteristic of physical education programmes (J.R. Morrow *et al.* 2009). The practice of monitoring HRPF in schools is commonplace in many countries internationally including USA, China, Russia, Hungary and Slovenia (Keating *et al.* 2018), however, its purpose in a physical education context has been a divisive topic (Lloyd *et al.* 2010). Advocates highlight the proposed educational (Csányi *et al.* 2015) and health (Welk *et al.* 2016) benefits of monitoring students’ HRPF, while critics suggest that HRPF testing may well represent a misdirected effort at health promotion (Cale and Harris 2009). Notwithstanding reservations regarding current implementation practices, Cale and colleagues (2014) indicated that, if integrated appropriately, there is no reason why fitness testing could not play a role in supporting healthy lifestyles and in educating young people about physical activity and fitness.

The surge in research identifying physical fitness as a powerful marker of health among adolescents (Ortega *et al.* 2008b; Ruiz *et al.* 2009a) has led to many countries
developing fitness test batteries and software platforms to facilitate monitoring health-related fitness in schools (Bianco et al. 2015; Csányi et al. 2015). However, despite World Health Organisation recommendations for the establishment of comprehensive health monitoring programmes in youth (Hallal et al. 2012), the Republic of Ireland lacks a clearly specified strategy for monitoring health-related fitness in school settings (O’Keeffe et al. 2020b). In addition, a recent review of HRPF monitoring practices from a nationally representative sample of secondary schools in the Republic of Ireland reported that over 95% of teachers used fitness tests in their physical education programmes, however, less than 12% tracked students’ results across year groups (O’Keeffe et al. 2020c). Furthermore, 87% of physical education teachers surveyed indicated that they were in favour of the development of a digital platform to facilitate monitoring the fitness levels of their students over time (O’Keeffe et al. 2020c). Therefore, the Youth-fit project was initiated with the aim of developing a pedagogically sound and scientifically rigorous fitness test battery for monitoring physical fitness in secondary school settings in the Republic of Ireland.

Guided by the Medical Research Council’s key elements for the development and evaluation of an intervention (Craig et al. 2008), the Youth-fit test battery was established through a systematic plan that included eight steps (Figure 1.1). Evaluating the feasibility of the test battery was the focus of the final step. A significant amount of funding resources, including participants’ and researchers’ time, may be wasted if feasibility has not been carefully examined and assured prior to conducting a randomised control trial (Orsmond and Cohn 2015). Therefore, the objective of the current study was to conduct a comprehensive evaluation of the Youth-fit project, guided by the five overarching objectives of a feasibility study (Orsmond and Cohn 2015).
8.4 Methods

8.4.1 Youth-fit test battery and software platform development

An eight step plan, comprised of three distinct phases as detailed in Chapter Four, was established to inform the development and implementation of the Youth-fit test battery and software platform in a systematic manner, culminating in an evaluation of the overall project. A rationale for the development of the Youth-fit test battery and software platform, the reliability of test administration protocols, and a comprehensive evaluation of student experiences of the test battery have been reported elsewhere (O’Keeffe et al. 2020b; O’Keeffe et al. 2020a; O’Keeffe et al. 2020c).

8.4.2 Recruitment

Research ethics approval for all phases of the Youth-fit study was granted by the Research Ethics Committee of the Faculty of Education and Health Sciences, University of Limerick, Ireland (EHS_2017_02_12). A randomised sample of 20 schools, stratified for sex (single-sex boys, single-sex girls and mixed-sex), location (urban and rural, categorised by population density) (Woods et al. 2010), and educational (dis)advantage (Department of Education and Skills 2017), agreed to participate following an initial recruitment email and telephone conversation with each school’s principal and cooperating physical education teacher. The procedure for generating a randomised sample was conducted by an experienced statistician using a special computerized code system in which all secondary schools in the mid-west and south-west region of Ireland were assigned a code and categorised according to pre-defined strata. Due to the geographical spread of schools, and the need to visit each school individually, 20 schools was considered to be the maximum sample size achievable from a logistical viewpoint, and the minimum required to obtain a sufficient number of
schools in each of the chosen strata. Following school approval, written informed consent was obtained from the parents of the students, and the students themselves. Test battery administration took place over a three month period between November 2018 and January 2019.

8.4.3 Induction and administration

The cooperating physical education teacher in each school selected eight senior student facilitators (final two years of second level education) to assist in the administration of the test battery. Student or peer-facilitated learning can be defined simply as a learning process whereby students learn from and with others, and this can be with students of the same-age or from those who are older (cross-age) (Jenkinson et al. 2012). Tests, with the exception of the 20 metre shuttle run test (20m SRT) which was administered by physical education teachers to groups of 15 students or less, were delivered in a station format to small groups of no more than five students. A senior student facilitator was responsible for one test item on the test battery. Tests included; 20m SRT, body mass index (BMI), hand-grip strength, standing broad jump (SBJ), isometric plank-hold, 90° push-up, 4x10m shuttle run, backsaver sit and reach (BSR), and blood pressure. A detailed standard operating procedure for each test item was designed for and read by both cooperating teachers and student facilitators one week in advance of data collection (Appendix A). Subsequently, cooperating physical education teachers and student facilitators participated in a three hour training workshop delivered by the lead author. During this workshop, student facilitators was assigned one test, and trained in the assigned test only. The test battery was administered during three timetabled physical education class periods lasting ≥80 minutes over three consecutive weeks. The focus of week one was on test protocol familiarisation and theoretical underpinning for each test item. The 20m SRT was administered in week two, and the remaining test battery
items were delivered in week three. Cooperating physical education teachers were responsible for uploading test results to the Youth-fit web-based application, hosted on a secured internally facing server at the lead author’s institution.

8.4.4 Feasibility benchmarks

An evaluation framework developed by Orsmond and Cohn (2015) was used to determine the feasibility of the Youth-fit test battery. Orsmond and Cohn (2015) defined feasibility studies as a process of developing, implementing and refining an intervention, which results in preliminary examinations of participant responses to the intervention, while randomised control trials more clearly focus on outcomes, rather than process (Dobkin 2009). Feasibility studies are conducted in advance of randomised control trials to assess the research and delivery process. Orsmond and Cohn (2015) identified five overarching objectives of feasibility studies including; assessment of recruitment capability and resulting sample characteristics, data collection procedures and outcome measures, acceptability and suitability of study procedures, resources and ability to manage and implement the study, and evaluation of participant responses. An overview of Orsmond and Cohn’s (2015) framework for evaluating feasibility studies is provided in Figure 8.1.
<table>
<thead>
<tr>
<th>Objective</th>
<th>Details</th>
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<tbody>
<tr>
<td>Objective 1: Evaluation of recruitment capability and resulting sample characteristics</td>
<td>The focus of objective one is on recruitment rates, eligibility criteria and relevance of the intervention to the target population.</td>
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<tr>
<td>Objective 2: Evaluation and refinement of data collection procedures and outcome measures</td>
<td>The focus of this objective is the appropriateness of data collection procedures. Follow up questions include participants ability to complete the test measures, suitability of study protocols, delivery time, value of each test item, and reliability of data gathered.</td>
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<td>Objective 3: Evaluation of acceptability and suitability of study procedures</td>
<td>Are the study procedures suitable for and acceptable to participants?” Follow up questions address retention, time, capacity, acceptability and satisfaction of the study to participants, and safety.</td>
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<td>Objective 4: Evaluation of resources and ability to manage and implement the study and intervention</td>
<td>The key focus for this objective is whether or not the research team have the resources and ability to manage the study. Factors including space, administrative capacity, expertise, budgetary considerations, equipment needs and technology should be addressed.</td>
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<tr>
<td>Objective 5: Preliminary evaluation of participant responses to intervention</td>
<td>This objective deals primarily with prospect of the proposed intervention or study being successful based on the experience of participants.</td>
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**Figure 8.1** The five overarching objectives of a feasibility study (Orsmond and Cohn 2015).

### 8.4.5 Analysis

Following completion of Youth-fit test battery, student participants (n=795, boys = 403) and the lead cooperating physical education teacher in each school (n=20) completed purposefully designed programme evaluation surveys. Although students in each of the 20 schools involved in the study were represented, response rates within schools varied between 60 and 100 percent, which could have resulted in some response bias. Four follow up reminder emails containing links to the student evaluation surveys were sent to all schools in an effort to minimise non-response bias and maximise the overall response rate.
Various sources were used to operationalise the feasibility framework proposed by Orsmond and Cohn (2015) including, student and teacher evaluation surveys, test-retest reliability indices (Chapter Five), and HRPF data from the 20 school feasibility phase (Chapter Six). The student evaluation survey comprised of an 18-item scale, developed by Mercier and Silverman (2014b), with valid scores for measuring students’ attitude towards fitness tests. The student evaluation survey also included specific questions regarding their experience of data collection procedures and test items, as recommended by Orsmond and Cohn (2015). The development of the student evaluation survey is outlined in detail in Chapter Seven. The teacher evaluation survey (Appendix J) was also informed by Orsmond and Cohn’s guiding questions for the evaluation of feasibility studies. The teacher evaluation survey comprised of four sections, namely; induction and resources, test battery administration and protocols, teacher perceptions of student experience, and teacher experience of the Youth-fit software platform. Orsmond and Cohn’s guiding questions informed the first three sections of the evaluation survey, and elements of Venkatesh and Davis’ (2000) Technology Acceptance Model were used to evaluate teachers’ experiences of the Youth-fit software platform.

For convenience and wide distribution, teacher and student surveys were administered via SurveyMonkey (SurveyMonkey, Palo Alto, CA) cloud-based software. Complete responses were extracted from SurveyMonkey and converted for use in the Statistical Package for Social Sciences (version 24; SPSS, IBM Corp., Chicago, IL) for analysis. Responses to closed-ended questions were analysed descriptively, which involved calculating and reporting percentages and frequencies. Responses to open-ended questions were reviewed and organized thematically in line with guidelines set out by Renner and Taylor-Powell (2003).
8.5 Results

8.5.1 Feasibility benchmarks for the Youth-fit test battery

8.5.1.1 Objective 1: Evaluation of recruitment capability and resulting sample characteristics

All secondary schools with access to an indoor hall space of ≥ 25 metres and students in year one of secondary school with no inhibiting health conditions were eligible to participate. A total of 1215 adolescents (girls = 609) aged 13.4 years (SD.41) from a randomised sample of 20 schools, stratified by sex (single-sex boys, single-sex girls and mixed-sex), location (urban and rural, categorised by population density), and educational (dis)advantage as defined by the Government of Ireland (2017), were recruited for this study. Of the initial sample of 20 schools, four schools declined to participate, in which case the next school on a randomised reserve list was recruited. Schools who declined to participate were asked to indicate the reason for non-participation. Contrasting reasons were provided by the principal and/or cooperating physical education teacher in the four schools that declined to participate, including; time constrains (two schools), unsuitable indoor facilities, and the aim of the project not aligning with the school’s ethos.

At an individual level, all participants and their parents were required to provide consent. Eligibility to participate was granted upon completion of a physical activity readiness questionnaire (PAR-Q) (Warburton et al. 2011), which was reviewed and approved by the lead investigator. A total of 27 students were deemed ineligible to participate due to underlying health conditions recorded on the PAR-Q. A minimum participation rate threshold of 70%, as used in other similar studies (Moreno et al. 2008), was set for a school to be considered eligible. Participation rates in the final sample were ≥75% in all schools, and reached 100% in many schools, as one teacher noted, “We had maximum participation
which is a great endorsement of their willingness to be involved” (female teacher, boys’ school).

Reasons for non-participation among student participants were recorded in the non-participant section of the student evaluation survey (Appendix H). The most commonly cited reasons were absenteeism, injury/sickness, parents not providing consent and/or the students themselves not wanting to participate. The time consuming process involved in gathering participant and parent consent forms was noted as a significant barrier by five of the 20 cooperating teachers surveyed. For example, one teacher stated that “the greatest challenge we faced was collecting consent forms from students” (male teacher, mixed sex school).

Finally, as noted in the introduction, the evidence of need for the development of a standardised fitness test battery and digital platform to facilitate monitoring physical fitness in schools was confirmed in a recent survey of health-related fitness monitoring practices from a nationally representative sample of secondary school teachers in the Republic of Ireland (O’Keeffe et al. 2020c).

8.5.1.2 Objective 2: Evaluation and refinement of data collection procedures and outcome measures

The training workshop and equipment provided by the lead investigator during the induction session in each school was cited by six of the 20 teachers surveyed as the most beneficial aspect of the project. One teacher stated, “Receiving the equipment, guidance manuals and training during the induction session on the protocols for delivering each test item was great CPD for our physical education department” (Male teacher, boys’ school). All lead cooperating teachers (n=20) agreed that the sequence of testing was appropriate, and 19 of the 20 teachers agreed or strongly agreed that the student facilitators improved the delivery of test battery. Similarly, the vast majority of student participants (86.8%, n = 690) who completed the evaluation survey agreed or strongly agreed that the senior student facilitators
made it easier for them to perform each test item. The test-retest reliability of the peer-facilitated administration protocol adopted in this study has been reported (O’Keeffe et al. 2020b), while the predictive capacity of physical fitness as a powerful marker of future health has been well established elsewhere (Ruiz et al. 2009a; Ortega et al. 2013).

All teachers agreed or strongly agreed that most test items were suitable for administration in a physical education context, however, five teachers questioned the necessity of the blood pressure test. A male teacher in a mixed sex school stated, “I do not think the students really understood the relevance of the blood pressure (test)....I thought all the tests had their place with the exception of blood pressure.” Encouragingly, values for test variables including BMI and estimated cardiovascular endurance were comparable to recently published nationally representative data involving the same age groups. For example, the prevalence of overweight, classified according to the same age and sex specific cut points (Cole et al. 2000), was 25% among a nationally representative sample of Irish adolescents in a recent longitudinal study (Williams et al. 2018), just one percent less than the figure reported from data generated as part of the current project. In addition, age-matched mean 20m SRT values were similar to those from the most recently reported national representative data (Woods et al. 2019). The research team defined an incomplete case as missing the body mass index (BMI) recording, or two or more fitness test items. Less than five percent (n= 66) of participant results inputted to the Youth-fit software platform were deemed incomplete, and subsequently excluded from all analyses. Following feedback from teachers in the initial four school pre-feasibility trial, the software platform was updated to include biologically plausible value limits for each test item at the point of data entry, which significantly reduced the number of unusable responses.
8.5.1.3 Objective 3: Evaluation of acceptability and suitability of study procedures

A key objective of the Youth-fit study was to develop a test battery that would be feasible to administer during timetabled physical education lessons. Although 19 of the 20 of teachers surveyed agreed that the test protocols and administration procedures were suitable, almost two thirds (65%) of teachers suggested that it would not be feasible for one PE teacher to deliver the test battery without the assistance of senior student facilitators. Furthermore, half of the teachers surveyed indicated that it was not feasible to deliver the full test battery within the recommended time allocation of two 80 minute class periods. Four teachers noted blood pressure test to be a particularly time consuming component of the test battery. For example, a female teacher in a girls’ school stated, “Some tests were quicker than others to complete, so those students were waiting quite a bit at the (blood pressure) station.” A recent evaluation of student experiences of the Youth-fit test battery reported that participating with friends in small groups was the most commonly cited enjoyable aspect of the test battery (n=196) (O’Keeffe et al. 2020c). For example, one student stated, (I enjoyed) “doing it with a small group of my closest friends and motivating each other to get a good score” (male, boys school).

When asked to provide recommendations to enhance the overall process, three teachers commented on the length of time taken to input results to the software platform. For example, a male teacher in a single sex girls’ school noted, “I think the concept of online tracking is great, but, the process of inputting could be made a bit more efficient. For example, not having to input the school code and year group for each student.” Additional issues pertaining to teachers’ interaction with the software platform are reviewed in more detail in the following paragraph. In terms of safety, no unexpected adverse events were recorded from any of the participating schools, however, one school teacher (female, mixed sex
school) did note that two students felt light headed following the 20m SRT and requested to go home from school. Teachers were encouraged to follow their physical education department’s adverse event response protocol, however, a response protocol specific to the Youth-fit test battery should also be developed in advance of a potential scaling-up of the project.

8.5.1.4 Objective 4: Evaluation of resources and ability to manage and implement the study and intervention

As mentioned in a previous section, the quality of the induction training and resources provided to participating schools was frequently cited as one of the biggest strengths of the project. While the current study was conducted within the allocated budget, significant investment at governmental level in testing equipment would be required, as noted by one teacher, “The provision of the testing equipment was super and made the testing possible. However, if I was to administer this test battery again, I would be caught for the relevant equipment” (female teacher, girls’ school). In addition, the individual school level induction sessions delivered by the lead investigator would not be feasible for a scale up of the project. Therefore, in-service professional development workshops coordinated through regional cluster sessions could represent a viable alternative.

A primary aim of the Youth-fit project was to develop a low-cost, user-friendly and efficient web-based solution to facilitate monitoring students HRPF levels. The teachers’ evaluation survey comprised of a full section evaluating their experience of the Youth-fit software package, guided by relevant elements of the technology acceptance model (Venkatesh and Davis 2000). A total of 80% of the teachers surveyed indicated that the Youth-fit software application had relevance to their work, and the same number of teachers indicated that their interaction with the software application was clear and understandable. Although 85% of teachers agreed or strongly agreed that the software platform was easy to
use, 50% of respondents were undecided or disagreed that the quality of the student report output generated was high. In addition, as mentioned in the previous section, some teachers raised concerns over the amount of time taken to upload results to the web-based platform. For example, one teacher stated they were “…not sure about the whole reporting infrastructure...I think the input process could have been made more efficient and the student reports could be better” (female teacher, boys’ school). Despite these concerns, 85% of teachers surveyed stated that they would continue to use the software package as part of their fitness education unit if made permanently available. Our project Partner’s iMosphere, in collaboration with the lead investigator, completed a White Paper review of the feasibility and scalability of the software platform available in Appendix K.

8.5.1.5 Objective 5: Preliminary evaluation of participant responses to initiative

Almost all teachers (95%, n=19) and 79% (n=618) of student participants surveyed agreed or strongly agreed that the Youth-fit project was a worthwhile experience. Indeed, 95% of teachers indicated that would like to incorporate the Youth-fit test battery as a regular component of their fitness education units in the future. Teachers (80%, n=16) and students (79%, n=618) agreed or strongly agreed that the project made them more aware of the importance of health-related fitness. For example, one teacher stated that “the youth-fit test battery is a much needed resource that can assist teachers to frame the importance of HRPF and make clear links with future health that is understandable for all young people” (male, mixed sex school). The inclusion of senior student facilitators and the small group design for administering the test battery were two strengths of the project commonly cited by both teachers and students. Furthermore, student attitudes toward participating in the Youth-fit project did not vary significantly based on the socio-demographic profile or location of the
school, and were significantly higher than age-matched values from students in the United States (Mercier and Silverman 2014a).

8.6 Discussion

The aim of this study was to assess the feasibility of the Youth-fit HRPF test battery and software platform. Much debate has surrounded the place of fitness testing in schools, and calls for more research on valid, reliable and pedagogically sound approaches to assess and monitor health-related fitness in school settings have mostly gone unanswered. Many research articles have identified best practice approaches for integrating fitness tests in schools. Recommendations included moving away from command style test administration to a more reciprocal approach, implementing a small group and peer-facilitated design (Graser et al. 2011), using criterion rather than norm-referenced health standards to promote a self-referenced comparison with attainable health standards (Mahar and Rowe 2008), and allowing students an opportunity to familiarize themselves with the tests prior to testing (Martin et al. 2010). However, very few empirical studies have been conducted to provide evidence for these recommendations. The current feasibility study, to the best of the authors’ knowledge, is the first study of its kind to evaluate both students and teachers experiences of a peer-facilitated fitness test battery and web-based monitoring platform. Based on the success of the recruitment capability, data collection procedures, resources and participant responses, the Youth-fit test battery and software platform represents a feasible approach for assessing and tracking health-related fitness in secondary school settings.

Benchmarks in relation to recruitment and acceptability were reached or exceeded as evidenced by high acceptance rates among the initial sample of schools, and student participation rates of greater than 75% in all schools. Interventions aimed at promoting
healthy lifestyle behaviours are a high priority for school management personnel, thus, emphasising the capacity of schools as powerful locations within which to systematically influence the health of children and adolescents (Kriemler et al. 2011). Five teachers cited the time consuming process involved in gathering parent and student consent forms as a barrier to recruitment and participation. Similar projects, including NFL Play 60, have been deemed exempt from gathering participant consent due to the participatory nature of the project and the use of de-identified data as part of normal school assessments (Welk et al. 2016). This unique participatory design offers schools the opportunity to voluntarily opt in and directly coordinate their own local programming with training and support provided by the institution coordinating the intervention (Welk et al. 2016).

One of the most frequently cited strengths to emerge from the current feasibility analysis was the positive response to test protocols and data collection procedures, specifically, the role of the peer-facilitators in assisting with the delivery of test battery. A total of 95% of teachers and 87% of students indicated that the peer-facilitators made it easier to perform the test battery. It has been suggested that peer-facilitated learning in a physical education context may overcome some aspects that impede student learning by providing opportunities for increased levels of individualised feedback, social learning and less direct instruction from the teacher (Ward and Lee 2005). In addition, given that most teachers indicated that it would not be feasible for one teacher to administer the test battery within the specified time, incorporating peer-facilitators to assist with the set-up and delivery could reduce the burden on teachers, as indicated in other school-based interventions (Lubans et al. 2011b). A conceptual model for targeted health behaviour interventions promoting physical activity by Morgan et al. (2016) noted the important, but often under-recognized, impact facilitators can have on the effectiveness of interventions. Although the experiences of
student facilitators was not formally evaluated as part of the current feasibility trial, other studies, that utilised a similar senior student facilitated approach, reported very positive impacts on the facilitators themselves (Jenkinson et al. 2012). However, Jenkinson and colleagues also cautioned that older student facilitators were reluctant to give up too much of their timetabled class time, which could be a potential barrier for a future expansion of the Youth-fit test battery, as facilitators are selected from students in the final three years’ of second level education, when pressures associated with state examinations are greatest (Banks and Smyth 2015).

The induction workshop and resources provided to deliver the test battery were cited by teachers as another strength of the study design. Remmington and Brownson (2011) caution that evidence based interventions aimed at promoting healthy lifestyle behaviours rarely get implemented in a sustainable manner in real-world settings. Furthermore, the integrity of pre-intervention induction workshops for facilitators has been reported as one of the factors limiting the impact of many multi-site interventions (Galbraith and Winterbottom 2011). The importance of providing sufficient training and resources, including test protocols, equipment, organisation and timing, to facilitators has been highlighted in similar school-based studies (Jenkinson et al. 2012). Morgan et al. (2016) also emphasised the importance of facilitators responsible for the delivery of an intervention being perceived as credible, likable and motivated, which may lead to increased participant engagement. This study involved a three hour test battery induction workshop, delivered to physical education teachers and senior student facilitators in all schools. During this induction session test battery equipment and a comprehensive manual detailing a rationale and protocol for each test item was provided (Appendix A). In a review of large-scale fitness testing, Martin and colleagues (2010) stated that fitness testing that documents and leads to improved physical
fitness and health will not occur unless those involved receive proper knowledge, preparation, motivation, and support. Therefore, the provision of in-service professional development workshops, in addition to investment in resources and testing equipment, would be required in advance of a potential future national expansion of the Youth-fit test battery. A national survey of HRPF monitoring practices in Ireland (O’Keeffe et al. 2020c), presented in Chapter Three, also reaffirms the need for the provision of professional development for teachers on best practice approaches to fitness monitoring in schools.

A key benchmark which did not appear to be acceptable was the recommended time allocated to deliver the test battery. Half of the teachers surveyed indicated that it was not feasible to deliver the full test battery within the recommended time of two 80 minutes periods of physical education. Jenkinson and colleagues (2012) stated that the compulsory context of curriculum-based sessions are important in enabling greater opportunities for intervention success. Therefore, the research team were keen to ensure that the Youth-fit test battery could be administered during timetabled physical education class periods. In order to sustain this approach, steps need to be taken to ensure that the recommended time allocated to complete the test battery is feasible. The high number of test items in the Youth-fit test battery in comparison to other similar school-based test batteries internationally, including Fitnessgram®, Netfit and SLOfit, is a key factor contributing to the time barrier. The time taken to administer the blood pressure test, in particular, was noted by a number of teachers. Although test items were delivered in small groups of no more than six students per station at any one time, a future roll out of the test battery could potentially include high priority and optional test items, as is the case in other similar health-related fitness test batteries, such as the ALPHA test battery (Ruiz et al. 2011). In addition, given the high coefficient of variation values reported in an analysis of the test-retest reliability of the Youth-fit test battery
(O’Keeffe et al. 2020b), the 90° push-up and isometric plank hold tests of muscular strength and endurance could also be included as optional items.

One of the primary objectives of this thesis was the development of a software platform to enable teachers to store and track student scores, while simultaneously transferring this data to an unidentifiable open access database, showing trends in real time, and enabling school level comparisons with regional and national norms. As previously indicated, computer based tracking technology to aid teachers in monitoring students’ health-related fitness is common in many test batteries internationally, including Fitnessgram® in the United States (Welk and Meredith 2013), SLOfit in Slovenia (Jurak et al. 2019) and Netfit in Hungary (Csányi et al. 2015). Researchers have highlighted the need for the development of efficient systems for large-scale collection of HRPF data, and the transfer of this data to centrally located databases (Ruiz et al. 2006b). Although the vast majority of teachers in the current study agreed or strongly agreed that their interaction with the software application was clear and understandable, there were issues in relation to both the time taken to input student results, and the quality of report outputs generated. A future update to the software platform should include the option to input multiple students test scores at once, significantly reducing the amount of time taken to input results. Furthermore, the individual student and teacher report outputs generated need to be improved, perhaps including more comparison charts to graphically depict a student or schools score against international age-matched norms or criterion referenced values, as used in similar software platforms used to monitor HRPF (Welk and Meredith 2013).

The final, and arguably most important, component of Orsmond and Cohn’s (2015) evaluation framework for feasibility studies required an examination of participant responses to the initiative. Notwithstanding the aforementioned concerns regarding time constraints,
total number of test items and software infrastructure, almost all teachers, and the vast majority of student participants, indicated that engaging in the Youth-fit project was a worthwhile experience. A large majority of teachers and students similarly indicated that the project made them more aware of the importance of HRPF. As mentioned in the previous chapter, participating with friends and having fun as the most commonly cited enjoyable aspect of the test battery from the perspective of student participants. It was also encouraging to note that most teachers confirmed that they would continue to use the Youth-fit test battery and software package as part of their physical education programmes.

8.6.1 Limitations

A range of different outcomes and limitations need to be considered prior to a potential larger-scale dissemination of the Youth-fit test battery. Firstly, although a randomised sample of secondary schools were recruited, participants were generated from one year group, with no control group. Future research should consider implementing the test battery across a range of ages. Furthermore, the non-experimental nature of the design limits the ability to make causal conclusions about the efficacy of the Youth-fit test battery in comparison to other approaches. All lead cooperating teachers in each of the 20 schools completed the process evaluation survey, however, student evaluation survey response rates varied between 60 and 100 percent, potentially leading to some response bias. A future evaluation should also analyse the experiences of senior student facilitators, given that they were not formally evaluated as part of the present feasibility study. Finally, this survey was based on a single data source, with no follow up. A longitudinal investigation of the implementation of the test battery over two or more occasions, with the addition of qualitative forms of evaluation such as focus groups, would provide a more comprehensive overview of the fidelity of the Youth-fit test battery.
8.7 Conclusion

This study demonstrated that the Youth-fit test battery and software platform represents a feasible, pedagogically sound and scientifically rigorous approach to monitoring HRPF in schools. It adds an important contribution to the current literature as one of the first studies to empirically evaluate both students’ and teachers’ experiences of recommended best practice approaches to fitness testing in a physical education context. Indeed, teachers indicated that they would continue to use the Youth-fit software platform to monitor students HRPF, if made available to them. Teachers should consider using a similar approach to that outlined in the current study when assessing students’ health-related fitness, including, using senior student facilitators, allowing student participants the opportunity to familiarise and practice tests prior to testing day, and utilising a small group design. Furthermore, the Youth-fit software infrastructure confirmed the capacity for large-scale collection of objective measures of health and physical fitness from population-based samples, and the transfer of this data in anonymised form to a centrally hosted database. Refinements to the number of test items, the time allocated for administering the test battery, and the efficiency of data input and quality of report output on the software platform should be addressed in advance of a future expansion of the test battery.
Chapter Nine: General Discussion
9.1 Introduction

The primary aim of this thesis was to develop a scientifically rigorous and pedagogically sound system for monitoring health-related fitness among adolescent youth in secondary school-based physical education programs. The nine chapters presented reflect the systematic process that was involved from the initial development of the concept (phase one), to the 20 school feasibility phase (phase two), and finally, the evaluation (phase three) of the overall project. Chapter Two provided a comprehensive review of physical fitness, its relationship with health in youth, and current monitoring trends internationally among adolescent populations. A critical appraisal of the opportunities and obstacles associated with monitoring physical fitness in schools was also provided in this chapter. The first national review survey of HRPF monitoring practices in the Republic of Ireland (O’Keeffe et al. 2020c) was presented in Chapter Three, and confirmed the evidence of need among key stakeholders for the development of a HRPF test battery and digital monitoring platform. Chapter Four outlined the steps involved in the design and development of the Youth-fit test battery and software platform, guided by the Medical Research Council’s key phases for the development and evaluation of a feasibility study (Craig et al. 2008), and the design science research methodology for information systems (Peffers et al. 2007). Positive test-retest reliability indices presented in Chapter Five provided evidence for the peer-facilitated test administration protocol utilised in the study (O’Keeffe et al. 2020b). Chapter Six presented results from the first analysis of all components of HRPF to be conducted among a stratified sample of adolescents in the Republic of Ireland. A significant school level socioeconomic divide in fitness test performance was reported ($p < 0.005$, t-test), in addition to significant age-matched disparities in muscular strength between adolescents in the current sample and European normative values (Ortega et al. 2011a) ($p < 0.01$, t-test). The software infrastructure
outlined in Chapter Four that was used to gather data presented in Chapter Six further emphasised the capacity for the development of efficient systems for large-scale collection of health related fitness data, and the transfer of data to centrally located databases. Student participant attitudes towards the Youth-fit test battery were reported in Chapter Seven, and indicated that both boys and girls had positive experiences of the Youth-fit test battery. Finally, positive feasibility benchmarks presented in Chapter Eight, including recruitment capability, data collection procedures, resources, and participant responses indicated that the Youth-fit test battery and software platform represents a feasible approach for monitoring health-related fitness in secondary school settings. Key findings from the studies included in the current body of work are summarised in the following section.

### 9.2 Key findings

- The survey of HRPF monitoring practices, involving a nationally representative sample of secondary schools in the Republic of Ireland, confirmed the high prevalence of fitness testing, with over 95% of teachers indicating that they incorporated fitness tests as part of their physical education programme. However, just over half (52%) of teachers discarded test results after a single use, less than 12% tracked students’ results from year to year, and only one third (33%) of teachers provided feedback to students parents’ on their results (O’Keeffe et al. 2020c).

- The survey also confirmed that the vast majority of teachers were in favour of the development of a digital platform that would facilitate tracking and reporting students’ HRPF results (M=6.4, SD.94) on a seven-point Likert scale ranging from one (strongly disagree) to seven (strongly agree) (O’Keeffe et al. 2020c).
• Intra-class correlation coefficients for student administered HRPF tests were high (ICC ≥0.797), and mean test-retest percentage error values were less than 10% for BMI, standing broad jump, handgrip strength and 4x10m shuttle run tests. Furthermore, the observed error (Bland–Altman plot) between test 1 and test 2 was close to zero for most tests. Therefore, following familiarisation training, student-administered fitness tests in school-based physical education programs can be considered reliable (O’Keeffe et al. 2020b).

• A linear mixed model analysis indicated that participants in designated disadvantaged schools had significantly higher BMI levels, and significantly lower CRE and muscular strength levels compared to participants in non-disadvantaged schools, when examined using adjusted mean differences controlling gender as a fixed effect and school as a random effect (p < 0.005, t-test) (O’Keeffe et al. accepted).

• When compared to age-matched European normative values, participants in the current study had significantly lower muscular strength (handgrip strength), however, both boys and girls had significantly higher CVE levels (20m SRT) (p < 0.01, t-test) (O’Keeffe et al. accepted).

• Although both boys and girls had positive attitudes’ towards fitness testing (M = 3.9, SD .59), the mean attitude score for boys (M=4.05, SD .59) was significantly higher than girls (M=3.79, SD .59; p < 0.01, t-test) on a five-point Likert scale ranging from one (strongly disagree) to five (strongly agree) (O’Keeffe et al. 2020c).

• When compared with single value age-matched mean scores from United States (Mercier and Silverman 2014a), participants in the current study had significantly more positive overall mean attitude scores (t (793) = 2.58, p < 0.01) (O’Keeffe et al. 2020c).
• The vast majority of teachers (95%, n=19) and 79% of students (n=618) surveyed agreed or strongly agreed that completing the Youth-fit test battery was a worthwhile experience. A total of 80% of the teachers surveyed indicated that the Youth-fit software application had relevance to their work, and the same number of teachers indicated that their interaction with the software application was clear and understandable. However, half of the teachers surveyed (n=10) were undecided or disagreed that the quality of the student report output generated was high.

• Positive feasibility benchmarks including recruitment capability, data collection procedures, resources, and participant responses confirmed the capacity for the large-scale collection of objective measures of health and physical fitness from population-based samples, and the transfer of this data in anonymised form to a centrally hosted database.

These findings will be discussed in more detail throughout the remainder of this chapter.

The potential implications for research and practice of this thesis will be outlined, before a summary of the limitations and directions for future research are addressed.

9.2.1 Schools as vehicles for health promotion

As discussed in Chapter Two, although schools have not been implicated as a cause for global trends of declining physical activity and physical fitness levels, they are an integral part of the solution, due to the ability to reach and influence large numbers of children in a comprehensive and systematic way (Welk 2017). The unique position of physical education, in particular, as the cornerstone through which to promote positive health behaviours has been commonly acknowledged (Pate et al. 2006; Csányi et al. 2015). The increasing number of countries who are implementing large-scale fitness test batteries to systematically monitor
physical fitness levels of adolescents through the medium of school-based physical education provided evidence of the growing recognition of physical education in promoting healthy lifestyle behaviours. A comprehensive review of the opportunities and obstacles associated with fitness testing in physical education presented in Chapter Two concluded that, if integrated appropriately, and subjected to informed critique, there is no reason why fitness testing could not play a role in supporting healthy lifestyles and in educating young people about physical activity and fitness. Findings from the review presented in Chapter Two were used to inform the development and feasibility phases of the current project.

9.2.2 National survey of health-related fitness monitoring practices in schools

The review of HRPF monitoring practices in secondary school-based physical education in the Republic of Ireland confirmed the prevalence of fitness testing, with over 95% of teachers using fitness tests on at least one occasion per year. Some encouraging findings were reported regarding teachers rationale for incorporating fitness testing in their physical education programmes. Teachers most frequently cited the opportunity for student learning, enhancing students’ awareness of the importance of HRPF, and promoting self-evaluation through the creation of personal fitness profiles as the most common reasons for using fitness tests. Claims of ‘fitness for performance’ discourse dominating the delivery of HRPF among physical education teachers reported in other studies (Harris and Cale 2007; Alfrey and Gard 2014; Harris and Leggett 2015b) were not in evidence from participants’ responses in this study. However, as noted in the previous section, just over half (52%) of teachers discarded results after a single use, less than 12% tracked students’ results from year to year, and only one third (33%) of teachers provided feedback to the parents/guardians of their student’s results. Furthermore, teachers were overwhelmingly in favour of having access to a digital
platform to facilitate tracking HRPF test scores, thus providing a conclusive rationale for the development of the Youth-fit test battery and software platform.

9.2.3 Reliability of student-administered HRPF tests

A critical step in the development phase of this project was determining the reliability of the student administered approach utilised for delivering the test battery. Rather surprisingly, given the prominence of fitness tests in schools, this was the first study of its kind to examine the reliability of student assessed measures of HRPF in a school-based physical education context. Participants were assigned into a student administered (SA) or research-assistant administered (RA) group and reliability indices were calculated and compared across both groups. Intra-class correlation coefficients for SA (≥0.797) and RA (≥0.866) groups were high, and the observed systematic error (Bland–Altman plot) between test 1 and test 2 was close to zero for most tests. The coefficient of variation was less than 10% for all tests in the SA group, aside from the 90° push-up (24.3%). The SA group had a marginally lower combined mean coefficient of variation across all tests (6.5%) in comparison with the RA group (6.8%). Therefore, this study demonstrated that, following familiarisation training, student-assessed measures of anthropometric (BMI), muscular fitness (handgrip strength, standing broad jump, and isometric plank hold), and performance-related fitness (4 × 10-m shuttle run) can be considered a reliable approach to administering HRPF tests in school settings. The paper concluded by cautioning that, any measurement of physical fitness in a school context should be delivered with a strong educational emphasis, and not conducted solely for the purpose of gathering data.
9.2.4 Profiling adolescents HRPF levels in the Republic of Ireland

9.2.4.1 A school level socioeconomic status divide
The feasibility phase of this project included the first examination of all components of HRPF among Irish adolescents from a randomised sample of 20 schools stratified by gender, location, and socioeconomic status. The extent of the disparity in HRPF levels between students in designated disadvantaged and non-disadvantaged schools was a finding of particular concern. Participants in designated disadvantaged schools ran (20m SRT) on average 19 shuttles (380 metres) fewer and jumped (standing broad jump) on average 10.9cm less than those in non-disadvantaged schools. These findings corroborate those reported by Jiménez Pavón et al. (2010) who reported that higher SES was positively associated with physical fitness independent of total body fat and habitual physical activity. Bel-Serrat and colleagues (2018) concluded that school level SES was a strong determinant of overweight and obesity in Irish schoolchildren. Welk et al. (2010) also noted that school level attainment of fitness was consistently higher in schools categorized as low diversity and high socioeconomic status. In light of these findings, the provision of additional support funds to designated disadvantaged schools, aimed at promoting healthy lifestyle behaviours, could represent an efficient model of funding by targeting those who are most in need.

9.2.4.2 Comparison with European norms
Chapter Six also included a comparison between data generated from this study with age-matched European normative values from the HELENA study (Ortega et al. 2011a). Encouragingly, girls in the current study had significantly higher mean scores in the SBJ, 4x10m shuttle run and 20m SRT in comparison to their European peers, while boys in this study scored significantly higher in the 20m SRT and back-saver sit and reach test ($p < 0.01$). However, European boys and girls had significantly higher handgrip strength ($p < 0.01$).
Participants’ scores were categorised using a quintile classification framework based on European normative values corresponding to “very low,” “low,” “moderate,” “high,” and “very high”. Over three quarters of participants in this study were classified as moderate or below average for handgrip strength. This is a finding of particular concern given the emerging evidence linking poor musculoskeletal fitness in adolescence with negative health outcomes later in life (Ortega et al. 2012; Smith et al. 2014). Therefore, future interventions aimed at improving the physical fitness and activity levels among youth in the Republic of Ireland should include a focus on muscular fitness.

9.2.5 Students’ attitudes towards fitness testing: Addressing the gender divide

Another finding of note to emerge from the current study was the disparity between boys’ and girls’ attitudes towards fitness tests in school-based physical education. As reported in Chapter Seven, boys (M=4.05, SD.59) reported significantly more positive attitudes in comparison to girls (M=3.79, SD.59; p < 0.01, t-test). Indeed, mean scores for students in single-sex boys’ schools and mixed-sex schools were significantly higher than single-sex girls’ schools. The survey of HRPF monitoring practices presented in Chapter Three also revealed that almost twice as many teachers felt that the boys had a more positive reaction to fitness testing compared with girls (O’Keeffe et al. 2020c). Engaging girls in physical education has been reported as a challenge for teachers across most aspects of a curriculum (Enright and O'Sullivan 2010), however, these gender differences appear to be augmented when it comes to fitness testing (Davis et al. 2018). Further research is needed on how best to integrate fitness tests to ensure that girls, in particular, are comfortable participating and motivated to try their best. It was promising to note that, when compared with single value age-matched mean scores from United States (Mercier and Silverman 2014a), boys and girls in this study had a significantly more positive overall mean attitude scores ($t (793) = 2.58$, $p$
This suggests that physical education teachers should consider adopting the peer-facilitated small group design used in this study, rather than the teacher-administered whole-class design implemented in the test batteries reviewed by Mercier and Silverman (2014a).

9.2.6 Feasibility of the Youth-fit test battery and software platform

9.2.6.1 Positive feasibility benchmarks
Positive feasibility benchmarks presented in Chapter Eight, including, recruitment capability and resulting sample characteristics, data collection procedures, resources, and evaluation of participant responses, indicated that the Youth-fit test battery and software platform represents a feasible approach for monitoring health-related fitness in secondary school settings. Participation rates in the final sample were ≥75% in all schools, and reached 100% in many schools. One of the most frequently cited strengths to emerge from the feasibility analysis was the positive role of senior student peer-facilitators in assisting with the delivery of the test battery. A total of 95% of teachers and 87% of students indicated that the peer-facilitators made it easier to perform the test battery. Ward et al. (2017) and Jenkinson et al. (2012) also noted the benefits of utilising a peer-facilitated approach in a physical education context. Furthermore, the induction workshop and resources provided to deliver the test battery was cited by six of the 20 teachers surveyed as the most beneficial aspect of the project. Galbraith and Winterbottom (2011) noted the integrity of pre-intervention induction workshops for facilitators as one of the factors limiting the impact of many multi-site interventions, while Morgan et al. (2016) also emphasised the importance of facilitators being perceived as credible, likable and motivated as a mechanism to enhance participant engagement. Overall, the vast majority of teachers (95%, n=19) and 79% of students (n=618) surveyed agreed or strongly agreed that completing the Youth-fit test battery was a worthwhile experience.
To implement targeted non-communicable disease prevention programmes, policy makers need data on the physical activity and physical fitness levels of youth (Hallal et al. 2012). The development of efficient systems for large-scale collection of health related fitness data, and the transfer of this information to centrally located databases, has been cited by leading experts as the next step in monitoring HRPF in youth (Ruiz et al. 2006b; Tabacchi et al. 2016). The multi-site data capture application used to harvest anonymised HRPF results gathered as part of the 20 school expansion phase confirmed the capacity for the collection of objective measures of health and physical fitness from population-based samples. Indeed, Welk (2017) noted that the publication of studies based on data gathered from field-based HRPF test batteries in prominent medical journals emphasised the acceptance of this form of data collection for research applications.

9.2.6.2 Feasibility benchmarks in need of improvement

A key benchmark which did not appear to be acceptable was the recommended time allocated to deliver the test battery. Half (n=10) of the teachers surveyed indicated that it was not feasible to deliver the full test battery within the recommended time of two 80-minute periods of physical education. The compulsory nature of curriculum-based sessions is important in enabling greater opportunities for intervention success. In order to maintain the curriculum-based approach, consideration should be given to reducing the total number of compulsory items on the test battery. The time taken to administer the blood pressure test, in particular, was noted by one quarter of the teachers surveyed. Therefore, consideration should be given to updating the test battery to include high priority and optional test items, as is the case in the ALPHA test battery (Ruiz et al. 2011).

Another key objective of this project was to develop a low-cost, user-friendly and efficient web-based solution to facilitate monitoring students HRPF levels. Although 85% of
teachers agreed or strongly agreed that the software platform was easy to use, 50% of respondents were undecided or disagreed that the quality of the student report output generated was high, and five teachers also raised concerns over the amount of time taken to input results. Future updates to the software platform should include the option to input multiple students' test scores at once, significantly reducing the amount of time taken to input results. Efforts should also be made to improve the quality of result report outputs. Updates could include, charts to graphically depict a student’s or school’s scores in comparison to criterion referenced or regional norms (Appendix K), in addition to personalised feedback statements as used in other similar platforms including Fitnessgram® (Welk and Meredith 2013). Notwithstanding the aforementioned concerns regarding time constraints, test items, and software infrastructure, almost all teachers, and the vast majority of student participants, indicated that engaging in the Youth-fit project was a worthwhile experience. Thus, this project has confirmed the feasibility of a standardised approach to large-sale fitness testing, and the secured transfer of anonymised data to a central processing system.

9.3 Potential impact of research findings

The findings presented in this thesis may have important implications for future research and practice in paediatric exercise science and sport pedagogy. These impacts can be summarised as follows:

- Although the national survey revealed several positive uses of fitness tests in schools, it confirmed that tests were often implemented in isolation of the broader physical education curriculum. In addition, just over half (51.7%) of teachers discarded test results after a single use, and less than one third of teachers indicated that they shared test results with their students’ parents. Actions are needed from pre-service and in-
service professional development providers to ensure that teachers use best practice approaches toward monitoring HRPF in schools, with a focus on learning that may lead to more positive testing experiences for students.

- Implementing a peer-facilitated and student-centred approach to HRPF testing in school settings has been recommended by several experts, however, this was the first study to measure the reliability of this approach. Positive reliability indices including high ICC values (≥0.797) and a low combined mean CV (6.5%) confirmed that student-assessed measures of anthropometric (BMI), muscular fitness (handgrip strength, standing broad jump, and isometric plank hold), flexibility (sit and reach) and performance-related fitness (4 × 10-m shuttle run) can be considered reliable. Therefore, with adequate training on test administration protocols, a student-led approach represents a feasible and reliable alternative to teacher administered or research-assistant administered fitness tests in school settings.

- Data from the profile of HRPF levels among Irish adolescents presented in Chapter Six revealed that school socioeconomic status was a strong determinant of performance among Irish adolescents. Participants in designated disadvantaged schools had significantly higher BMI levels, and significantly lower CRE and muscular fitness levels compared to participants in non-disadvantaged schools (p < 0.005). Consideration needs to be given to targeting disadvantaged schools, in particular, with funding to promote healthy lifestyle behaviours.

- The same study reported that age-matched comparisons of HRPF levels with European normative values were broadly positive for all components, aside from muscular fitness (handgrip strength) in which European adolescents scored significantly higher (Cohen’s d 0.6 to 0.8, p < 0.01). European boys also had
significantly higher SBJ scores (Cohen’s $d = 0.5$, $p < 0.01$), however, girls SBJ scores did not differ significantly. In light of these findings, and the growing evidence-base confirming the predictive capacity of muscular strength as an indicator of future health (Smith et al. 2014), future interventions designed to promote healthy lifestyle behaviours among adolescents in the Republic of Ireland should consider including a muscular fitness focus.

- Boys’ attitudes ($M=4.05$, SD .59) towards fitness testing were significantly more positive than girls ($M=3.79$, SD .59; $p < 0.01$, $t$-test). However, as noted in Chapter Seven, when compared with single value age-matched mean scores from United States (Mercier and Silverman 2014a), boys and girls in this study had significantly more positive mean attitude scores towards fitness testing ($t (793) = 2.58$, $p < 0.01$). Indeed, when asked to rank who they would like to administer fitness tests from most preferred to least preferred, over half (52.8%) indicated that they would be in favour of the student-centred format used in the Youth-fit test battery, in comparison to an external expert (27.0%) or their teacher (20.2%) recording test scores. Therefore, coupled with the positive reliability indices presented in Chapter Five, teachers should consider implementing a small group, peer-facilitated design as a mechanism to enhance students’, and girls’ in particular, engagement in HRPF testing.

- As mentioned in the previous section, establishing web-based systems for large-scale collection of health related fitness data, and the transfer of data to centrally located databases, has been cited by leading experts as the next step in monitoring HRPF in youth. This study has demonstrated the capacity for the collection of objective measures of health and physical fitness on a large-scale through a centrally managed anonymised database. The availability of such data in real-time could serve as a
crucial information source for policy-makers, healthcare professionals and education authorities in the timely planning of prevention programs. However, any measurement of physical fitness in a school context should be delivered with a strong educational emphasis, and not conducted solely for the purpose of gathering data (O’Keeffe et al. 2020b).

9.3.1 Practical applications for schools

A key objective of the current body of work was to develop real-world, evidence-based solutions for integrating fitness testing in school settings. In an effort to maximise the fidelity of the project, each phase of the thesis was designed with the practical applications of the research outputs, for both teachers and students, in mind. Overall, the Youth-fit test battery resource pack, including the teachers guidance manual (Appendix A), theoretical underpinning for each test (Appendix A), test protocol displays (Appendix D), and software guidance manual (Appendix C), represents a ready-to-use pedagogical tool for teachers. Data presented in Chapters Five and Seven indicate that the Youth-fit test battery could enhance students experiences of fitness testing in a physical education context, while simultaneously improving the accuracy of the test measures obtained. Specifically, teachers should consider utilising the small-group, senior peer-facilitated approach presented in Chapter Four. Teachers should also provide students with an opportunity to familiarise themselves with test items prior to testing days, and testing should always be conducted with a strong educational rationale, both key components of the student-centred approach utilised in the Youth-fit test battery.
9.4 Limitations

This thesis was completed following a systematic eight step plan, as detailed in Chapter Four. Although the development and design of the test battery and web-based platform were guided by well-established frameworks (Craig et al. 2008; Orsmond and Cohn 2015), there are a number of limitations that should be noted when interpreting the results of this study.

- Firstly, although the sample from the survey of HRPF monitoring practices, presented in Chapter Three, was shown to be nationally representative, it was not random. The survey was sent to each school’s general e-mail address as opposed to directly to physical education teachers, which may have led to some nonresponse bias. Furthermore, the survey did not include information on the impact of key variables, including student age and ability level, on engagement with fitness testing.

- Student participants in this study were in year one of secondary school education. Therefore, despite the relatively large and stratified nature of the sample, results cannot be generalised for all year groups (grades). The decision to focus on one year group was made due to the already over-crowded nature of the physical education curriculum and principals/teachers reluctance to give up too much curriculum time. A future expansion of the current project should include all year groups (grades) to facilitate comparisons of HRPF levels across all adolescent ages.

- The sample size of 20 schools was small for the linear mixed model analysis of non-disadvantaged (n=14) versus designated disadvantaged (n=6) schools, reported in Chapter Six. However, due to the geographical spread of schools, and the need to visit each school individually, 20 schools was considered the maximum sample size achievable from a logistical viewpoint, and the minimum required to obtain a sufficient number of schools in each of the chosen strata.
• Data collected as part of the student and teacher evaluation was based on a single data source. Therefore, data were not verified a second time, potentially resulting in a lack of depth in the interpretation of responses for which qualitative methods may have provided deeper insights. Furthermore, although participants from each of the 20 schools were represented in the student evaluation presented in Chapter Seven, response rates within schools varied between 60 and 100 percent, which could have resulted in some response bias. It is well established that attitudes towards physical education decline as students get older (Silverman, 2017), therefore, a longitudinal analysis over two or more years across all secondary school year groups would provide a more comprehensive evaluation of the Youth-fit test battery. A future evaluation of the Youth-fit test battery should also analyse the experiences of senior student facilitators, given that they were not formally evaluated as part of the present feasibility study.

• The reliability study presented in Chapter Five included a relatively small sample size (n=86) and tight age range (13.4 SD 0.33) of participants from one school. Therefore, our findings cannot be generalized to all field-based testing settings at this time. A larger sample size, involving a more diverse age range, and the inclusion of an additional trial, could have improved the precision of the reliability estimates, while also allowing for a more detailed examination of results by age group. However, the two-group study design (student administrators and research-assistant administrators) and the wide variety of fitness tests examined, in addition to the authenticity of the environment in which testing took place, were notable strengths of this study.

• Several data quality control measures were implemented, including: the development of a detailed teacher guidance manual (Appendix A) and software video tutorials
(Appendix C); the introduction of biologically plausible value limits to the result input fields on the software platform; and randomised cross referencing of results inputted to the software platform. However, due to the field-based nature of the test administration and data input procedures, some pragmatic sacrifice of validity and reliability is inevitable.

9.5 Future research directions

1. Building on the Medical Research Council’s framework for the development and evaluation of feasibility studies (Figure 4.1) (Craig et al. 2008), a longitudinal study design examining the implementation of the Youth-fit test battery and software platform over two or more years across all secondary school year groups would provide a more comprehensive overview of the fidelity of the initiative, prior to a potential future national dissemination. This would simultaneously facilitate the first longitudinal analysis of HRPF levels among Irish adolescents.

2. Future examinations of HRPF should consider cross validating established criterion reference values for body composition, cardiorespiratory endurance and musculoskeletal fitness, to determine their acceptability among adolescents in the Republic of Ireland. Schools are encouraged to use criterion referenced comparisons rather than normative comparisons (Zhu et al. 2011), however, the validity of such values need to be determined for specific populations in advance of their use.

3. The ALPHA project (Ruiz et al. 2011) represented a significant step forward in confirming the validity and reliability of commonly administered field-based tests, however, there remains a need for further research to confirm the criterion validity of field-based tests of muscular endurance. Such research could also provide
recommendations on prioritising or removing specific test items in the current Youth-fit test battery in an effort to address time allocation constraints, as noted in Chapter Eight.

4. Despite calls to critically reconsider fitness testing procedures and fitness practice in school settings, little empirical research has been conducted investigating how modifications to tests or administration protocols could improve the experiences of students. Building on some of the recommendations from the current study, future experimental investigations should examine the effects of specific changes to how fitness tests are delivered on the quality of the experience that students derive. Researchers need to consider mechanisms to enhance student motivation in order to ensure students’ are willing to try their best.

5. Finally, data on health and fitness of youth that has been transferred to centrally hosted platforms could serve as a rich source of information beyond the school environment for parents, policy makers and health professionals. Using international best practice examples of an integrated approach, such as the SLOfit model in Slovenia, further research is needed on technological solutions to maximise the potential use of relevant data among key stakeholders.

9.6 Conclusion

Remington and Brownson (2011) suggested that evidence-based programming rarely gets disseminated, effectively implemented, and sustained in real-world settings. The importance of paying close attention to the specific needs of practitioners and other key stakeholders cannot be overstated, as Green (2006, p.406) noted, “If you want evidence-based practice, you need to have practice-based evidence”. In an effort to maximise the fidelity of the project,
each phase of the current thesis was designed with the practitioner (teacher) and key stakeholders (students and researchers) in mind. This research project represents the first coordinated attempt to establish a standardised approach to monitoring HRPF in secondary school-based physical education programmes in the Republic of Ireland. In summary, the national survey of HRPF monitoring practices, presented in Chapter Three, highlighted the prevalence of fitness testing in schools, and the demand among key stakeholders for the development of a standardised HRPF test battery and web-based monitoring system. Positive feasibility benchmarks presented in Chapter Eight, including recruitment capability, data collection procedures, resources, and participant responses indicated that the Youth-fit test battery and software platform represents a feasible and pedagogically sound approach for monitoring health-related fitness in secondary school settings. This project also confirmed the feasibility of a standardised approach to large-sale fitness testing, and the transfer of anonymised data to a secured central processing system. Availability of such data in real-time could serve as a rich source of information for policy-makers, healthcare professionals, and education authorities, in the timely planning of prevention programs. Furthermore, positive reliability indices for the peer-facilitated approach, presented in Chapter Five, confirmed the scientific rigour of the test administration protocols utilised. Collectively, as detailed over the course of this concluding chapter, the results of this thesis have important implications that can inform and enhance current research and practice approaches to HRPF monitoring in youth, putting in place the foundations for a potential future national dissemination of the project to all secondary schools in the Republic of Ireland.


Cohen, J. (1988) 'Statistical power analysis for the social sciences'.


Cooper, K.H. (1968) 'A means of assessing maximal oxygen intake: correlation between field and treadmill testing', Jama, 203(3), 201-204.


Ladwig, M.A., Vazou, S. and Ekkekakis, P. (2018) “My best memory is when I was done with it”: PE memories are associated with adult sedentary behavior, Translational Journal of the American College of Sports Medicine, 3(16), 119-129.


Lubans, D.R., Morgan, P.J., Aguiar, E.J. and Callister, R. (2011b) 'Randomized controlled trial of the Physical Activity Leaders (PALs) program for adolescent boys from disadvantaged secondary schools', Preventive Medicine, 52(3-4), 239-246.


WHO (2018) 'Global action plan on physical activity 2018–2030: more active people for a healthier world'.


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Appendices
Appendix A. Youth-fit Teachers’ Guidance Manual

The Youth-fit Health Related Fitness Test Battery for Adolescents

Teachers’ Guidance Manual

Youth Fit

The Youth-fit Health Related Fitness Test Battery

What is health related physical fitness?

Physical fitness can be defined both in terms of performance and health. Performance or skill related fitness refers to those components of fitness that are necessary for optimal sports performance (Bouchard et al. 1994). Health related physical fitness (HRPF) can be defined simply as the ability to do everyday tasks without undue fatigue (Pate 1988). HRPF is made up of a number of key components, including: cardiorespiratory fitness, musculoskeletal fitness and body composition.

Physical fitness in youth is a powerful marker of health in later life (Ortega et al. 2008). Mounting evidence suggests that the precursors to cardiovascular disease have their origin in childhood and adolescence. According to the World Health Organisation (WHO 2010) measuring, assessing and monitoring physical fitness of children and adolescents should be considered a public health priority. Despite WHO recommendations, and unlike the US, Australia and many European countries, Ireland lacks a clearly specified strategy for monitoring HRPF in youth.

Youth-fit test battery development

The Youth-fit fitness test battery (FTB) aims to provide a set of valid, reliable and safe field-based fitness tests for the assessment of HRPF in adolescents. The FTB is developed specifically for use in physical education settings, with the teacher and student in mind. This low cost, time-efficient and evidenced based test battery can be easily administered to a large group of students during a PE lesson.

Physical Education teachers oversee the administration of all tests which are performed by students using the standardised protocols outlined in this manual. Results can be uploading to the Youth-fit database where teachers can monitor students’ scores and generate individual reports to share with students and their parents. It is important to note that the results of these test measures should never be publicly displayed, used to grade students’ performance or to evaluate the success of a physical education program. In addition, HRPF tests should not be included in isolation as a standalone part of the PE curriculum. An information sheet detailing uses and misuse of fitness tests is provided on page 56.

Youth-fit guiding principles

The Youth-fit FTB has three guiding principles; ‘Building Awareness’, ‘Developing Understanding’, and ‘Generating Action’ (Figure 1).

Awareness: Build students awareness of the importance of HRPF.

Understanding: Enhance students understanding of HRPF.
**Action:** Using the monitoring software and health referenced standards, highlight areas in need of improvement and set goals in order to meet these targets.

Building on the guiding principles, students can complete the ‘Youth-fit Student Profile’ provided on page 50 of this manual. The Youth-fit profile allows students to identify their health zone for each measure, reflect on their scores and set personal targets. It also directly aligns with curricular requirements at both junior and senior cycle physical education, as identified on page 4.

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**Health Related Physical Fitness** is one of the 6 instructional models that make up the SCPE syllabus. This model based syllabus encourages recording, monitoring and evaluating health related physical fitness. The Senior Cycle Physical Education syllabus is available at the following link: [click here](#).

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**Youth-fit test battery design**

The Youth-fit test battery is made up of two units; a high priority unit and an optional unit. There are 10 HRPF tests in all, 5 in each unit. All participants should aim to complete the ‘High Priority Unit’. Although it is recommended to complete the full test battery, it is up to the teacher whether or not they implement the optional unit. In addition to the administration guidelines provided in this manual, a workshop on conducting valid and reliable field based HRPF tests is available to participating schools.

**High priority unit**

The high priority unit contains 5 tests with proven validity, reliability and safety for administration in school settings. Each test measures a specific component of HRPF.

![High Priority Unit](image)

**Optional unit**

The optional unit comprises of five additional tests.
Fig. 1: Optional Unit.

Administering the Youth-fit FTB

Safety considerations

Maximising student safety should be the primary objective when conducting the tests. While the Youth-fit test battery involves measures that would be commonly used in a physical education context, we still recommend that all students complete the Physical Activity Readiness Questionnaire (PAR-Q) and have it signed by a parent or guardian prior to completing the test battery. If significant health issues are raised in the PAR-Q, the student should not take part. Knowledge of the current and former health status of each student is important in order to ensure safe testing. It is important to be alert to subjective symptoms such as skin pallor and dizziness. The tests should be immediately interrupted if there is any sign of a problem or risk. Teachers should implement their PE Department’s response protocols in the event of an incident. Students should perform some light jogging and stretching prior to commencing the test battery.

Catering for all abilities

HRPF is important for students of all abilities. Increasingly, students with a disability are completing their education in mainstream schools. Although specific criteria referenced-based standards for students with a disability are not provided in this manual, most of the tests included are suitable for students of all abilities. Modified tests are available for students who are unable to complete certain tests. For a student who is unable to participate in any of the tests due to a disability, the Physical Education and Sport Science Department at the University of Limerick is offering an individual assessment of health related fitness in the Department’s physiology lab. For teachers working with large groups of students with a disability, we recommend consulting the ‘Breaksport Physical Fitness Test Manual’ available here.

Equipment set up

- Weighing scales
- Height measure
- Sit & reach box
- Automated Blood Pressure monitor
- Hand-grip dynamometer
- Long Jump Mat/Measuring tape
- Exercise mats (x2)
- Floor markers/cones (x4)
- Sponges/Bean bags x3
- 20m measuring tape

Fig. 4: Measuring equipment and resources checklist.

Standardisation

Physical fitness can be objectively and accurately measured in lab settings. However, such tests are not practical for use in school settings. Field-based tests are easy to administer, involve minimal equipment and a larger number of participants can be evaluated at once. However, field-based tests are more prone to error. The following test administration guidelines are provided in an effort to minimise the risk of error and maximise the validity of the tests and the reproducibility of test results. As the FTB coordinator, you should familiarise yourself with all test protocols and sequencing recommendations.
Recommended sequence of testing

**Phase One: 20m Shuttle Run Test and equipment familiarisation**

*Estimated Time Requirement:* 50 – 60 minutes.

The 20m Shuttle Run Test (20m SRT), also known as the PACER or beep test, is a maximal aerobic endurance test. Therefore, it should be completed on a separate day to the remainder of the test battery. To enhance the accuracy of the test, divide your class group into pairs (one recorder and one participant). Students switch roles when all students from the first group have completed the test. The 20m SRT protocol is outlined in the next section of this manual. The test should take about 15 minutes to set up and administer per group. The remainder of this class period can be used to familiarise students with the FT3 equipment in advance of phase two, which will be completed during the next PE class period.

**Fig. 5: Phase One: Sports hall layout. *Indicates high priority test.**

**Phase Two: Test battery administration day**

*Estimated Time Requirement:* 50 – 60 minutes.

Administer the tests using a circuit style format (Fig. 6). Divide students into groups of 3-6 per station. Students should complete the FT3 in groups of 3 (1 participant; 1 assistant; 1 recorder). Students rotate in a clockwise direction between stations 1 and 5. Students should spend approximately 8 to 10 minutes at each station. Recovery zones (chairs/benches) should be present at each station to facilitate rest time between each test.

**Fig. 6: Phase Two: Sports hall layout. *Indicates high priority test.*  
- Student Assistants.

**Student Assistants**

To enhance the reliability of the test measures, it is strongly encouraged to use senior cycle students (between 5 and 8) to assist with the delivery of the test battery. Each test measure, with the exception of body mass and height for sensitivity reasons, should have a student assistant to guide the participants. Student assistants should receive training on how to administer the test. There is a guidance manual available in the Youth fit resource pack designed specifically for student assistants. Their role is to demonstrate the correct technique and encourage maximum effort where appropriate. Student assistants will not record any results.

**Instructions to participants**

All participants should abstain from exercise in the 24 hours preceding test day. All participants should wear comfortable loose clothing and sports shoes. A notable and constant level of encouragement from the teacher and observers/recorders is recommended to ensure maximum performance from participants. Teachers should aim to distribute their attention equally to all participants. Students should keep hydrated by drinking water during both phases of testing, particularly following the 20m SRT.

**Analysing individual results**

When analysing individual results, the use of criterion-referenced standards as opposed to norm-referenced standards is recommended. When a student has two or more sets of results, self-
Referenced assessment is strongly recommended. Self-reference assessment allows for personal goal setting and facilitates monitoring progress over time. Criterion referenced standards are designed to measure student performance against a fixed set of predetermined criteria. The use of health-related criteria helps to minimize comparisons between participants (norm-referenced) and to emphasize personal fitness for health rather than goals based on performance. Criterion referenced standards for all tests are provided in the Youth Fit Health Zones section of this manual.

Strategies that promote fitness tests as enjoyable

Teachers are encouraged to adopt the following strategies that promote fitness tests as enjoyable and challenging.

- All tests should be taught and practiced prior to testing day.
- A multi-station circuit format is recommended (Fig. 5).
- Utilise the services of volunteers; e.g. senior student assistants.
- Perform the test battery during PE class time.
- Display the test protocols on the sports hall wall.
- Provide students with feedback and encourage them to set personal fitness goals.
- Never announce or publicly display all students’ results.
- Challenge students on their understanding of the components of HRP.
- Use the web-based software to track results and print reports for students and their parents.
- Complete the fitness test battery on two occasions per year.
- Students should always be encouraged to improve on their own performance (self-referenced), and avoid peer comparisons.
- Display individual best scores per year group for appropriate tests to motivate athletically talented students.
Youth-fit Test Protocols

Cardiorespiratory endurance (Aerobic capacity)

Cardiorespiratory Endurance (CRE) or aerobic capacity is defined as the ability to perform exercise at moderate to high intensities for extended periods of time. CRE is considered perhaps the most important component of HRPP. Acceptable levels of CRE are associated with reduced risk of high blood pressure, coronary heart disease, obesity, diabetes and other metabolic disorders. Many terms are used interchangeably to describe CRE including, cardiovascular endurance, aerobic endurance and aerobic capacity among others. A lab based measure of maximal oxygen uptake is considered to be the best measure of CRE. CRE measures are usually expressed relative to body mass (i.e. millilitres of O2 consumed per kg of body mass or ml.kg-1.min-1). In this test battery, the 20 metre Shuttle Run Test (20m SRT) is recommended to calculate CRE. This test involves continuous running between two lines 20m apart in time to record beeps. A space of at least 23m is required to complete the test. If a student is unable to partake in the 20m SRT or your school is unable to facilitate this test due to space constraints, a timed distance run or walk test (e.g. one mile run/walk) can be used as an alternative test of CRE.

20m shuttle run test

Purpose: To assess cardiorespiratory endurance.

Equipment

- Tape measure (20m)
- 25m flat, non-slippery surface.
- Markers or cones
- Youth-fit CD and a CD-player.
- Results sheet

Set up:

- Measure the 20m area and mark it out with cones at each end.
- Divide the class in to pairs; one performer and one observer who will then switch roles. Ensure recorder has their partners 20m SRT record sheet.
- Place CD in CD player and start at track 1 (w/music) or track 2 (without music).
- Warm-up: consist of 5 minutes of moderate intensity aerobic activity (light jogging) followed by dynamic stretches upper and lower body.
- Cool-down will consist of 5 minutes of moderate intensity aerobic activity (light jogging) followed by some light stretching.

Instructions to participant:

1. The test commences with a 5 second countdown to the start.
2. Following this, single beeps will sound at regular intervals.
3. Try to reach the opposite end to the start before the next beep is heard.

4. If you get there before the bleep, wait until the bleep is heard before running back to the opposite end. This is important in the first level, as the speed is very slow.
5. After each level, the time between beeps will decrease so you need to run faster.
6. Each level lasts approximately one minute; changing levels is marked by a triple bleep and from instruction on the tape.
7. Race one foot on the line at the end of each shuttle run.
8. Give your maximum effort.

Procedure for withdrawing students:

I. If participants are not complying with the instructions, they should be given two warnings before being withdrawn from the test.
II. Examples include not touching the line at the end of each shuttle, or starting each shuttle before the bleep sounds.

I. Note: Students complete the test in pairs; one observer and one participant. If the observer sees that their partner has missed the line, they should raise their hand.

IV. The test is completed the next time (second time) he or she fails to reach the line before the bleep.

V. Record the level and shuttle number e.g.: level 8 shuttle 7

Precautions:

- In order for the test results to be accurate and reproducible, it is essential that the test protocol is strictly adhered to.
- This includes exact measurements of the 20-meter distance, as well as standardisation of the running surface, pre-test preparations and environmental conditions.
- The 20m SRT requires maximal effort if the test result is to be valid. Individuals with any injury or illness are advised not to take the test.
- Since the test starts very slowly, there is a gentle warm-up as the test progresses. However, it is advisable to have some very light jogging and dynamic stretching before starting.

The following equation can be used to estimate Aerobic Capacity (VO2 Max) from the 20m SRT score:

\[
\text{VO2 max (ml.kg\textsuperscript{-1.min\textsuperscript{-1}})} = 31.025 + 3.238X - 3.248A + 0.1536AX
\]

X = maximum shuttle run speed (km.hr\textsuperscript{-1}) (Formula = B + 0.5* last level completed
A = age (year)

(Leger et al. 1988)

*Note: the online system will automatically calculate aerobic capacity.
Body composition

Body composition refers to the division of total bodyweight (mass) into components; most commonly fat mass and fat-free mass. Body composition is an important health-related indicator because high levels of body fatness are associated with increased risk of coronary heart disease, stroke, and diabetes. Body Mass Index or BMI has been selected to assess body composition for this HRPF test battery. BMI is an indicator of weight for height. Higher BMI is associated with a worse cardiovascular profile. While BMI may not be the most accurate measurement of body composition among athletic populations with a muscular build, it is the most suitable for use among adolescents in school settings (IOM 2012). It is calculated by dividing total body mass (weight) in kilograms by one’s height squared (kg/m²).

Height:

Purpose: To record body height for BMI calculation.

Equipment:
- Standard collapsible portable stadiometer
- Results sheet

Set-up:
- Construct stadiometer following instructions
- Ensure base is on a hard and level surface.

Instructions to participant:
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
2. Remove shoes.
3. If hairstyle affects participant’s height, ask them to adjust it for the test.
4. Stand with heels and toes together on the base.
5. Arms loosely by their side.
6. Back straight against the vertical measuring rod.
7. Look straight ahead.
8. Take a deep breath, exhale, and stand as straight as possible without heels lifting off the ground.
9. Complete this measurement twice. If there is a difference of over 0.5 cm, take a third measurement.

Record in metres to the nearest cm e.g. 1.65m

Note: These can be difficult instructions for students to follow. Make sure the head is not tilted or the shoulders elevated, breathe normally and check posture before measuring.

Body Mass Index (BMI)

Height and body mass recordings are used to calculate Body Mass Index (BMI). BMI measurements help classify the body mass of an individual as underweight, healthy, overweight or obese. The online software automatically calculates BMI, however, students are also encouraged to calculate their BMI.

Sample calculation:

An individual has a height of 1.65m and body mass of 55.5kg.

$$\text{BMI} = \frac{\text{Mass (kg)}}{\text{Height (m)}^2}$$

$$e.g. \frac{55.5 \text{kg}}{1.65^2 \text{m}^2} = 20.39 \text{ (BMI)}$$
Flexibility

Flexibility is defined as the range of motion of muscle and connective tissues at a joint or group of joints. In contrast to other fitness components, flexibility is highly specific to each of the joints of the body. Consequently, linking it to future health outcomes is difficult and so the back-saver sit and reach flexibility test is an optional component of this test battery. However, maintaining adequate joint flexibility is important to functional health and it is important to remind students that flexibility and range of motion will be important as they get older. The back-saver sit and reach is very similar to the traditional sit and reach except that the measurement is performed on one side at a time.

Back-saver sit and reach test

**Purpose:** To measure the flexibility of the lower back and hamstrings.

**Equipment:**
- Sit and Reach Box
- Ruler
- Results Sheet

**Set up:**
- Position the Sit and Reach box against a wall.
- Ensure it is flat.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder.
2. Switch roles after each participant has completed 3 tests.
3. Sit on the floor with legs stretched out straight.
4. Remove shoes.
5. Extend one leg fully placing foot flat against the box.
6. The other knee is bent with sole of the foot flat on the floor in line with the knee of the extended leg.
7. With the palms bring downwards, and his arms on top of each other or side by side, the subject reaches forward along the measuring line as far as possible.
8. Ensure that the hands remain at the same level, not one reaching further forward than the other.
9. Hold the position at full extension for 2/3 seconds, avoid jerking forwards.
10. If hands are staggered, measure from the fingertip of the hand closest to the start line.
11. Switch legs & complete 2 measures of both sides.
12. If there is a difference of over 3cm on the same leg, take a third measurement.

Record your highest score from the left and right to the nearest centimetre e.g. 14cm (left) 15 cm (right).

Musculoskeletal fitness

Musculoskeletal fitness is a multidimensional component comprising of muscle strength, muscle endurance, and flexibility. These three subcategories have been combined into one broad fitness category because the primary objective is determining the functional health status of the musculoskeletal system. Musculoskeletal fitness is inversely associated with established and emerging cardiovascular disease risk factors, back pain and with bone mineral content and density. Musculoskeletal fitness improvements from childhood to adolescence have significant health benefits. There are two compulsory tests of musculoskeletal fitness (standing long jump and handgrip strength) and two optional tests (90° push-up and plank hold).

Muscular Strength

Standing long jump (lower body muscular strength and power)

**Purpose:** To measure lower body muscular strength and power.

**Equipment:**
- Non-slippery hard surface
- Standing long jump mat/ tape measure (5m) and adhesive tape
- Cores
- Results Sheet

**Set up:**
- Place two cones at the starting position.
- If a long jump mat is unavailable, use a tape measure, mark distances of 0.5m on the full floor up to 3m.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant completes 3/4 trials.
2. Stand with feet shoulder width apart and toes just behind the line.
3. Bend your knees bringing arms in front, parallel to the ground.
4. Swing both arms back, push off vigorously and jump as far as possible forward.
5. Land with feet together (no stagger), bending knees to absorb impact.
6. Hands can't touch the ground on landing, feet can't move/ slide.
7. Mark the position at the back of the heel where the participant lands. If feet are staggered on landing, measure from the heel closest to the start line.
8. Perform a 2nd and 3rd jump repeating the same procedure.
9. Measure the distance of the longest jump to the nearest centimetre.

Record to 2 decimal places in metres e.g. Jump = 140cm → Score = 1.40m

Handgrip strength (upper body muscular strength)
Flexibility

Flexibility is defined as the range of motion of muscle and connective tissues at a joint or group of joints. In contrast to other fitness components, flexibility is highly specific to each of the joints of the body. Consequently, linking it to future health outcomes is difficult and so the back-saver sit and reach flexibility test is an optional component of this test battery. However, maintaining adequate joint flexibility is important to functional health and it is important to remind students that flexibility and range of motion will be important as they get older. The back-saver sit and reach is very similar to the traditional sit and reach except that the measurement is performed on one side at a time.

Back-saver sit and reach test

**Purpose:** To measure the flexibility of the lower back and hamstrings.

**Equipment:**
- Sit and Reach Box
- Ruler
- Results Sheet

**Set up:**
- Position the Sit and Reach box against a wall.
- Ensure it is flat.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder.
2. Switch roles after each participant has completed 3 tests.
3. Sit on the floor with legs stretched out straight.
4. Remove shoes.
5. Extend one leg fully placing foot flat against the box.
6. The other knee is bent with sole of the foot flat on the floor in line with the knee of the extended leg.
7. With the palms facing downwards, and the hands on top of each other or side by side, the subject reaches forward along the measuring line as far as possible.
8. Ensure that the hands remain at the same level, not one reaching further forward than the other.
9. Hold the position at full extension for 3/4 seconds, avoid jerking forwards.
10. If hands are staggered, measure from the fingertip of the hand closest to the start line.
11. Switch legs & complete 2 measures of both sides.
12. If there is a difference of over 3cm on the same leg, take a third measurement.

Record your highest score from the left and right to the nearest centimetre e.g. 14cm (left) 15 cm (right).

Musculoskeletal fitness

Musculoskeletal fitness is a multidimensional component comprising of muscle strength, muscle endurance, and flexibility. These three sub categories have been combined into one broad fitness category because the primary objective is determining the functional health status of the musculoskeletal system. Musculoskeletal fitness is inversely associated with established and emerging cardiovascular disease risk factors, back pain and with bone mineral content and density. Musculoskeletal fitness improvements from childhood to adolescence have significant health benefits.

There are two compulsory tests of musculoskeletal fitness (standing long jump and handgrip strength) and two optional tests (90° push-up and plank hold).

Muscular Strength

**Standing long jump (lower body muscular strength and power)**

**Purpose:** To measure lower body muscular strength and power.

**Equipment:**
- Non-slippery hard surface
- Standing long jump mat/ tape measure (5m) and adhesive tape
- Cones
- Results sheet

**Set up:**
- Place two cones at the starting position.
- If a long jump mat is unavailable, use a tape measure, mark distances of 0.5m on the half floor up to 3m.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant completes 3/4 trials.
2. Stand with feet shoulder width apart and toes just behind the line.
3. Bend your knees bringing arms in front, parallel to the ground.
4. Swing both arms back, push off vigorously and jump as far as possible forward.
5. Land with feet together (no stagger), bending knees to absorb impact.
6. Hands can’t touch the ground on landing, feet can’t move/slide.
7. Mark the distance at the BACK OF THE HEEL where the participant lands. If feet are staggered on landing, measure from the heel closest to the start line.
8. Perform a 2nd and 3rd jump repeating the same procedure.
9. Measure the distance of the longest jump to the nearest centimetre.

Record to 2 decimal places in metres e.g. Jump = 140cm ➔ Score = 1.40m

Handgrip strength (upper body muscular strength)
**Purpose:** To measure the isometric strength of the forearm.

**Equipment:**
- Hand dynamometer with adjustable grip.
- Optimal grip span ruler and table.

**Set up:**
- Use the grip span sheet to calculate the optimal grip span for the participant.
- Ensure the dynamometer digital scale is reading 0.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
2. Measure grip span from the 1st to the 5th digits using a ruler.
3. Note the optimal size from the scale on the table provided and adjust accordingly.
4. Press the ‘On’ button and take the dynamometer with one hand.
5. Elbow/arm fully extended, avoiding contact with any other body part.
6. Squeeze forcefully and continually for 2/3 seconds.
7. Perform twice per hand.
8. Record highest score from each hand.

Record in kilograms to nearest 0.1kg e.g. 25.2kg

**Alternative = Adapted 90° push-up**

As above, only knees rest on the ground (less body mass to support). Ensure knee, hip and shoulder alignment is maintained throughout movement. Only use the adapted version if the participant is unable to complete 1 repetition of the full version.

**Muscular Endurance**

**90° push-up (upper body strength & endurance)**

**Purpose:** To measure upper body muscular strength and endurance by completing as many 90° push-up repetitions as possible to a set cadence.

**Equipment:**
- Audiotape with recorded cadence (x1 repetition every 3 seconds)
- Non slip surface/mat
- Results sheet

**Set up:**
- Position the cadence recorder in close proximity to the participant.
- Ensure participant understands the correct depth for a 90° repetition.

**Plank hold (torso muscular endurance)**

**Purpose:** To measure isometric muscular endurance of the torso.

**Equipment:**
- Stopwatch
- Non slip surface/Mat
- Results sheet

**Set up:**
- Review the test protocol and technique with each participant.
- Ensure body is aligned correctly.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
2. Maintain a prone position with forearms rested on the floor/mat.
3. Kneel on to toes, maintaining alignment of the knees, hips and shoulders.
4. The timer starts once the plank position is assumed by the participant.
5. Hold this position for as long as possible.
6. The time stops if the participant fails to maintain correct alignment or if excessive shaking occurs.
7. The test ends when a break in form occurs or 3 minutes have elapsed.

**Performance related fitness**

Physical fitness can be defined in terms of both performance and health. Performance or skill related fitness refers to those components of fitness that are necessary for optimal sports performance. The components of performance related fitness include: agility, balance, coordination, power, reaction time and speed.

**4x10m shuttle run**

**Purpose:** To measure speed of movement, change of direction and coordination.

**Equipment:**
- Clean, non-slippery floor
- Stopwatch
- Tape measure
- Three sponges/bean-bags of different colours and four cones.

**Set up:**
- Mark two lines 10 meters apart using marking tape or cones.
- At the start line there is one sponge (B) and on the opposite line there are two sponges (A, C).
- When the assistant calls ‘go’, the student (without sponge) runs as fast as possible to the other line, collects sponge A and returns to the starting line with the sponge (A).
- Exchange sponge A for sponge B on return to the starting line. Then run as fast as possible to the opposite line and change the sponge B for sponge C. The recorder stops the timer once the participant runs back through the starting line.

**Instructions to participant:**
1. Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
2. This test should be performed at maximum speed.
3. Get ready with both feet behind the start line.
4. When the start is given, run as fast as possible to the other line and return to the starting line with the sponge A.
5. Exchange sponge A for sponge B and go back running as fast as possible to the opposite line. Exchange sponge B for C.
6. Finally, run back to the starting line as fast as possible. Perform the test twice and record the highest score to one decimal place e.g. 12.5 seconds.

**Click here for a video demonstration of the 4x10m Shuttle Run Test**

*Note: If a participant has difficulty handling the sponges/bean bags, please measure from each time they touch their hand on the opposite line.*
Cardiovascular health

Blood pressure

Blood pressure (BP) is the force exerted by the blood on the wall of a blood vessel (arteries) as the heart pumps (contracts) and relaxes. Systolic blood pressure (higher number) is the degree of force when the heart is pumping (contracting). Diastolic blood pressure (lower number) is the degree of force when the heart is relaxed. If this pressure is too high it puts a strain on the arteries and your heart, which makes it more likely that you will suffer a heart attack, a stroke or other cardiovascular related issues. In the event of an abnormal BP recording, follow the protocol provided at the end of this section. It is important to stress that the goal of this test is strictly educational. A teacher or student should never diagnose a student with high or low BP. For the most accurate BP recordings, the measure should be taken at least three times throughout the day following long periods of rest.

Purpose: To measure arterial blood pressure.

Equipment:

- Automated blood pressure monitor
- Table and chair
- Benches

Set-up:

- BP monitor & table
- Chair
- Benches for students to rest between measures

Pre-test set up:

a) Sit down with back against chair and with feet flat on the floor.
b) Relax and breathe normally for a 3-4 minutes.
c) Expose your upper left arm, don’t clench your fist.
d) The recorder should place the cuff on the left upper arm with the tube facing out. Ensure the participant is comfortable and that there is no clothing interfering with the cuff.
e) The participants forearm should be supported on a table at elbow height, with the arm in a horizontal position at heart level.
f) The cuff shouldn’t be too tight before starting the test.
g) When the participant indicates they are happy to proceed, press the start button on the automated recorder, the cuff will begin to get tighter.

Instructions to participant:

1. Place the cuff on the left upper arm with the tube facing out.
2. Locate the pulse of the brachial artery at the inner side of the upper arm, approximately 1 inch above the bend in the elbow.
3. The participants should be supported on a table at elbow height with the arm in a horizontal position at heart level.
4. Turn the monitor on and the cuff will begin to inflate.
5. Minor discomfort may be experienced as the cuff tightens. After a period of 5 to 10 seconds, the cuff will begin to deflate.
6. The systolic and diastolic blood pressures will be displayed on the screen.
7. Record the result on the data collection sheet in mmHg.
8. A 2-3 minute rest period should be given between measurements.

Protocol for abnormal recordings:

I. Normal systolic blood pressure in teenagers (15-17) varies between 80 and 110 mmHg and diastolic pressure ranges from 50 and 80 mmHg.

II. Ensure two accurate recordings using the standardised protocol have been taken.

III. The teacher will arrange an appropriate time to oversee another recording at least two days after the original recording with both the recorder and participant.

IV. If both recordings are significantly out of range, the teacher will inform either the school nurse or students tutor who can contact the parents of the student and encourage them to arrange a visit to their local GP.

V. It is important to stress that the goal of this is strictly educational. A teacher or student should never diagnose a student with high or low BP.
**Youth-fit Health Zones (Criterion Reference values)**

<table>
<thead>
<tr>
<th>AGE</th>
<th>BODY MASS INDEX (BMI) (kg/m²)</th>
<th>VERY LEAN</th>
<th>HEALTHY ZONE</th>
<th>NEEDS IMPROVEMENT (HEALTH RISK)</th>
<th>NEEDS IMPROVEMENT</th>
<th>HEALTHY ZONE</th>
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<tr>
<td>12</td>
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<td>16.0-22.0</td>
<td>22.1-26.9</td>
<td>≥27.0</td>
<td>≥27.0</td>
<td>≥27.0</td>
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<tr>
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<td>≥28.7</td>
<td>≥28.7</td>
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<tr>
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<td>≥29.6</td>
<td>≥29.6</td>
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<tr>
<td>15</td>
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<td>≥30.0</td>
<td>≥30.0</td>
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<tr>
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<td>≥30.0</td>
<td>≥30.0</td>
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<td>≥30.0</td>
<td>≥30.0</td>
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<td>≥30.0</td>
<td>≥30.0</td>
<td>≥30.0</td>
</tr>
</tbody>
</table>

**Cardiorespiratory Fitness (20m Shuttle Run/PACER)**

<table>
<thead>
<tr>
<th>AGE</th>
<th>SHUTTLE #</th>
<th>AEROBIC CAPACITY (ml/kg/min)</th>
<th>NEEDS IMPROVEMENT (HEALTH RISK)</th>
<th>NEEDS IMPROVEMENT</th>
<th>HEALTHY ZONE</th>
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<td>16</td>
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<td>24-31</td>
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<tr>
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<td>18</td>
<td>≤27</td>
<td>≤35.2</td>
<td>25-31</td>
<td>≥30.0</td>
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</tr>
</tbody>
</table>

**Handgrip Strength (kg) Standing Long Jump (cm) Push Ups (reps) 4x40m Shuttle (seconds) Back-Saver Sit & Reach (cm) Plank Hold (seconds)**

<table>
<thead>
<tr>
<th>AGE</th>
<th>HEALTHY ZONE</th>
<th>HEALTHY ZONE</th>
<th>HEALTHY ZONE</th>
<th>HEALTHY ZONE</th>
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<td>15</td>
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<td>≥142</td>
<td>≥7</td>
<td>N/A</td>
<td>≥31</td>
</tr>
</tbody>
</table>

*Note all criterion referenced values, with the exception of the 4x10m shuttle run (Ortega et al., 2010) are generated from Fitnessgram (2010) and Netfit (2014).

*Note all criterion referenced values, with the exception of the 4x10m shuttle run (Ortega et al., 2010) are generated from Fitnessgram (2010) and Netfit (2014).
### Normative Reference Values

The following reference values are based on those provided in the ALHFA Fitness Test Battery (ALPHA 2009). These values are based on a randomized sample of students from 10 European cities. No national normative data is available.

#### Body composition:

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
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<td>23.3-26.4</td>
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<td>14 y</td>
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<td>17.7-19.7</td>
<td>20.0-24.6</td>
<td>24.7-27.5</td>
<td>≥ 27.6</td>
</tr>
<tr>
<td>15 y</td>
<td>≥ 18.1</td>
<td>18.3-19.6</td>
<td>20.6-24.6</td>
<td>24.7-27.5</td>
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<tr>
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#### Body mass index (Boys) (kg/m²)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 16.7</td>
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<td>14 y</td>
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<td>19.1-23.3</td>
<td>23.4-26.5</td>
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<tr>
<td>15 y</td>
<td>≤ 17.9</td>
<td>18.0-19.5</td>
<td>19.6-23.8</td>
<td>23.9-26.7</td>
<td>≥ 26.8</td>
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<tr>
<td>16 y</td>
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<td>18.1-19.6</td>
<td>19.7-23.7</td>
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<td>24.7-27.5</td>
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#### Body mass index (Girls) (kg/m²)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
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<td>15.0-19.0</td>
<td>19.3-23.2</td>
<td>23.3-26.4</td>
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<tr>
<td>14 y</td>
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<td>≥ 25.7</td>
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<tr>
<td>15 y</td>
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<td>18.2-19.4</td>
<td>19.5-23.5</td>
<td>23.1-25.6</td>
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<td>23.4-25.8</td>
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#### Cardiorespiratory endurance:

**20m shuttle run test (Boys)**

<table>
<thead>
<tr>
<th>Level &amp; Shuttle</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≥ 3.4</td>
<td>3.5-4.5</td>
<td>4.6-6.0</td>
<td>6.1-7.5</td>
<td>≥ 7.6</td>
</tr>
<tr>
<td>14 y</td>
<td>≥ 3.8</td>
<td>4.0-5.5</td>
<td>5.6-6.5</td>
<td>6.6-8.5</td>
<td>≥ 8.6</td>
</tr>
<tr>
<td>15 y</td>
<td>≥ 4.4</td>
<td>4.5-5.5</td>
<td>5.6-7.0</td>
<td>7.1-8.5</td>
<td>≥ 8.6</td>
</tr>
<tr>
<td>16 y</td>
<td>≥ 4.4</td>
<td>4.5-5.5</td>
<td>5.6-7.0</td>
<td>7.1-8.5</td>
<td>≥ 8.6</td>
</tr>
<tr>
<td>17 y</td>
<td>≥ 4.9</td>
<td>5.0-6.0</td>
<td>6.1-7.5</td>
<td>7.6-9.0</td>
<td>≥ 9.1</td>
</tr>
</tbody>
</table>

**20m shuttle run test (Girls)**

<table>
<thead>
<tr>
<th>Level &amp; Shuttle</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 2.0</td>
<td>2.1-2.8</td>
<td>3.0-3.8</td>
<td>4.0-4.9</td>
<td>≥ 5.0</td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 2.0</td>
<td>2.1-2.8</td>
<td>3.5-4.4</td>
<td>4.5-5.4</td>
<td>≥ 5.5</td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 2.0</td>
<td>2.1-2.8</td>
<td>3.5-4.4</td>
<td>4.5-5.4</td>
<td>≥ 5.5</td>
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<tr>
<td>16 y</td>
<td>≤ 2.0</td>
<td>2.1-2.8</td>
<td>3.5-4.4</td>
<td>4.5-5.4</td>
<td>≥ 5.5</td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 2.0</td>
<td>2.1-2.8</td>
<td>3.5-4.4</td>
<td>4.5-5.4</td>
<td>≥ 5.5</td>
</tr>
</tbody>
</table>


#### Muscular Strength:

**Hand grip strength (Boys)** (kg)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 21.4</td>
<td>21.5-24.7</td>
<td>24.8-27.8</td>
<td>27.9-31.8</td>
<td>≥ 31.9</td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 25.3</td>
<td>26.4-30.4</td>
<td>30.5-34.0</td>
<td>34.1-38.5</td>
<td>≥ 38.6</td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 23.3</td>
<td>23.4-26.7</td>
<td>26.8-30.7</td>
<td>29.8-34.3</td>
<td>≥ 34.0</td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 35.9</td>
<td>36.0-40.0</td>
<td>40.1-43.7</td>
<td>43.8-48.1</td>
<td>≥ 48.2</td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 39.9</td>
<td>40.0-43.5</td>
<td>43.6-46.7</td>
<td>46.8-50.6</td>
<td>≥ 50.7</td>
</tr>
</tbody>
</table>

**Hand grip strength (Girls)** (kg)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 15.9</td>
<td>20.0-23.5</td>
<td>23.6-28.8</td>
<td>28.4-32.7</td>
<td>≥ 32.7</td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 21.5</td>
<td>21.6-24.1</td>
<td>24.2-26.4</td>
<td>26.5-29.2</td>
<td>≥ 29.3</td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 22.5</td>
<td>22.6-25.1</td>
<td>25.2-27.4</td>
<td>27.5-30.3</td>
<td>≥ 30.4</td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 23.9</td>
<td>23.0-25.5</td>
<td>25.5-27.8</td>
<td>27.9-30.8</td>
<td>≥ 30.9</td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 24.5</td>
<td>24.0-26.4</td>
<td>26.5-28.9</td>
<td>28.9-32.1</td>
<td>≥ 32.2</td>
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</table>


**Standing long jump (Boys)** (cm)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 118</td>
<td>119-133</td>
<td>134-147</td>
<td>148-163</td>
<td>≥ 164</td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 121</td>
<td>122-137</td>
<td>138-151</td>
<td>152-167</td>
<td>≥ 168</td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 123</td>
<td>124-138</td>
<td>139-152</td>
<td>152-167</td>
<td>≥ 168</td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 126</td>
<td>127-141</td>
<td>142-154</td>
<td>155-169</td>
<td>≥ 170</td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 129</td>
<td>130-144</td>
<td>145-157</td>
<td>158-172</td>
<td>≥ 173</td>
</tr>
</tbody>
</table>

**Standing long jump (Girls)** (cm)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
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<td>13 y</td>
<td>≤ 95</td>
<td>95-103</td>
<td>104-111</td>
<td>114-121</td>
<td>≥ 121</td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 103</td>
<td>104-117</td>
<td>118-126</td>
<td>127-134</td>
<td>≥ 134</td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 105</td>
<td>106-119</td>
<td>120-128</td>
<td>129-137</td>
<td>≥ 137</td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 112</td>
<td>113-125</td>
<td>126-134</td>
<td>135-143</td>
<td>≥ 143</td>
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</tbody>
</table>

Normative Reference values
The following reference values are based on those provided in the ALPHA Fitness Test Battery (ALPHA 2009). These values are based on a random sample of students from 10 European cities. No national normative data is available.

Body composition:

<table>
<thead>
<tr>
<th>Body mass index (Boys) (kg/m²)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 16.7</td>
<td>16.8 - 18.0</td>
<td>18.1 - 22.2</td>
<td>22.3 - 25.7</td>
<td>≥ 25.8</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 17.5</td>
<td>17.6 - 19.0</td>
<td>19.1 - 23.3</td>
<td>23.4 - 26.5</td>
<td>≥ 26.6</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 17.9</td>
<td>18.0 - 19.5</td>
<td>19.6 - 23.8</td>
<td>23.9 - 26.7</td>
<td>≥ 26.8</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 18.0</td>
<td>18.1 - 19.6</td>
<td>19.7 - 23.7</td>
<td>23.8 - 26.4</td>
<td>≥ 26.5</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 19.0</td>
<td>19.1 - 20.5</td>
<td>20.6 - 24.6</td>
<td>24.7 - 27.5</td>
<td>≥ 27.6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body mass index (Girls) (kg/m²)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 17.5</td>
<td>17.6 - 19.0</td>
<td>19.1 - 23.2</td>
<td>23.4 - 26.4</td>
<td>≥ 26.5</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 17.6</td>
<td>17.7 - 18.9</td>
<td>19.0 - 22.8</td>
<td>22.9 - 25.6</td>
<td>≥ 25.7</td>
<td></td>
</tr>
<tr>
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<td>≤ 18.1</td>
<td>18.2 - 19.4</td>
<td>19.5 - 23.0</td>
<td>23.1 - 25.6</td>
<td>≥ 25.7</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 18.3</td>
<td>18.4 - 19.6</td>
<td>19.7 - 23.1</td>
<td>23.2 - 25.8</td>
<td>≥ 25.9</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 18.2</td>
<td>18.3 - 19.5</td>
<td>19.6 - 23.2</td>
<td>23.3 - 25.8</td>
<td>≥ 25.9</td>
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Cardiorespiratory endurance:

<table>
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<tr>
<th>20m shuttle run test (Boys) (Level &amp; Shuttle)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 3.4</td>
<td>3.5 - 4.5</td>
<td>4.6 - 6.0</td>
<td>6.1 - 7.5</td>
<td>≥ 7.6</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 3.8</td>
<td>4.0 - 5.5</td>
<td>5.6 - 6.5</td>
<td>6.6 - 8.5</td>
<td>≥ 8.6</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 4.4</td>
<td>4.5 - 5.5</td>
<td>5.6 - 7.0</td>
<td>7.1 - 8.5</td>
<td>≥ 8.6</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 4.4</td>
<td>4.5 - 5.5</td>
<td>5.6 - 7.0</td>
<td>7.1 - 8.5</td>
<td>≥ 8.6</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 4.9</td>
<td>5.0 - 6.0</td>
<td>6.1 - 7.5</td>
<td>7.6 - 9.0</td>
<td>≥ 9.1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>20m shuttle run test (Girls) (Level &amp; Shuttle)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 2.0</td>
<td>2.1 - 2.8</td>
<td>3.0 - 3.8</td>
<td>4.0 - 4.9</td>
<td>≤ 5.0</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 2.0</td>
<td>2.1 - 3.4</td>
<td>3.5 - 4.4</td>
<td>4.5 - 5.4</td>
<td>≥ 5.5</td>
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<tr>
<td>15 y</td>
<td>≤ 2.0</td>
<td>2.1 - 3.4</td>
<td>3.5 - 4.4</td>
<td>4.5 - 5.4</td>
<td>≥ 5.5</td>
<td></td>
</tr>
<tr>
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<td>≤ 2.0</td>
<td>2.1 - 3.4</td>
<td>3.5 - 4.4</td>
<td>4.5 - 5.4</td>
<td>≥ 5.5</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 2.0</td>
<td>2.1 - 3.4</td>
<td>3.5 - 4.4</td>
<td>4.5 - 5.4</td>
<td>≥ 5.5</td>
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</table>


Muscular Strength:

<table>
<thead>
<tr>
<th>Hand grip strength (Boys) (kg)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 21.4</td>
<td>21.5 - 25.7</td>
<td>24.8 - 27.8</td>
<td>27.9 - 31.8</td>
<td>≥ 31.9</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 25.3</td>
<td>25.4 - 30.4</td>
<td>29.5 - 34.0</td>
<td>34.1 - 38.5</td>
<td>≥ 38.6</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 21.2</td>
<td>21.3 - 26.7</td>
<td>24.8 - 30.7</td>
<td>30.8 - 36.8</td>
<td>≥ 36.4</td>
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</tr>
<tr>
<td>16 y</td>
<td>≤ 33.9</td>
<td>36.0 - 40.0</td>
<td>40.1 - 43.7</td>
<td>43.8 - 48.1</td>
<td>≥ 48.2</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 39.9</td>
<td>40.0 - 43.5</td>
<td>43.6 - 46.7</td>
<td>46.8 - 50.6</td>
<td>≥ 50.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hand grip strength (Girls) (kg)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 19.9</td>
<td>20.0 - 22.5</td>
<td>22.6 - 27.8</td>
<td>27.9 - 32.7</td>
<td>≥ 32.7</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 21.5</td>
<td>21.6 - 24.1</td>
<td>24.2 - 26.4</td>
<td>26.5 - 29.2</td>
<td>≥ 29.3</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 22.5</td>
<td>22.6 - 25.1</td>
<td>25.2 - 27.4</td>
<td>27.5 - 30.3</td>
<td>≥ 30.4</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 23.6</td>
<td>23.7 - 25.6</td>
<td>25.5 - 28.8</td>
<td>28.9 - 30.8</td>
<td>≥ 30.9</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 23.9</td>
<td>24.0 - 26.4</td>
<td>26.2 - 28.9</td>
<td>29.0 - 32.1</td>
<td>≥ 32.2</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Standing long jump (Boys) (cm)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 135</td>
<td>136 - 152</td>
<td>153 - 167</td>
<td>168 - 184</td>
<td>≥ 185</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 151</td>
<td>152 - 169</td>
<td>170 - 183</td>
<td>184 - 200</td>
<td>≥ 201</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 165</td>
<td>166 - 182</td>
<td>183 - 196</td>
<td>197 - 212</td>
<td>≥ 213</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 175</td>
<td>176 - 192</td>
<td>193 - 206</td>
<td>207 - 223</td>
<td>≥ 222</td>
<td></td>
</tr>
<tr>
<td>17 y</td>
<td>≤ 184</td>
<td>185 - 201</td>
<td>202 - 215</td>
<td>218 - 239</td>
<td>≥ 238</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standing long jump (Girls) (cm)</th>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≤ 118</td>
<td>119 - 133</td>
<td>134 - 147</td>
<td>148 - 163</td>
<td>≥ 164</td>
<td></td>
</tr>
<tr>
<td>14 y</td>
<td>≤ 121</td>
<td>122 - 137</td>
<td>138 - 151</td>
<td>152 - 167</td>
<td>≥ 168</td>
<td></td>
</tr>
<tr>
<td>15 y</td>
<td>≤ 123</td>
<td>124 - 138</td>
<td>139 - 151</td>
<td>152 - 167</td>
<td>≥ 168</td>
<td></td>
</tr>
<tr>
<td>16 y</td>
<td>≤ 126</td>
<td>127 - 141</td>
<td>142 - 154</td>
<td>155 - 169</td>
<td>≥ 179</td>
<td></td>
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<tr>
<td>17 y</td>
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<td>140 - 154</td>
<td>155 - 159</td>
<td>158 - 172</td>
<td>≥ 173</td>
<td></td>
</tr>
</tbody>
</table>

## Performance Related Fitness:

### 4x10m shuttle run test (Boys) (seconds)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≥ 13.0</td>
<td>12.9 - 12.3</td>
<td>12.2 - 11.8</td>
<td>11.7 - 11.2</td>
<td>≤ 11.1</td>
</tr>
<tr>
<td>14 y</td>
<td>≥ 12.5</td>
<td>12.5 - 11.9</td>
<td>11.8 - 11.4</td>
<td>11.3 - 10.9</td>
<td>≤ 10.8</td>
</tr>
<tr>
<td>15 y</td>
<td>≥ 12.1</td>
<td>12.0 - 11.5</td>
<td>11.4 - 11.0</td>
<td>10.9 - 10.5</td>
<td>≤ 10.4</td>
</tr>
<tr>
<td>16 y</td>
<td>≥ 11.8</td>
<td>11.7 - 11.1</td>
<td>11.0 - 10.7</td>
<td>10.6 - 10.2</td>
<td>≤ 10.1</td>
</tr>
<tr>
<td>17 y</td>
<td>≥ 11.5</td>
<td>11.6 - 11.1</td>
<td>11.0 - 10.7</td>
<td>10.6 - 10.2</td>
<td>≤ 10.1</td>
</tr>
</tbody>
</table>

### 4x10m shuttle run test (Girls) (seconds)

<table>
<thead>
<tr>
<th>Age</th>
<th>Very Low</th>
<th>Low</th>
<th>Average</th>
<th>High</th>
<th>Very High</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 y</td>
<td>≥ 13.9</td>
<td>13.8 - 13.1</td>
<td>13.0 - 12.5</td>
<td>12.4 - 11.9</td>
<td>≤ 11.8</td>
</tr>
<tr>
<td>14 y</td>
<td>≥ 13.8</td>
<td>13.7 - 13.0</td>
<td>12.9 - 12.4</td>
<td>12.3 - 11.8</td>
<td>≤ 11.7</td>
</tr>
<tr>
<td>15 y</td>
<td>≥ 13.7</td>
<td>13.6 - 13.0</td>
<td>12.9 - 11.4</td>
<td>12.3 - 11.8</td>
<td>≤ 11.7</td>
</tr>
<tr>
<td>16 y</td>
<td>≥ 13.5</td>
<td>13.5 - 12.9</td>
<td>13.0 - 12.3</td>
<td>12.2 - 11.7</td>
<td>≤ 11.6</td>
</tr>
<tr>
<td>17 y</td>
<td>≥ 13.5</td>
<td>13.4 - 12.9</td>
<td>12.8 - 12.3</td>
<td>12.3 - 11.8</td>
<td>≤ 11.7</td>
</tr>
</tbody>
</table>


## Cardiovascular Health:

### Blood Pressure Category

- **Low blood pressure (Hypotension)**: SBP ≤ 80 or DBP ≤ 50
- **Normal**: SBP 80 – 120 and DBP 50-80
- **Prehypertension**: SBP 120-139 or DBP 80-89
- **High blood pressure (Hypertension Stage 1)**: SBP 140-159 or DBP 90-99
- **High blood pressure (Hypertension Stage 2)**: SBP 160 or higher or DBP 100 or higher
- **High blood pressure crisis**: SBP 180 or higher or DBP 110 or higher

Source: American Heart Association (https://www.heart.org/).

## Extended Fitness Test Battery:

### Boys

#### Measure

- 90° Push-up (reps)
- Sit & Reach (cm)
- Plank hold (seconds)

#### Healthy Zone

- **13 y**: ≥ 12, ≥ 20, ≥ 20
- **14 y**: ≥ 14, ≥ 20, ≥ 20
- **15 y**: ≥ 16, ≥ 20, ≥ 20
- **16 y**: ≥ 18, ≥ 20, ≥ 20
- **17 y**: ≥ 18, ≥ 20, ≥ 20

*Criterion referenced values are not available for the plank hold.

### Girls

#### Measure

- 90° Push-up (reps)
- Back-Saver Sit & Reach (cm)
- Plank hold (seconds)

#### Healthy Zone

- **13 y**: ≥ 7, ≥ 25, ≥ 25
- **14 y**: ≥ 7, ≥ 25, ≥ 25
- **15 y**: ≥ 7, ≥ 30, ≥ 30
- **16 y**: ≥ 7, ≥ 30, ≥ 30
- **17 y**: ≥ 7, ≥ 30, ≥ 30

*Criterion referenced values are not available for the plank hold.

Appendix B. Youth-fit students results sheets

<table>
<thead>
<tr>
<th>Name:</th>
<th>Year Group:</th>
</tr>
</thead>
</table>

### Station One

<table>
<thead>
<tr>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3 (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>1 cm</td>
<td>1 cm</td>
</tr>
<tr>
<td>Body Mass/Weight</td>
<td>1 kg</td>
<td>1 kg</td>
</tr>
<tr>
<td>Back-Saver Sit &amp; Reach</td>
<td>1 cm</td>
<td>1 cm</td>
</tr>
</tbody>
</table>

### Station Two

<table>
<thead>
<tr>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Pressure</td>
<td>Systolic:</td>
</tr>
<tr>
<td>Standing Long Jump</td>
<td>1 m</td>
</tr>
<tr>
<td>Hand Grip Strength</td>
<td>1 kg</td>
</tr>
</tbody>
</table>

### Station Three

<table>
<thead>
<tr>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>90° Push-Up</td>
<td>Total Repetitions:</td>
<td>Time:</td>
</tr>
<tr>
<td>Plank Hold</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Station Four

<table>
<thead>
<tr>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x10m Shuttle Run</td>
<td>10m Shuttle Run (Separate Day)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>20m Shuttle Run Test <em>Separate Day</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Level:</td>
</tr>
</tbody>
</table>

### Station Five

<table>
<thead>
<tr>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>20m Shuttle Run Test <em>Separate Day</em></td>
<td></td>
</tr>
</tbody>
</table>
Calculating optimal grip span for handgrip strength test

Steps:
1. Stick a ruler to a flat surface (table) & place thumb at 0cm, spread your hand, keep it flat.
2. Record the distance from the thumb to the small finger.
3. Measure to the nearest 5cm and use the table below to calculate your optimal grip span.
4. Adjust the handgrip dynamometer to the correct level by twisting the knob.

### Grip Span FEMALEs

<table>
<thead>
<tr>
<th>Hand Size (cm)</th>
<th>10 cm</th>
<th>11 cm</th>
<th>12 cm</th>
<th>13 cm</th>
<th>14 cm</th>
<th>15 cm</th>
<th>16 cm</th>
<th>17 cm</th>
<th>18 cm</th>
<th>19 cm</th>
<th>20 cm</th>
<th>21 cm</th>
<th>22 cm</th>
<th>23 cm</th>
<th>24 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>4.5</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Grip Span MALES

<table>
<thead>
<tr>
<th>Hand Size (cm)</th>
<th>10 cm</th>
<th>11 cm</th>
<th>12 cm</th>
<th>13 cm</th>
<th>14 cm</th>
<th>15 cm</th>
<th>16 cm</th>
<th>17 cm</th>
<th>18 cm</th>
<th>19 cm</th>
<th>20 cm</th>
<th>21 cm</th>
<th>22 cm</th>
<th>23 cm</th>
<th>24 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>5.5</td>
<td>6</td>
<td>6.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adapted from Hult et al., 2005.

---

Youth-fit students results sheet: completed template

<table>
<thead>
<tr>
<th>Name: Student A</th>
<th>Year Group: 2nd Year</th>
</tr>
</thead>
</table>

### Station One

<table>
<thead>
<tr>
<th>Height</th>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>154</td>
<td>155</td>
<td>cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body Mass/Weight</th>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>65 kg</td>
<td>65 kg</td>
<td>kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Back-Saver Sit &amp; Reach</th>
<th>Measure 1 (Right)</th>
<th>Measure 2 (Right)</th>
<th>Measure 3 (Right)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm</td>
<td>14 cm</td>
<td>17 cm</td>
<td>17 cm</td>
</tr>
</tbody>
</table>

### Station Two

<table>
<thead>
<tr>
<th>Blood Pressure</th>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic:</td>
<td>110</td>
<td>106</td>
</tr>
<tr>
<td>Diastolic:</td>
<td>60</td>
<td>59</td>
</tr>
</tbody>
</table>

### Station Three

<table>
<thead>
<tr>
<th>Standing Long Jump</th>
<th>Measure 1</th>
<th>Measure 2</th>
<th>Measure 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>1 m 25 cm</td>
<td>1 m 30 cm</td>
<td>1 m 30 cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hand Grip Strength</th>
<th>Measure 1 (Right)</th>
<th>Measure 2 (Left)</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg</td>
<td>10 kg 1 g</td>
<td>15 kg 3 g</td>
</tr>
</tbody>
</table>

### Station Four

<table>
<thead>
<tr>
<th>90° Push-Up</th>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plank Hold</th>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20 seconds</td>
<td>20 seconds</td>
</tr>
</tbody>
</table>

### Station Five

<table>
<thead>
<tr>
<th>4x10m Shuttle Run</th>
<th>Measure 1</th>
<th>Measure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>13.5</td>
<td>13.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>20m Shuttle Run Test (Separate Day)</th>
<th>Level: 4</th>
<th>Shuttle: 3</th>
<th>Total Shuttles: 26</th>
</tr>
</thead>
</table>
Appendix C. Youth-fit software platform user guideline

Software user guidelines: CarePartner®

What is CarePartner®?
CarePartner is the web-based system teachers can use to input results generated from the Youth-fit test battery. CarePartner offers a secure, easy to use and interactive web-based platform to upload, record and monitor students health-related physical fitness measures. All data uploaded to CarePartner is stored on a server based at the University of Bath which is secured with state-of-the-art firewall protection.

Software infrastructure

Fig. 8 Youth-fit Software Infrastructure

CarePartner login
CarePartner is available at the following link: https://youthfit.uel.ac.uk. When you open CarePartner, you will see the screen below. To login, enter the username and password that have been provided to you, and click the 'Login' button. Confirm your selection by double clicking on your name. This will take you to the home screen. You will be asked to create a new password after logging in for the first time. Passwords should be alphanumeric and at least 7 characters long. Click here for a video tutorial on how to upload students’ results to the online platform.

Home screen orientation

1. Main Search – Click here to search all students in your school. Click the magnifying glass to open advanced search.
2. Work List – Click here to return to the home screen from any screen in CarePartner.
3. Registration – Click here to register a new student. If a student is missing, you can manually add them to the system here. Student’s details can be imported into the online system in bulk (i.e. full year group at once). Details of how to do this are provided in the next section.
4. User Information – Click on your username to see a drop-down list with your account details and to log out. You can also update your password here.
5. Plus (+) Icon – Click the ‘+’ icon next to ‘My List‘ to create a quick access tab to your school. Your designated school code will appear on the home screen once created and all students registered in your school will appear below. If a school code that you are not associated with appears, please contact the system administrator.

Uploading students to the web-based system

Note: You will need administrator access to complete a bulk import of all students in your school.

1. Open the excel file template document provided in the resource pack entitled ‘Bulk import of students’.
2. Contact your school secretary for a list of names and dates of birth.
3. Copy and paste the names in to cells under the correct headings.
4. Make sure you are including the information under the correct headings. Once created, select the ‘Save as’ drop down menu beside the save icon and save as a ‘csv’ comma delimited file.

When you have developed the csv file with all students details, follow the steps below:

1. Select the ‘Admin’ icon from the options on the top right of the screen.
2. Select ‘Students’ from the tab underneath.
3. Select ‘Import Students’ and drag and drop the file in to the text box as indicated.
1. **Student Name:** Select to view a student’s profile. You can update information and input results by clicking on the student’s name.

2. **Enrolment Start Date:** The date the student enrolled in the school. If registering a student manually, this cannot be a date in the future.

3. **Month of Birth:** All dates of birth will default to the 1st of each month as a data protection measure.

4. **City/Town:** The location of the school.

5. **Student ID:** This is the anonymised ID number that has been randomly assigned to each student. If manually enrolling a student, this field should be left blank and the system administrator will assign a code.

### Student’s Profile

- **Test Results:**
  - **Test 1:** [No Results]
  - **Test 2:** [No Results]
  - **Test 3:** [No Results]

### Personal Details

- **First Name:** [No Details]
- **Last Name:** [No Details]

### Current Enrolments

- **School 1:** [Enrolled]
- **School 2:** [Enrolled]

### Recent Activities

- **Date:** [No Activities]
- **Location:** [No Activities]

---

1. **Personal Details:** Update a student’s personal details (e.g., name, address, month of birth). Click the green ‘Update Student’ icon at the bottom screen to save changes. Only fields with a red asterisk (*) are required to be filled, all other fields are optional.

2. **Current Enrolments:** This will display the school in which the student is enrolled. All students, unless new or not included on the school list, should automatically link to your school when uploaded to the system using the bulk import function. If manually registering a student for the first time, you need to enrol them in your school. This can be done by selecting the ‘Start New Enrolment’ tab in ‘Current Enrolments’.

3. **Recent Activities:** Results from the Youth-fit fitness test battery can be entered by selecting this tab. The procedure for creating a results sheet and inputting results is outlined in the next section. When multiple test results have been saved, they will appear here.

### Uploading Students Results

**Step 1: Select a Student**

Select the student for whom you want to input results by scrolling to their name or using the main search icon. A summary of the student’s personal details, current enrolments and recent activities will appear.

**Step 2: Create a results sheet (starting a new activity)**

In a student’s individual profile, select the ‘Activities’ tab at the top and click the blue icon, ‘Start New Activity’. The screen below will appear. The system will default to the assessment tab (highlighted in blue). The ‘Activity record’ and ‘Contact record’ tabs should be ignored.
1. **Enrolment**: Select your school from the dropdown menu. You need to select the school in order to access the fitness test battery results page. If your school does not appear, or if a school you are not associated with appears, please contact the system administrator.

2. **Location**: Click the location tab and select the students’ year group from the dropdown menu.

3. **Form**: Select ‘Fitness Test Battery’ from the dropdown menu and click ‘Start New Activity’.

4. **Date & Time**: The date and time fields do NOT need to be adjusted.

*Note: You will not be able to start a new activity if there is an activity already open for the student. Closing an activity is explained in the next section.

### Step 3: Input results

Using the fitness test battery results sheets completed by your students in class, input the results to all relevant fields by clicking in the white space and typing the numeric value. Ensure that the correct measurement unit was used for the values you are inputting. Biologically plausible value limits have been applied to all fields. Results will automatically save once a field has been populated. Any fields for which no results have been recorded can be left blank. All results will save automatically.

### Step 4: Measurement details

Select the small icon with 3 lines beside the measurement name for an explanation of the measure and an example of the correct measurement unit.

### Step 5: View History

This allows you to view the student’s past results. When two or more results sheets have been completed, clicking the ‘view history’ tab will display all previous measurements.

### Step 6: Closing an activity

Selecting ‘Close Activity’ will permanently close the activity. No results can be added or edited once an activity has been closed. If some results require clarification from a student, the results sheet should be left open. All results will save automatically, even if not closed. However, two results sheets cannot be open for the same student at one time.

### Step 7: Printing Results

Select the print icon in the top right corner of the screen to print a summary report of the results. A new webpage displaying all the results will open.
5. **Moving on to the next student:** Once you have inputted all the results for one student, click the ‘Worklist’ icon at the top of the screen and repeat the same process for the next student.

**Ending your session**

Ensure that you log out when you are ready to end your session. Click your name on the top right of the home screen and select ‘log out’ from the dropdown menu.

**CarePartner video tutorial**

*Click here* for a video tutorial on how to use CarePartner or copy and paste the following link: [https://www.youtube.com/watch?v=EnMzkuIJfms](https://www.youtube.com/watch?v=EnMzkuIJfms).

**System administrator**

If you encounter any difficulties with the website, or notice any errors, please contact brendan.okieffe@uhi.ie.

**Sample student report**

<table>
<thead>
<tr>
<th>Student ID</th>
<th>Month of Birth</th>
<th>Gender</th>
<th>Status</th>
<th>Date of Activity</th>
<th>Fitness Test Battery</th>
<th>Body Composition</th>
<th>Body weight</th>
<th>Body mass index</th>
<th>BMI</th>
<th>Flexibility</th>
<th>Blood pressure</th>
<th>Muscular Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>10001</td>
<td>01-Mar-2021</td>
<td>Female</td>
<td>Student</td>
<td>06-Feb-2021</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Body composition**

- **Height:** Measure of standing height in metres. 
  - Instrument: Stadiometer. Read in metres correct to two decimal places e.g. 1.51m.
  - 1.51 metres

**Body weight**

- **Measure of total body weight:** Instrument: Scales. Read in kilograms to nearest 0.1kg e.g. 68.9kg.
  - 68.9 kg

**BMI**

BMI is an indicator of weight for height. Higher BMI is associated with a more cardiovascular profile. It is calculated by dividing total body weight in kilograms by one’s height squared in metres.

**Flexibility**

- **Sit & Reach:** Measure of flexibility of the lower back and hamstring muscle. 
  - Reach as far as possible keeping both feet pressed against the measure box and legs flat on the floor. Instrument: Sit & Reach box. Record to the second decimal e.g. 31.3 cm.

**Blood pressure**

- **Systolic blood pressure:** Systolic blood pressure (SBP) is the force exerted by the blood on the walls of a blood vessel (artery). 
  - Measure in mmHg: 115 mmHg

**Diastolic blood pressure:**

- Measure in mmHg: 70 mmHg

**Muscular Strength**

- **Standing broad jump (lower body):** 
  - Measure of power and explosive muscular strength. 
  - Record in metres correct to two decimal places e.g. 2.51m.
  - 2.51 metres

**Hand grip strength test (upper body):**

- Measure of grip strength. 
  - Use a dynamometer. 
  - Squat the dynamometer with maximum effort for 3 seconds. 
  - Record kilograms to nearest 0.1 kg e.g. 37.1 kg.
  - 37.1 kg
**Muscular Endurance**

The ability of a muscle or group of muscles to produce repeated contractions against a constant external load.

**Push Up (Upper Body)**

*Exercise of upper body muscular strength and endurance. Complete as many full push-ups possible in a set standard. Instrument - Digital push-up counter. Score = total number of completed push-ups. Example: 10 reps, 1 min.

**Peak Hold (Ardrominosis): Minutes**

Supporting body weight on arms and knees, maintain a stable body position for as long as possible. Instrument - Stopwatch, digital timer.

**Peak Hold (Ardrominosis): Seconds**

41.3 seconds

**Motor/Skill-Related Fitness**

Components of physical fitness that bear a relationship with performance in sport and work skills.

**400m Shuttle Run**

Measure change of direction and speed components of motor related fitness. Instrument - Stop watch, digital timer.

**Cardiorespiratory Fitness**

The ability to perform exercise at moderate to high intensity for extended periods.

**20m Shuttle Run Test (20 MST)**

Measures aerobic fitness. Instrument - Stopwatch, shuttle run is performed for 5 min with increases in pace at set intervals. Instrument - 20 MST CD book. Must record level A to Shutter 5, level B to Shutter 7, level C to Shutter 9, level D.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Level</th>
<th>Shuttle</th>
<th>Max speed (kmph)</th>
<th>Student age</th>
<th>VO2 max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push Up</td>
<td>Level</td>
<td>5 shelves</td>
<td>6.0</td>
<td>14 years</td>
<td>43.56</td>
</tr>
</tbody>
</table>

---

**Software User Guidelines: Atmolytics®**

**What is Atmolytics®?**

Atmolytics is a new technology that streamlines the integration of data from multiple sources and simplifies analysing data for both specialist and non-specialists end-users. When data is uploaded to the secured Carepartner server, it will automatically transfer, in anonymised form, to the Atmolytics server.

The Atmolytics platform allows you to analyze the data you have uploaded, compare your data to regional trends and generate graphic summary reports.

**Atmolytics Login**

The Atmolytics database is available at the following link: [https://atmolytics.youthfit.ie](https://atmolytics.youthfit.ie). When you open Atmolytics you will see the screen below. To login, enter the username and password that have been provided to you, and click the ‘Login’ button. Confirm your selection by double clicking on your name. This will take you to the home screen. You will be asked to create a new password after logging in for the first time. Passwords should be alphanumeric and at least 7 characters long. If you have difficulty logging in, or you have forgotten your username or password, either click on the link on screen or contact the system administrator. Click here for quick access to Atmolytics.
Key Terms

It is important that the user is familiar with the following key terms before using the system. Click here for an introduction to Atmalytics video tutorial or copy and paste the following link: https://www.youtube.com/watch?v=kptT-CNCG.

1. **Base cohort**: Is the total number of students with data uploaded to Carepartner which are available for analysis. Nobody can view, report on, or share any data belonging to any service user who is not included in their base cohort.

2. **Cohort**: A cohort is a subset of the base (overall) cohort. Cohorts are easy to create and allow for simple comparative analysis. Cohorts can be as broad (e.g., All students) or specific (e.g., all females from school F01 with BMI > 20) as you want. A cohort needs to be created before you can use an app to run an analysis.

Home screen orientation

1. **Home**: Selecting the home icon in the top left corner will return you to the home-screen from any window in Atmalytics.

2. **Cohort Discovery**: This allows you to create a new cohort (subsample of the total student population). You must click the blue ‘save’ icon in the top right corner to save any changes you make when creating a new cohort. How to create a cohort is explained in the next section.

3. **My Cohorts**: Allows you to view and organise the cohorts that you have created.

4. **Apps**: Select the Apps icon to start building a report. There are 4 Apps available (details on the next page).

5. **My reports**: View all the reports that you have created or that have been shared with you.

6. **Base cohort**: Displays the total number of students with data uploaded to Carepartner which are available for analysis. The figure in the white circle beside base cohort shows the percentage of the total base cohort that is available to you for analysis.

Creating a cohort

You will need to create some key cohorts before using the apps. Examples of key cohorts might include:

- All students in your school;
- All Females;
- All Males;
- All 1st year students.

The process for how to create a cohort is outlined below or click here for a video tutorial (2 minutes 45 seconds).

1. Select the ‘Cohort Discovery’ icon. From here you can set the criteria that will be used to select the individuals in your cohort. If you have already created a cohort, select the ‘create new’ blue icon.

2. **Name your cohort**: Click the text that says ‘Unnamed Cohort’ to assign a name to your cohort.

3. **Scope**: The screen will default to the ‘scope’ tab. Here you can select the students you wish to include in your cohort. The ‘At any school code’ icon will allow you to select all students, or select students from a specific school using the anonymised code system. Only the PE teachers...
in your school will have access to your school code. The coding system key is available from the system administrator.

4. Select ‘Apply Filters’ to create a more specific cohort.

- Dataset: There are two datasets. The ‘Fitness Test Battery’ dataset which lists all the measures that are part of the FTB. The ‘Registration Creepartner’ dataset lists the demographics (e.g. month of birth, gender).
- Create Filter: choose the specific question you want to filter (e.g. ‘Gender equals to Female’). Click the blue ‘include’ icon. The tracker on the right of the screen will show you how many students are in your filtered cohort.

5. The cohort you create is labelled UNSAVED. It is not saved until you explicitly choose to do so by clicking either the Save button or the Finish editing button, located at the top right of the screen. Give your cohort a name before closing (e.g. All Female).

6. My Cohorts: Once a cohort is saved, it will appear in ‘My Cohorts’ where it is available for analysis. Cohorts can be arranged in folders by selecting the folder icon, as displayed in the image below.

Contact the system administrator for a comprehensive ‘Cohort Discovery Guide’ for more information on using the various filters available to you.

Apps

Data can be analysed using the following 4 applications:

1. All the Answers: Generates graphic summaries (bar and pie charts) of how many students fall into the various health zone bands for each health related fitness test measure.

2. Identity Check: Generates easy to read tabular lists of measures for each student. Each row represents one student. This app also enables you to download data in .csv format for further analysis in Excel or dedicated statistical packages such as SPSS or SAS.

3. Data Export: This app also enables you to export data on selected cohorts in .csv format. Note that each row in this export represents a completed test. A student who has two tests completed will generate two rows of data.

4. Activity Counter: This app provides frequency counts of the number of occasions a Fitness Test Battery was undertaken.

Creating reports using Apps

Reports are created using a simple, 4 step process which begins once you select the App you wish to use:

- Who: Which students do you want to report on?
- What: What settings do you wish to use to produce your report?
- Where: Which schools do you want the report data to be drawn from?
- When: Do you want to report on data from a particular period of time?
  The ‘Who’, ‘Where’, and ‘When’ steps are the same for every App.

Generating a report (step by step guide)
The following is a step by step guide that details the process of generating a report using the ‘All the Answers’ app. Select the ‘All the Answers’ app icon from the Apps menu. Click here for a video tutorial on how to create a report.

- **Step 1 (Who):** Select the cohort you want to report on. Remember, you need to create your cohorts first! In this case, I have selected to compare an ‘All Female’ cohort with an ‘All Male’. Click the blue next icon on the bottom right of the screen.

- **Step 2 (What):** Select the dataset you want to report on (Fitness Test Battery). A list of tests will appear on the screen. You can select 4 tests to appear on the cover page of your report by ticking/un-ticking the ‘Cover Sheet’ column. Select the graph output format you want under the ‘Graph Type’ column. The ‘bands’ column have defaulted health zone values. Scroll down to ‘Base on’ and select ‘The most recent recorded answer’.

  *Note: Band values are averaged for males and females. See the ‘Reference Values’ section of this manual for the most accurate values. You can also set your own band values by clicking the ‘change’ icon or simply clone one of the reports already created to use the same values.*

- **Step 3 (Where):** You will skip this step for most reports as you will have already selected your cohorts in step one. Click the blue next icon in the bottom right corner. If you wish to select a specific school(s), click the ‘all school codes’ icon and select the school codes you want to include.

- **Step 3 (When):** This allows the user to compare results from a specified time period.

- **Step 5 (Finish):** Name your report and click ‘Save & Finish’. Your report will be available for analysis in the ‘My Reports’ section of the home screen.
Viewing a report

- Once a report has been created using one of the Apps, it will be available to view, print and share in the ‘My Reports’ section of the home screen, as displayed in the image above.
- Select the printer icon to generate a printable summary of the report you have created.
- Select the arrow icon to share the report with another service user. You will not be able to see other users’ data, and they won’t be able to see yours, unless you explicitly choose to share it and have the necessary user permissions to do so.

Sample Report Output

Ensure that you log out when you are ready to end your session. Click your initials in the top right of the home screen and select ‘Log out’ from the dropdown menu.

Atmolytics video tutorials

Video 1: Introduction to Atmolytics: https://www.youtube.com/watch?v=xpexT-CNClQ

Video 2: How to create graphic summaries (bar and pie charts) using ‘All the Answers’: https://www.youtube.com/watch?v=V7hs9Nj1dBQ

Video 3: How to download a summary of your students results on an excel (csv) spreadsheet using ‘Identity Check’: https://www.youtube.com/watch?v=nNCP1g3FeTQ

System administrator

If you encounter any difficulties with the website, or notice any errors, please contact brendan.okeeffe@ul.ie.

Ending your session
Appendix D. Test protocol displays

**Measure: Height**

**HRPF Component: Body Composition**

**Steps:**

1. **Remove shoes.** If hairstyle affects participant’s height, ask them to adjust it for the test.
2. Stand with feet flat on the base plate, arms by side.
3. Back straight against the vertical measuring rod and look straight ahead. Adjust the measure so that it rests on the participant’s head.
4. Take a deep breath and stand as straight as possible without heels lifting off the ground. Identify the Frankfort Plane.
5. Exhale, make sure the head is not tilted or the shoulders raised.
6. Take this recording twice. If different (>1cm), take a third recording.

*Record in metres to the nearest cm e.g. 165cm*

---

**Measure: Body Mass (Weight)**

**HRPF Component: Body Composition**

**Steps:**

1. Wear only light clothing & remove shoes.
2. Remove items such as keys and money from pockets.
3. Press the scales and wait for it to read 0.0kg.
4. Stand on the scales, with both feet fully on the platform, heels towards the back edge, and arms loosely by their side.
5. Remain as still as possible, looking straight ahead.
6. Step down from the scale.
7. Take this recording twice. If different (>0.5kg), take a third recording.

*Record in kilograms to nearest 100 grams e.g. 55kg .1kg*
Measure: Back-Saver Sit and Reach
HRPF Component: Flexibility

Steps:
Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.

1. **Remove shoes.** The soles of the feet are placed flat against the box with one leg **fully extended** & other knee is bent with sole of the foot flat against the floor in line with the extended knee.

2. The assistant should assist by **applying light pressure** above or below the knee to keep the legs flat.

3. Hands on top of each other or side by side, reach forward along the measuring line as far as possible.

4. Ensure that the hands remain at the same level, not one reaching further forward than the other.

5. **Hold the position at full extension for 2/3 seconds.**

6. Switch legs & complete 2 measures of both sides. If there is a difference of over 3cm on the same leg, take a third measurement.

*Record the highest score on each leg to the nearest cm e.g. 14cm*

---

Measure: Blood Pressure
Cardiovascular Health

Steps:
Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.

1. Before starting, **relax** and breathe normally for 2-3 minutes.

2. Sit with your back against the chair and feet flat on the floor.

3. Place your **left forearm** on the table. **Don’t clench** your fist.

4. The assistant should **place the cuff on the left upper arm**, with the tube facing out. Ensure the participant is comfortable.

5. The participant’s **arm should be supported on a table** at elbow height with the arm in a horizontal position as pictured.

6. The **cuff shouldn’t be too tight before starting the test.**

7. When the participant indicates they are happy to proceed, press the start button, the cuff will begin to get tighter. **Note:** The cuff will tighten for approx. 10 seconds.

8. Using the monitor, record both the **systolic** (higher number) and **diastolic** (lower number) figures that appear on the screen.

9. Two measures should be taken from the same arm. Allow 2-3 minutes rest between recordings.
Measure: Standing Long Jump
HRPF Component: Muscular Strength

Steps:
Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
1. Stand with feet shoulder width apart and toes just behind the line.
2. Bend your knees and swing both arms, push off vigorously and jump as far as possible (maximum effort).
3. Land with feet together (no stagger), bending knees on landing.
4. Hands can’t touch the ground on landing, feet can’t move/slide.
5. Note the distance from the BACK OF THE HEEL where the participant lands. Measure from the heel closest to the start line.
6. Perform 3 jumps and record your longest effort.

Measure: Handgrip Strength Test
HRPF Component: Muscular Strength

Steps:
Complete in groups of 3: one participant; one assistant; one recorder. Switch roles after each participant is finished.
1. Measure your hand span from the 1st to the 5th digits. See hand span sheet.
2. Note the optimal size from the scale on the table provided and adjust the grip to that height.
3. Take the dynamometer with one hand and turn it on.
4. Arm fully extended by your side.
5. Squeeze forcefully, as hard as you can for just 3 seconds.
6. Perform twice with both hands (switch sides after each hold).
7. Record the highest score on each hand.

Record in kilograms to nearest 0.1 kg e.g. 25.2kg
Measure: 90° Push-Up
HRPF Component: Muscular Strength/Endurance

Steps:
Complete in groups of 5: one participant; one assistant; one recorder. Switch roles after each participant is finished.
1. Lie facing down, hands flat, shoulder width apart and facing down.
2. The assistant observes each repetition and the recorder controls the recorded CD cadence and counts each rep.
3. Rise until arms fully extended, hands under shoulder. Check for ankle, hip shoulder alignment. (see red line below).
4. Lower the body until elbows bend to 90° or chest dips to assistants fist. Repeat as many times as possible.
5. Students stop once they cannot maintain pace with the pre-set cadence.

Record total repetitions e.g. 21 repetitions.

*Adapted 90° Push Up: As above, knees rest on the ground (Only complete adapted version if unable to do 1 rep of full version).

Measure: Plank Hold
HRPF Component: Muscular Strength/Endurance

Steps:
Complete in groups of 5: one participant; one assistant; one recorder. Switch roles after each participant is finished.
1. Lie facedown, rise on to toes and forearms.
2. Maintaining a straight line from the ankles to hips to shoulders.
3. The timer starts once the participant rises on to their forearms.
4. Hold this position for as long as possible. Make sure hips don’t drop too low or rise too high.
5. The time stops if the participant fails to keep correct alignment or if he/she shakes.
6. The test ends after 180 seconds (3 minutes). Record total time in minutes and seconds e.g. 45 seconds.

*Adapted Plank Hold: As above, knees rest on the ground (Only complete adapted version if unable to do 5 seconds or less of full version).
Measure: 4x10m Shuttle Run
Skill Related Fitness

Steps:

1. This test should be performed at maximum speed.
2. Get ready with both feet behind the start line.
3. The assistant should give the call, “Ready, Go”.
4. On “Go”, sprint as fast as possible to the opposite line, pick up sponge A and return to the starting line with the sponge A, crossing both lines with both feet.
5. Exchange sponge A for sponge B and sprint as fast as possible to the opposite line. Exchange sponge B for sponge C.
6. The clock stops once the participant crosses the ‘start’ line.
7. Perform twice. Record the fastest score.

Record to the nearest 0.1 second e.g. 11.9 seconds = 11.5
Appendix E. Health-related physical fitness monitoring practices in schools questionnaire
Participant Consent

Consent:
- I am currently teaching or have taught Physical Education.
- I have read and understood the participant information sheet.
- I understand what the project is about, and what the results will be used for.
- I understand that the results of this study may be published, but that my name or my school’s name will not be given to anyone in any written material developed.
- I know that I am choosing to take part in this study and that I can stop taking part in the study at any stage without giving any reason to the researchers.

This research study has received Ethical approval from the Education and Health Sciences Research Ethics Committee (2017_02_11_EHS). If you have any concerns about this study and wish to contact someone independent you may contact:
Chairman Education and Health Sciences Research Ethics Committee
EHS Faculty Office University of Limerick. Tel (061) 234101

* I agree with the above statements and consent to participate in the study:
  ○ Yes
  ○ No

Key Terms Explained

- Health Related Physical Fitness (HRPF): Physical fitness is defined as the ability of an individual to perform everyday tasks without excessive fatigue. Health Related Physical fitness (HRPF) is made up of five components, namely: Body Composition; Cardiorespiratory Endurance; Muscular Strength; Muscular Endurance; Flexibility.
- Cardiorespiratory Fitness (COE) Aerobic Capacity: Is the heart’s ability to transport bloodO2 to working muscles and their ability to use it.
- Muscular Strength: The extent to which muscles can exert force by contracting against resistance.
- Muscular Endurance: Is the ability of a muscle or group of muscles to perform repeated contractions against a constant external load for an extended period of time.
- Flexibility: The functional capacity of the joints to move through a full range of motion.
- Body Composition: The percentage of fat, muscle, water and bone found in the human body.
- Skill Related Fitness (SRF): Skill related fitness is made up of 6 components which are important for success in sport, namely; agility, balance, coordination, power, reaction time and speed.
- Measuring HRPF: Recording measures of one or more of the components of HRPF during a PE lesson.
- Monitoring HRPF: Tracking HRPF test scores on two or more occasions.
### Section 1: Demographics

2. Please provide your school roll number in the space provided below.

*Note: The roll number will be coded to ensure anonymity and used only for tracking response rates.*

3. Gender:
- [ ] Male
- [ ] Female

4. What year did you gain your Physical Education teaching qualification?

5. Please indicate the location of your pre-service Physical Education teacher training:
- [ ] I have no formal qualification in PE
- [ ] Institute of Technology Tralee (ITT)
- [ ] Dublin City University (DCU)
- [ ] University College Cork (UCC)
- [ ] University of Limerick (UL)
- [ ] United Kingdom
- [ ] Other (please specify):

6. How many years in total have you been teaching Physical Education?

7. What is the gender of the school you currently teach in?
- [ ] Boys
- [ ] Girls
- [ ] Mixed

8. What type of school do you currently teach in?
- [ ] Voluntary (Fee-paying)
- [ ] Voluntary (Non-Fee Paying)
- [ ] Vocational schools/Community College (ETB)
- [ ] Community Comprehensive School

9. Please select the option which most accurately describes the current weekly time allocation for Physical Education in your school per class for each year group (LCA1 & LCA2 can be aligned with 5th & 6th year respectively).

<table>
<thead>
<tr>
<th>Year</th>
<th>45 minutes or less</th>
<th>45 - 59 minutes</th>
<th>60 - 69 minutes</th>
<th>70 minutes or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Year</td>
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<tr>
<td>2nd Year</td>
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<tr>
<td>3rd Year</td>
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<td>4th Year</td>
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<tr>
<td>5th Year/LCA1</td>
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<td>[ ]</td>
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<tr>
<td>6th Year/LCA2</td>
<td>[ ]</td>
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</tbody>
</table>

10. On average, how many students do you have in a PE class?
- [ ] 10 or less
- [ ] 11 - 19
- [ ] 20 - 25
- [ ] 26 - 30
- [ ] 31 or more

11. Does your current PE timetable contain any PE classes that occur in the same space at the same time as another PE class?
- [ ] Yes
- [ ] No
* 12. What size is the indoor area (gymnasium/sports hall) you teach PE in?

- [ ] No access to an indoor space for PE
- [ ] 24m² (6.5m x 3.6m) (Approx. 1 Badminton Court)
- [ ] 170m² (10m x 17m) (Approx. 2 Badminton Courts)
- [ ] 400m² (15.5m x 20m) (Approx. 3 Badminton Courts or 1 Full Size Basketball Court)
- [ ] 600m² (15m x 50m) or more (Approx. 4 Badminton Courts)

* 15. If you do not have access to an indoor area, please specify the surface (e.g. All Weather, Tarmac) and dimensions of the outdoor space used for PE lessons in the space below.
Section 2: Health Monitoring in Schools

14. Is students' physical health monitored in your school OUTSIDE of PE lessons?
   - Yes
   - No

15. What aspects of students' physical health are monitored in your school OUTSIDE of PE lessons. (Tick all that apply)
   - Body mass (weight)
   - Height
   - Body composition
   - Cardiovascular health (heart rate; respiratory function)
   - Blood pressure
   - Other (please specify) [________]  

16. What resources or equipment are used to monitor pupils' health? (Please tick all boxes that apply)
   - Heart rate monitors
   - Weighing scales
   - Sphygmomanometer (blood pressure monitor)
   - Spirometers (for measuring lung function)
   - Blood pressure monitors
   - Physical Activity Monitors (Pedometers/Accelerometers)
   - Relaxation monitors
   - Questionnaires/Surveys
   - Other (please specify) [________]  

17. Who is primarily responsible for taking these measures?

- PE Teacher
- School Nurse/health representative
- SPHE Teacher
- Other (please specify)

18. Do you use any form of health related physical fitness (HRPF) test as part of your PE curriculum? (See key terms for definitions)

- Yes
- No

If No, please briefly explain reason for your answer:
Section 2: Health Related Fitness Testing in Schools

16. Please select the components of HRPF you assess with each year group. *Note: Provide a response for EACH year group regardless of whether you teach a class in that year group or not.

<table>
<thead>
<tr>
<th>Year</th>
<th>Do Not Assess</th>
<th>All Components</th>
<th>CV/Endurance</th>
<th>Muscular Endurance</th>
<th>Muscular Strength</th>
<th>Flexibility</th>
<th>Body Composition (Weight/Height)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Year</td>
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<td>2nd Year</td>
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<td>3rd Year</td>
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<td>4th Year</td>
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<td>5th Year/CA</td>
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<tr>
<td>6th Year/CA</td>
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</tbody>
</table>

20. What cardiovascular endurance/aerobic capacity test(s) do you use? (Tick all that apply)

- N/A (I do NOT test Cardiovascular Endurance)
- 20 MTS (20 Meter Test)
- Yo-Yo Test
- 1 Mile Run/Walk
- Step Test
- 12 minute run
- Other (please specify)

21. What muscular strength/muscular endurance test(s) do you use? (Tick all that apply)

- N/A (I do NOT test Muscular Strength or Endurance)
- Push Up Test
- Sit Up Test
- Standing Long Jump
- Vertical Jump
- Handgrip Strength
- Pull Up
- Plank Hold
- Barbell Max Lifts (e.g. Squat/Bench Press)
- Other (please specify)

22. What body composition and/or flexibility test(s) do you use? (Tick all that apply)

- N/A (I do NOT test Body Composition or Flexibility)
- Height
- Weight
- Skinfolds
- Waist Circumference
- Sit & Reach
- Back/Shoulder flexibility
- Other (please specify)
25. What skill related components of fitness do you assess? (See key terms for definitions) (Tick all that apply)
- Agility
- Balance
- Coordination
- Power
- Speed
- Reaction Time
- Other (please specify)

24. How long in total does it take to administer the tests you use?
- 45 mins (or less)
- 45 - 60 mins
- 61 - 80 mins
- 81 - 120 mins (or more)

25. How many times during a school year do you measure students HRPF?
- Once
- Twice
- Three or more

26. What time(s) of year do you typically measure students HRPF? (Tick all that apply)
- September
- October
- November
- December
- January
- February
- March
- April
- May
- Other (please specify)

27. Do you teach your students the theory (purpose) behind doing the fitness test(s)?
- Yes
- No

28. Do you keep a record of students fitness test results?
- Yes
- No
Section 2: Health Related Fitness Testing in Schools

29. What do you do with your students' results once you have completed the test(s)?
   - Store them on a computer (excel/word file)
   - Store hard copies (sheets) in folders
   - Upload to a Web or App monitoring site
   - Store on a school based student record system eg Violearn/Moodle etc.
   - Other (please specify)

30. Do you track (monitor) students HRPF across year groups while they are in secondary school?
   - No
   - Only in 1st year
   - Yes, up until 3rd year
   - Yes, up until 4th year
   - Yes, up until 5th year
   - Yes, up until 6th year
   - Yes, for the full 6 years
   - Tracked on a yearly basis but not tracked across years
   - Other (please specify)

31. Do your students receive feedback on their results (e.g., areas to improve, strengths, weaknesses etc.)?
   - Yes
   - No

32. Do your students' parents/guardians receive feedback on their child's results (e.g., end of term reports)?
   - Yes
   - No

33. Generally, how do your students respond to Health Related Physical Fitness testing within the curriculum? *NOTE: If your school is mixed, please answer the question separately for boys and girls.

<table>
<thead>
<tr>
<th>Boys</th>
<th>Neutral Response</th>
<th>Respond Positively</th>
<th>Respond Negatively</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Girls</th>
<th></th>
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</thead>
</table>
Section 3: PE Teachers Views (Final Page)

35. PE Teachers Attitudes toward Fitness Testing:

Please comment on the extent to which you agree/disagree with the following statements:

<table>
<thead>
<tr>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Uncertain</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
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<tbody>
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</table>

- HRPY testing should be part of the PE curriculum.
- Ireland should have a standardised fitness test battery that is administered annually by PE teachers.
- Participating in HRPY testing during PE lessons should be optional for all students.
- The proposed introduction of the PE Junior Cycle Short Course would encourage more structured tracking of students HRPY.
- HRPY testing in physical education is a waste of time.
- I enjoy implementing fitness tests in my PE classes.
- HRPY testing has no educational value for students.
- I dislike spending my teaching time on implementing fitness tests.
36. Briefly (in a few words) explain the reason(s) why you think fitness testing should or should not be part of the PE curriculum:

37. Barriers to implementing HRPF tests in PE:

Please comment on the extent to which you agree/disagree with the following statements:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Somewhat Agree</th>
<th>Uncertain</th>
<th>Somewhat Disagree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>My school has adequate facilities to deliver a successful PE curriculum.</td>
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<tr>
<td>Administering a fitness test lesson is more challenging than a normal PE lesson.</td>
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<td>I have the required knowledge to make HRPF testing educational.</td>
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<td>My pre-service teacher training in administering HRPF tests was adequate.</td>
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<tr>
<td>School management or my Head of Department do not allow me to use fitness tests.</td>
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<tr>
<td>Students respond negatively to fitness testing.</td>
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<tr>
<td>HRPF testing is not appropriate in mixed gender settings.</td>
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</tr>
<tr>
<td>HRPF testing in PE poses a significant danger to students’ health.</td>
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</tr>
</tbody>
</table>

38. If you have any suggestions or ideas for the design of the HRPF test battery based on your current practice, please record them below:

Thank you for taking the time to complete this questionnaire.

If you have any further questions regarding the questionnaire, please do not hesitate to contact me (brendan.okeefe@ul.ie), or my research supervisors (claran.madonncha@ul.ie) or alan.donnelly@ul.ie).

PLEASE ENCOURAGE ALL PE TEACHERS IN YOUR SCHOOL TO COMPLETE THIS QUESTIONNAIRE!
Appendix F. Reliability study information sheet and consent forms

The development of a web-based system to monitor health-related fitness levels of adolescents in school.

What happens to the information?
Participant confidentiality is the first priority of our research team. All result sheets on both days will be collected and stored securely by the lead researcher (Brendan O’Keefe). Results will be anonymised using an unidentifiable numeric tag and uploaded to a secured software system for analysis. The participant's name or school name will not appear on any published information.

Who else is taking part?
It is hoped that all first-year students in the school will participate in this study.

What if something goes wrong?
In the unlikely event that something goes wrong during the PE lesson, the testing session will immediately stop until the teacher and student(s) are ready to restart the session. The school’s injury response protocol will be strictly adhered to.

What happens at the end of the study?
All data gathered will be anonymised and stored securely and anonymously on the lead researcher’s secured PC (Brendan O’Keefe). This data will be deleted at the conclusion of the project.

If I have any questions or do not understand something?
If you have any questions about the study feel free to contact Brendan O’Keefe at brendan.okeefe@ul.ie. It is important that you feel that all your questions have been answered.

Contact number and name of Project Investigators.
Principal Investigator: Prof. Alan Donnelly
Faculty Member, PESS Dept., University of Limerick, Tel (061) 202808.
Email: alando@ul.ie

PhD Investigator: Brendan O’Keefe
PhD Candidate, PESS Department, 087-2722093.
Email: brendan.okeefe@ul.ie

Please complete the attached consent form and return by image or scan to brendan.okeefe@ul.ie or printed copy to the school PE teacher.

Yours sincerely,
Prof. Alan Donnelly
Brendan O’Keefe
Faculty Member
PhD Candidate

This research study has received Ethics approval from the Education and Health Sciences Research Ethics Committee (2017_02_12_EHS).

If you have any concerns about this study and wish to contact someone independent you may contact Chairman Education and Health Sciences Research Ethics Committee
EHS Faculty Office University of Limerick Tel (061) 234101

This research is supported by the Irish Research Council.
The development of a web-based system to monitor health related fitness levels of adolescents in schools.

CONSENT

- I have read and understood the information sheet.
- I understand what the study is about.
- I understand where the research will be carried out.
- I understand that participants' names will not appear on any research data from this study.
- I understand participants' data can be used anonymously in report format or published output.
- I am fully aware of all the risks and benefits associated with the study.

Physical Activity Readiness Questionnaire: To be completed by participant (child) (Please tick)

1. Has your doctor ever said you have heart trouble?  YES ☐  NO ☐
2. Do you frequently have pains in your heart and chest?  YES ☐  NO ☐
3. Do you often feel faint or have spells of severe dizziness?  YES ☐  NO ☐
4. Has a doctor ever said your blood pressure is too high?  YES ☐  NO ☐
5. Has your doctor ever told you that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise?  YES ☐  NO ☐
6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?  YES ☐  NO ☐
7. Are you over the age of 66 and not accustomed to vigorous exercise?  YES ☐  NO ☐

If you ticked "Yes" to any of the above, please provide additional information in the space provided below:

__________________________________________________________

Please indicate whether or not you would like your child to participate by ticking below:

Please Tick

Name of child: __________________________

Parent/Carer Signature: __________________________ Date: __________

Participant Signature: __________________________ Date: __________

Please return hard copies to your teacher or email images/scanned copies to brendan.okeffe@ul.ie stating your child’s school, thank you.
Appendix G. Feasibility study information sheet and consent forms

The development of a web-based system to monitor health-related fitness levels of adolescents in schools.

What if something goes wrong?
In the unlikely event that something goes wrong during the lesson, the testing session will immediately stop until the teacher and student(s) are ready to restart the session. The schools injury response protocol will be strictly adhered to.

What happens at the end of the study?
It is hoped that the health test battery will be delivered in all schools in Ireland. No student's name or school name will appear in any of the results. All data gathered will be stored securely and anonymously on the primary investigator's password protected PC (Prof Alan Donnelly). This data will be deleted at the conclusion of the project.

What if I have more questions or do not understand something?
If you have any questions about the study feel free to contact Brendan O'Keeffe at brendan.okeeffe@ul.ie or printed copy to the school PE teacher.

Dear [Teacher Name],

I am writing to inform you about a study that is currently being conducted in your school. The study aims to assess the health-related fitness levels of adolescents in your school. As part of this study, students will be asked to participate in a series of tests that will assess their physical fitness. The tests will be conducted under the supervision of trained staff who will ensure that all participants are safe and comfortable.

The study will be conducted in the coming weeks, and I would like to request your support in helping us to ensure the success of this project. The cooperation of your students and staff will be essential in making this study a success.

Thank you for your time and consideration.

Yours sincerely,

[Principal Investigator Name]

This research study has received Ethics approval from the Education and Health Sciences Research Ethics Committee (2017.02.13, ER01). If you have any concerns about this study and wish to contact someone independent you may contact: Chair, Education and Health Sciences Research Ethics Committee, ER01 Faculty Office University of Limerick Tel: 061 234 101.

This research is supported by the Irish Research Council.
CONSENT

- I have read and understood the information sheet.
- I understand what the study is about.
- I understand where the research will be carried out.
- I understand that participants' names will not appear on any research data from this study.
- I understand participants' data can be used anonymously in report format or published output.
- I am fully aware of all the risks and benefits associated with the study.

Physical Activity Readiness Questionnaire: To be completed by participant (Please tick)

1. Has your doctor ever said you have heart trouble? [ ] Yes [ ] No

2. Do you frequently have pains in your heart and chest? [ ] Yes [ ] No

3. Do you often feel faint or have spells of severe dizziness? [ ] Yes [ ] No

4. Has a doctor ever said your blood pressure is too high? [ ] Yes [ ] No

5. Has your doctor ever told you that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise? [ ] Yes [ ] No

6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to? [ ] Yes [ ] No

7. Are you over the age of 65 and not accustomed to vigorous exercise? [ ] Yes [ ] No

Please return hard copies to your teacher or email images/scanned copies to ishr@york.ac.uk stating your child's school, thank you.

Please indicate whether or not you would like your child to participate by ticking below:

Please Tick
STUDENT FACILITATOR INFORMATION SHEET

Title: The development of a web-based system to monitor health related fitness levels of adolescents in schools.

Dear Student/Volunteer,

As part of my PhD research at the University of Limerick, I am carrying out a study on the development of a web-based solution to record and monitor students' health-related fitness levels in schools. You have been selected by your PE teacher to help with the delivery of the Youth-Fit Ireland Health Related Fitness Test Battery. This information sheet will tell you what the study is about.

What is the study about?
The study will involve the design and development of an online database to record and monitor the health-related fitness levels of Irish adolescents in school settings.

What will I have to do?
Following a training workshop, you will be asked to facilitate the delivery of a Health Related Physical Fitness test battery to 1st year students in your school during their timetabled PE class. You will receive training on how to perform and demonstrate the test measures by a trained expert. 1st year PE teachers in your school will also be present at the training workshop. The workshop will last approximately two hours and will take place in your school's sports hall. You will also receive a manual outlining the protocols for each test. You will be trained on how to demonstrate and assess 10 health-related physical fitness tests. The tests are: 20m shuttle run; standing long jump; hand grip strength; body mass; height; blood pressure; plank hold; sit and reach; push up; and 60m shuttle run. You will not record any results, your purpose is to demonstrate the test and to ensure that the participants are performing the tests correctly. You will facilitate the delivery of the health related fitness test battery on two occasions: September 2018 and January 2019.

What are the benefits?
You will receive expert training on how to administer, perform and assess various health-related fitness tests. On successful completion of the workshop and test battery, you will receive a certificate acknowledging your participation and competence in performing and assessing health-related physical fitness.

What are the risks?
There are no significant perceived risks. Muscle soreness and fatigue may occur following the training workshop. However, these risks are no greater than what you would expect from a normal PE lesson.

What if I do not want to take part?
Participation in this study is voluntary and you can choose not to take part or to stop your involvement in this study at any time. It is hoped that all students in your year group will take part.

What happens to the information?
No data will be gathered from you as part of this study. The data gathered from the 1st year student participants will be handled in complete confidence. The results and confidentiality are the first priority of the researchers carrying out the study. The student results will be entered in to an online database that only your PE teacher and our research team has access to. Your name or school name will not appear on any published information. Unidentifiable numeric tags will be assigned to all names. When the study is finished, the anonymous data will be kept in a coded file on the lead researcher's computer that is password protected.

Who else is taking part?
Between 5 and 8 senior student facilitators (4th or 5th year) and all 1st year students from your school will be invited to take part in the study.

What if something goes wrong?
In the unlikely event that something goes wrong during the lesson, the testing session will immediately stop until the teacher and student(s) are ready to restart the session. The schools injury response protocol will be strictly adhered to.

What happens at the end of the study?
It is hoped that the standardised HRF test battery will be expanded to all schools in Ireland at the conclusion of this study. No student's name or school name will appear in any of the results. All data gathered will be stored securely and safely on the primary investigator's password protected PC (Prof Alan Donnelly). This data will be deleted after a period of 10 years.

What if I have more questions or do not understand something?
If you have any questions about the study feel free to contact Brendan O' Keeffe, at brendan.okeeffe@ul.ie. It is important that you feel that you have your questions have been answered.

Contact name and number of Project Investigators:
Principal Investigator: Prof. Alan Donnelly
Faculty Member, PESS Dept. University of Limerick, Tel (061) 202808.
Email: alan.donnelly@ul.ie

PhD Investigator: Brendan O'Keeffe
PhD Candidate, PESS Department, 087-2722003.
Email: brendan.okeeffe@ul.ie

Thank you for taking the time to read this. I would be grateful if you would complete the attached consent form.

Yours sincerely,

Prof. Alan Donnelly
Brendan O’Keeffe
Faculty Member
PhD Candidate

This research study has received Ethics approval from the Education and Health Sciences Research Ethics Committee (2012_02_12, EHS).

If you have any concerns about this study and wish to contact someone independent you may contact Chairperson Education and Health Sciences Research Ethics Committee EHS Faculty Office University of Limerick Tel (061) 234301.
PARTICIPANT ASSENT

Title: The development of a web-based system to monitor health related fitness levels of adolescents in schools.

Should you agree to participate in this study, please read the statements below and if you agree to them, please sign the assent form.

- I have read and understood the participant information sheet.
- I understand what the project is about, and what the results will be used for.
- I understand that what the researchers find out in this study may be shared with others but that my name will not be given to anyone and confidentiality will be ensured.
- I am fully aware of what I will have to do, and of any risks and benefits of the study.

I agree to the statements above and I consent to taking part in this research study.

Name (please print): ______________________
Signature: ______________________ Date: ___________
Investigator’s Signature: ______________________ Date: ___________

Physical Activity Readiness Questionnaire (please tick)

1. Has your doctor ever said you have heart trouble? [ ] YES [ ] NO
2. Do you frequently have pain in your heart or chest? [ ] YES [ ] NO
3. Do you often feel faint or have spells of severe dizziness? [ ] YES [ ] NO
4. Has a doctor ever said your blood pressure is too high? [ ] YES [ ] NO
5. Has your doctor ever told you that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise? [ ] YES [ ] NO
6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to? [ ] YES [ ] NO
7. Are you over the age of 65 and not accustomed to vigorous exercise? [ ] YES [ ] NO

Thank you.

PARENT/CARER CONSENT

Title: The development of a web-based system to monitor health related fitness levels of adolescents in schools.

- I have read and understood the parent/carer information sheet.
- I understand what the study is about, and what is required of my child.
- I understand where the research will be carried out.
- I understand that my child’s name will not appear on any research data from this study.
- I am fully aware of all the procedures involving my child, and of any risks and benefits associated with the study.

After considering the above statements, I consent to my child’s involvement in this research project.

Name of child (please print): ______________________
Name of parent/carer (please print): ______________________ Date: ___________
Parent/Carer Signature: ______________________ Date: ___________
Investigator’s Signature: ______________________ Date: ___________
The development of a web-based system to monitor health-related fitness levels of adolescents in schools.

CONSENT

- I have read and understood the information sheet.
- I understand what the study is about.
- I understand where the research will be carried out.
- I understand that participants’ names will not appear on any research data from this study.
- I understand that participants’ data can be used anonymously in report format or published output.
- I am fully aware of all the risks and benefits associated with the study.

Physical Activity Readiness Questionnaire. To be completed by participant (child) (Please tick)

1. Has your doctor ever said you have heart trouble?
   YES ☐ NO ☐
2. Do you frequently have pain in your heart or chest?
   YES ☐ NO ☐
3. Do you often feel faint or have spells of severe dizziness?
   YES ☐ NO ☐
4. Has a doctor ever said your blood pressure is too high?
   YES ☐ NO ☐
5. Has your doctor ever told you that you have a bone or joint problem, such as arthritis, that has been aggravated by exercise or might be made worse with exercise?
   YES ☐ NO ☐
6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
   YES ☐ NO ☐
7. Are you over the age of 65 and not accustomed to vigorous exercise?
   YES ☐ NO ☐

If you ticked “Yes” to any of the above, please provide additional information in the space provided below:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

Please indicate whether or not you would like your child to participate by ticking below:

Parent/Carer Signature: ______________________  Date: __________

Participant Signature: ______________________  Date: __________

Please return hard copies to your teacher or email images/scanned copies to brendanpkeeffe@iol.ie stating your child’s school, thank you.

Name of child: (please print): ______________________

Parent/Carer Signature: ______________________  Date: __________

Participant Signature: ______________________  Date: __________

Please print name and provide your signature.
Appendix H. Student evaluation survey

Welcome to the Youth-Fit Review Survey.

Dear student,

The following survey is made up of two parts. You should complete the survey regardless of whether you took part in the Youth-Fit test battery or not.

Part 1 focuses on your attitude towards fitness testing in Physical Education.

Part 2 is a review of your experience of the Youth-Fit Fitness Test Battery.

The survey should take around 15-15 minutes to complete (3 minutes for those who did not take part). Take your time, answer the questions honestly and please complete all sections of the survey.

Your name is not required, so all answers are confidential.

Thank you.

Participant Information

* 1. Gender.
   ○ Male
   ○ Female

* 2. Please select your year of birth from the drop-down menu.

* 3. Please select your month of birth from the drop-down menu.

* 4. School type:

* 5. Did you take part in the Youth-Fit test battery?
   ○ Yes
   ○ No
Non participants

6. If you did not take part, please indicate the reason(s) why.
- Parent(s)/Guardian did not provide consent
- I am (was) injured
- I did not provide consent
- I had no interest/did not want to take part
- Other (please explain)

Participant Information

7. Please enter your 5 digit YouthFit ID number (ask your teacher to provide this).

Note: if you do not have a YouthFit ID, please enter ‘00000’.
### Section 1: Students' Attitudes Towards Fitness Testing Scale

**Part 1**

Please comment on the extent to which you agree/disagree with the following statements. The scale goes from option 1, 'Strongly Disagree', to option 5, 'Strongly Agree'.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoy fitness tests.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness testing allows me to evaluate (understood) my fitness.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My teacher organizes activities that make fitness testing more enjoyable.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I do not enjoy fitness tests.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My teacher causes me to like fitness testing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness test results provide me with knowledge to evaluate my own fitness.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My teacher designs fitness-testing activities in ways that make them more interesting.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use fitness test results to improve my fitness levels.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness tests are fun.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Part 2**

Please comment on the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel concerned about performing fitness tests in front of my friends.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel nervous performing fitness tests when my friends are watching.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I do not feel nervous about fitness tests.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness testing provides me with a sense of how fit I am.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness testing motivates me to improve my levels of fitness.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My teacher designs fitness testing activities in ways that make them boring.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can use fitness test results to help me set fitness-related goals.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My teacher causes me to hate fitness testing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fitness testing makes me nervous.</td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>
Section 2: The Youth-Fit Fitness Test Battery Evaluation

*10.

Youth-Fit Test Battery Evaluation.

You will now be asked some questions about your experience of the Youth-Fit test battery which you recently completed during physical education.

A test battery is a group of tests done at the same time.

The scale goes from option 1, ‘Strongly Disagree’, to option 5, ‘Strongly Agree’.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The YOUTH-FIT stress test battery was a worthwhile experience.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would like to keep track of my health related fitness measures while in secondary school.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Youth-Fit test battery made me more aware of the importance of Health Related Physical Fitness.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I tried my best for all tests.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would prefer if someone from outside my school recorded my test scores rather than my classmates.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would prefer to record my test scores with one of my classmates than my teacher.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The 4th/5th year student assistants made it easier to perform each test.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I was nervous performing in front of the 4th/5th year student assistants.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*11. Please rank, from 1 to 4, who you would like to record your test scores the most. (1 = Most like . . . 4 = Least like)

- Teacher
- Classmate
- TYF5th Year Student
- Someone from outside your school


Please comment on the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The YOUTH-FIT Fitness test battery was a waste of time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I learned nothing new from taking part in the YOUTH-FIT Fitness test battery.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I will use my Youth-Fit test results to improve my own fitness.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I had no issues with getting consent from my parents/carer to participate in this study.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I had experience of trying each test before taking my measures on the test day.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Section 2: The Youth-Fit Test Battery Evaluation (Final Page)**

* 13. Please rate your experience of each test.

<table>
<thead>
<tr>
<th>Test</th>
<th>Very Poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>20m Shuttle Run Test (Breeze Test)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Mass (Weight)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit &amp; Reach (Flexibility)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing Long Jump</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plank Hold</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Push Up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x10m Shuttle Run (Sprint)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* 14. Did you receive a report with your test results?

- [ ] Yes
- [ ] No

* 15. Did you share your Youth-Fit report with your parent(s)/guardian?

- [ ] Yes
  - [ ] I didn’t receive a report.
- [ ] No
  - If no, can you provide your reasons for not doing so.

* 16. What was the most enjoyable part of the Youth-Fit test battery?

* 17. What was the least enjoyable part of the Youth-Fit test battery?

**18. If you have any suggestions or changes for the Youth-Fit test battery, please record them below:**
Appendix I. Teacher evaluation survey

Welcome to the Youth-Fit Evaluation Survey.

Dear cooperating teacher,

The following survey will ask you to reflect on your experience of delivering the Youth-Fit test battery. Your feedback is of utmost importance as we look to improve the overall experience of the test battery. Each section has a comment field for you to record some additional feedback on the specific topic in question.

The survey should take no longer than 15 minutes to complete. Please complete all sections of the survey. Your confidentiality is ensured, so try to answer all questions honestly.

Thank you.

Participant Information

1. Gender:
   - Male
   - Female

2. What type of school do you currently teach in?
   - Boys
   - Girls

3. Please select the number of years you have been teaching Physical Education from the options provided below:
   - <5
   - 5-10
   - 10-15
   - 20+

4. Please select the average number of students per class in the class groups you tested:
   - 15 or less
   - 16-20
   - 21-25
   - 26-30
   - 31 or more
### Section 1: Induction & Resources

5.

**Please comment on the extent to which you agree/disagree with the following statements. The scale goes from option 1, 'Strongly Disagree', to option 5, 'Strongly Agree'.**

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The overview of the test battery procedure provided by the researcher on their visit to your school was sufficient.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The equipment provided for the delivery of the test battery was sufficient.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The Teacher's User Guide Manual adequately outlined the purpose and procedures involved in delivering the test battery.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The software guide in the manual was easy to follow for uploading results to the online system.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The software video tutorial clearly explained how to upload student results.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The Student Facilitator Guide was a useful educational tool for student facilitators.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

6. Please record any recommendations you have that would improve the **induction or resource package** provided by the lead investigator:

### Section 2: Test Battery Administration + Relevance of Test Items

7.

**Test Battery Administration**

Please comment on the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administering the Youth-Fit test battery was a worthwhile experience.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The sequence of testing used was appropriate (e.g., circulation formatted).</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>The Youth-Fit test battery made me more aware of the importance of Health Related Physical Fitness.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Assistance from the student facilitators improved the delivery of the Youth-Fit test battery.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>It is <strong>NOT</strong> feasible for one physical education teacher to coordinate the delivery of the Youth-Fit fitness test battery.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>It is feasible to administer the test battery (excluding 20m Shuttle Run) in a 60 minute or double class period of PE.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>It was <strong>NOT</strong> appropriate to have Year 7 and Year 8 student facilitators assist with the delivery of the test.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

8. I would like to use the Youth-Fit Fitness test battery in my PE programme to track student HRPF.

- [ ] Yes
- [x] No
9. If yes, please indicate how many times per year you would include HRPF testing:
- Once
- Twice
- Three or more

10. Test Measures

Please rate the value/usefulness of each measure included in the test battery:

<table>
<thead>
<tr>
<th>Measure</th>
<th>High</th>
<th>Moderate</th>
<th>Low</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>20m Shuttle Run Test (Bleep Test)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (Height + Weight)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit &amp; Reach (Flexibility)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing Long Jump</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handgrip Strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plank Hold</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Push Up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4x10m Shuttle Run</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. Please record any recommendations you have that would improve the delivery/administration of the test battery:


Section 3: Student Experience

12. Student Experience

Please comment on the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>My students learned something new from taking part in the YOUTH-FIT test battery.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My students seemed to enjoy doing the YOUTH-FIT test battery (on average as a group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The tests included in the battery are not appropriate for students in a physical education class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My students had interest in the results of their test measures (on average across the class/group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. Please record any recommendations you have for improving the student experience of the test battery:


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Section 4: Evaluation of Software (Final Section)

14. Evaluation of Software/Web-based system (Final Section)
Please comment on the extent to which you agree/disagree with the following statements.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The youth-fit software package has improved the quality of my work.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>My interaction with the Youth-fit software package has been clear and understandable.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>I have the resources (facilities) to use the Youth-fit software package.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>As a PE teacher, use of the Youth-fit software has relevance.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>The quality of the output (results report) generated is high.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Overall, the Youth-fit software package was easy to use.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>I am able to confidently use the software package</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>I would continue to use the Youth-fit software package to perform my job if it is available.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

15. Please record any recommendations you have that would improve the software package provided:

Recommendations/Suggestions (Final Page)

16. What was the most beneficial part of the Youth-Fit test battery?

17. What was the least beneficial part of the Youth-Fit test battery?

18. Have you any final recommendations, thoughts or suggestions on the test battery? All feedback is welcome.


Appendix J. Objectives and guiding questions for a feasibility study (Orsmond and Cohn 2015)

Objective 1: Evaluation of Recruitment Capability and Resulting Sample Characteristics.

Main Question: Can we recruit appropriate participants?
1. How many potential eligible members of the targeted population are accessible in the local community?
2. What are the recruitment rates?
   a. How many participants enter the study at a time?
   b. How long does it take to recruit enough participants into the study?
   c. What are the refusal rates for participation?
3. How feasible and suitable are eligibility criteria?
   a. Are criteria clear and sufficient or too inclusive or restrictive?
4. What are the obstacles to recruitment?
   a. Are colleagues and local organizations willing to assist with recruitment?
   b. What are the reasons for refusal or ineligibility?
5. How relevant is the intervention to the intended population?
   a. Do study participants show evidence of need for the intervention?
   b. Are the characteristics of the study participants consistent with the range of expected characteristics as informed by the research literature?

Objective 2: Evaluation and Refinement of Data Collection Procedures and Outcome Measures.

Main Question: How appropriate are the data collection procedures and outcome measures for the intended population and purpose of the study?
1. How feasible and suitable are the data collection procedures?
   a. Do participants understand the questions and other data collection procedures?
   b. Do they respond with missing or unusable data?
2. How feasible and suitable is the amount of data collection?
   a. Do the participants have the capacity to complete the data collection procedures?
   b. Does the overall data collection plan involve a reasonable amount of time or does it create a burden for the participants?
3. Do the measures appear to be performing in a consistent way with the intended population as compared to measurement information available in the research literature?
   a. Are internal consistency indicators of measures with the recruited sample congruent with expectations based on prior studies reported in the research literature?
   b. Do planned outcome measures appear to be sensitive to the effects of the intervention?
   c. Does a suitable outcome measure need to be developed?
Objective 3: Evaluation of Acceptability and Suitability of Intervention and Study Procedures.

Main Question: Are study procedures and intervention suitable for and acceptable to participants?
1. What are the retention and follow-up rates as the participants move through the study and intervention?
2. What are the adherence rates to study procedures, intervention attendance, and engagement?
   a. Does the intervention fit with the daily life activities of study participants?
   b. Do the participants have enough time and capacity to complete the intervention?
   c. Does the intervention involve a reasonable amount of time or does it create a burden for the participants?
   d. To what extent is the intervention acceptable and appealing to participants?
   e. If appropriate, how many participants agree to be randomized to group?
3. What is the level of safety of the procedures in the intervention?
   a. Are there any unexpected adverse events?

Objective 4: Evaluation of Resources and Ability to Manage and Implement the Study and Intervention.

Main Question: Does the research team have the resources and ability to manage the study and intervention?
1. Does the research team have the administrative capacity, expertise, skills, space and time to conduct the study and intervention?
2. Can we conduct the study procedures and intervention in an ethical manner?
   a. To what extent does staff comply with the approved human participants’ protocol?
   b. How effectively are adverse events during implementation identified, documented, and reported?
3. Can the study and intervention be conducted within the designated budget?
4. Is the technology and equipment sufficient to conduct the study and intervention, including collection, management, and analysis of data?
   a. Is equipment available when needed?
   b. What is involved in training personal and/or participants to use the equipment?
5. Are we able to efficiently and effectively manage data entry and analysis?
Objective 5: Preliminary Evaluation of Participant Responses to Intervention.

Main Question: Does the intervention show promise of being successful with the intended population?

1. Does examination of quantitative data suggest that the intervention is likely to be successful?
   a. Does examination of the data at the participant level suggest that changes in key outcome variables occurred?
   b. Are the changes of the outcome variable(s) in the expected direction?
   c. Do the estimates of effects suggest that the intervention has promise?

2. Do participants or relevant others provide qualitative feedback that may be indicative of the likelihood that the intervention will be successful?

3. If the quantitative and/or qualitative data suggest that the intervention is not promising:
   a. Are the data collection procedures and outcome measures appropriate for the population and study?
   b. Are the outcome measures and intervention theoretically aligned?
   c. Is there evidence that the intervention does not produce change in the desired outcomes?
   d. Is there evidence that the intervention was not implemented in the intended manner?
   e. Have too many adaptations been made in the intervention process to adequately assess the participants’ responses to the intervention?
   f. Are the findings congruent with the proposed theoretical model for the intervention?
Appendix K. iMosphere software platform White paper review

Improving adolescent health in Ireland
How to present insights from data to those who can act upon it

The University of Limerick has been working with iMosphere on a research project with the objective of creating a national database with key predictors of adolescent health. They have been using care record management system Care Partner in conjunction with Atmoslytics, the Amb health platform. As the phase one part of the project draws to an end, we take a look at what the best mechanism is to share the insights from the data with the schools who are participating.

Collecting the data
The information required to achieve the project objective is collected on a pupil-by-pupil basis in schools across Ireland. Before this project, there was no coordinated approach bringing it together. A physical education teacher from a school involved in the pilot explained, “Originally we did not record students’ health related fitness, and those of us that did stored the results on sheets and did not track the students’ measures”.

Care Partner is being centrally managed at the University of Limerick by PhD candidate Brendan O’Keeffe. He is coordinating the collection of fitness test battery data with the physical education teachers across Ireland. Each school will be able to securely enter the anonymised results for each student. The data includes:
- physical attributes, such as weight and height
- cardio respiratory endurance
- muscular strength

The data is then transferred into Atmoslytics for analysis, initially by Brendan, “I want to analyse which health zone bands students from specific schools or regions are categorized in to”.

Scaling the project
Now that the feasibility stage is complete, the project will be scaled to capture details on the health and physical fitness of every pupil in Ireland. Data will be measured twice a year over the two years of the study.

“While schools may only conduct the test battery on two occasions per year, I think if this could be standardized using the health related fitness test battery, there is huge merit in having a simple, secure system for harvesting this information on a national basis,” says Brendan.

The research objective is to prevent the growth in incidence of diseases, such as diabetes, that have been closely related to obesity and lack of physical activity. It is hoped that the project will achieve this by identifying insights and interventions that optimise physical fitness during school years.

Changing behaviours
Staff at the schools will be pivotal in converting these insights into tangible change in behaviours that lead to a positive impact on adolescent health. They will become the primary consumers of Atmoslytics’ products, and Brendan hopes to be able to provide this: “Based on this data, I want to generate detailed graphic reports comparing a specific school or year group’s performance to the pre-determined health zones and national averages.”

Brendan wants to use the results to inform intervention, creating awareness of the importance of monitoring health over time. Feedback from teachers involved at this early stage suggests there is interest in acting upon the insights that this project brings. One teacher wanted “a reporting mechanism that would enable us to easily analyse, compare and print health related fitness test scores.” They added, “It would be nice to show individual students’ results in comparison to the norms in graph form”.

Knowing your audience
A key consideration is to understand how teachers are going to interact with the software. The initial pilot stage has shown that teachers have found the user of Care Partner straightforward and intuitive for the purpose of capturing data. However, is the same true of Atmoslytics? One teacher who had evaluated both platforms said: “I think the Care Partner system was a little more straightforward to use (in terms of interface) etc.”

Educational staff have not been regularly exposed to the use of population analytics tools. However, there has been encouraging feedback on how quickly they can utilise Atmoslytics. “After using it a few times it becomes easier & easier to generate reports.”

The key factor to consider here is time – how much time will the average teacher have to practice using Atmoslytics to get what they need? The answer is very little.

The audience in educational setting extends beyond the frontline staff. As one teacher, who has been involved in the evaluation of the software shared with us, “I think school management would be interested in this. Some principals are keen to know how their school compares to others of a similar nature”.

This reaffirms that results need to be presented to end users in a succinct and readable way that allows them to instantly interpret the results and act accordingly. Some may then go on to use the software to explore some of the detail behind the headlines.

Presenting results
Great care has been taken to ensure that the data is anonymous, and no particular student can be identified outside of their own staff and school. Similarly, the individual schools within the project have also been de-identified within Atmoslytics. This puts the onus on Brendan to manage the distribution of the cohorts to the respective schools, who won’t know which school is which, but will be able to view and analyse the dataset in its entirety.

This means Brendan will need to be up to speed on Atmoslytics quickly.

“I think the system is easily navigable. It is quite simple to generate reports once familiar with the key terms. Particularly for non-specialist end users, it is more accessible than say looking at a spreadsheet of countless numbers.”

There may be some way to go to get teachers and those in educational settings up such level of confidence. Those that fed back to us about their early experiences with Atmoslytics think it was clear that the software was not originally designed for educational use, more healthcare. “It was clear that some fields had no specific relevance to a school context and seemed to be more medical/general health related.”

The terminology can be customized to suit the language of the users, terms in a school context. In this instance, despite an initial attempt to do this – by changing terms such as ‘patient’ to ‘student’ and ‘clinician’ to ‘teacher’ – it seems that a more detailed look at the language needs to be undertaken before the full rollout happens. As the system is configurable from top to bottom, this should not be an issue.
The quality and variety of outputs available to teachers and other educational staff are going to be key factors in the success of this project. Educational staff were keen to use the ‘print’ function within the reports. This produces a PDF print of the page currently being viewed. “I think the print option should allow you to print the full report, not just the specific test measure,” says Brendan.

The one-page-print functionality does seem restrictive, as it results in teachers having to print several PDF documents for each report, whereas it would be more convenient if all the selected pages were in one document.

Preparing reports

Brendan is looking to the All the Answers app in Atamalytics in order to produce some summary reports to distribute to users in the schools. “I think it is important to be able to generate male-female comparisons in separate bands, as the criterion referenced health standards are different for both,” says Brendan.

He first has to create the necessary cohorts of students to feed into the reports. This will involve initially creating two cohorts per school – one of males and one of females. He also has to create cohorts for comparison, such as counties, each of which will need to be duplicated for male and female variations. For national comparisons he can simply apply the entire base cohort within the database.

He then needs to make the reports. Again, the best approach seems to be to generate a report for males and another for females. This will allow Brendan to configure the bandings in the charts differently for the pre-determined health zones and national averages for each gender.

From here, one approach would be to do the above once, then use the ‘clone’ feature to replicate the same reporting parameters, only changing the cohort to suit the relevant school and comparator.

In total, Brendan would need to generate in excess of 116 cohorts and 100 reports, in preparation for the pilot extension, around 2-3 hours work. Each of the schools’ Atamalytics users would receive the following reports showing data for the fitness test battery dataset.

1. All females at school compared to all females in county
2. All females at school compared to all females nationally
3. All males at school compared to all males in county
4. All males at school compared to all males nationally

Devolved analytics?

An alternative approach might be to simply send two report definitions – one for male and one for females. Along with this, Brendan can send the two cohort definitions relevant to each school along with the two national comparator groups. The school then has all the equipment necessary to assemble the reports themselves in Atamalytics.

This approach shifts the onus onto teachers to construct the reports themselves. Given the discussion above about ease of use and time constraints, it is clear that the results need to be presented to them and in as accessible format as possible, otherwise the likelihood is that the system will not be adopted by busy professionals.

The level of devolution of analytics does need careful management: too much and users will feel they have been handed more responsibility, or lost support from other departments, too little and they cannot harness the information any more effectively than they currently have the facility to.

Getting the presentation right

Brendan wants to be able to ‘toggle’ between the four different views listed above within the same report.

Male-female comparisons can be done if the bandings are identical. But because the criterion are different, the bandings would need to be represented on two y axes – this is currently beyond the capabilities of the All the Answers report definition.

Comparing just two cohorts is also a restricting factor. It would be nice to be able to load more than just two comparator cohorts into any one report and perhaps toggle between them. The All the Answers report currently has the option to switch off a comparator cohort’s data on any given chart.
Cohort Insights
We discuss an alternative option. Cohort Insights offer user-definable dashboards that dynamically update themselves when exploring a new cohort to reflect the impact of any factors added to the cohort definition. It is possible that these can be developed specifically for University of Limrick.

“I would also like to be able to generate a ‘one click’ comparison report which shows how my students’ scores compared to the healthy zone bands (male & female) and the national averages”

The Cohort Insights idea fits perfectly with the ‘one click’ request. They load instantly for a selected cohort when a user logs in. They are also available as part of Cohort Discovery, meaning a user would only have to load a cohort and then a comparator cohort to see the insights compared.

The advantage of using Cohort Insights is that there is a multitude of graphical outputs that can be deployed. The catalogue of insights can be configured to meet the needs of any group of users within an organization. Specific analyses can be developed, if the standard insights are not sufficient.

Earlier in the project Bebanan had thought about how he would like to display results, “maybe a graphical regional breakdown where you could highlight a specific region on a map and get the key data for that region?” The Amoheds project has allowed Inosphere to develop a geo-mapping insight, which would permit data to be represented on a choropleth map.

Conclusion
Getting the presentation of this information right for the audience is a critical factor in the success of the project. Amoheds project has low barriers for non-technical users to be able to explore data and it can also represent results in attractive graphical forms. However, considerable thought is still required about how much to devolve the analytical process and how to present focused headline findings to those who need to act on them. In practice, no one delivery method is likely to meet the entire need, and a combination of presentation techniques will best support the embedding of the software into regular use.

About Horizon 2020
The Amoheds project has received funding from the European Union’s Horizon 2020 research and innovation programme. We are working with four leading European clinical research organisations, which have been conducting in-depth testing and evaluation of Inosphere’s Amoheds platform using large-scale health datasets covering a wide spectrum of medical conditions. Their feedback, from both technical end users and clinical end users perspectives, will shape the platform to ensure it is fully fit for purpose by March 2018.
Appendix L. Peer reviewed publications


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**Health-Related Fitness Monitoring Practices in Secondary School-Based Physical Education Programs**

Brendan T. O’Keeffe and Ciaran MacDonncha
University of Limerick

Kwok Ng
University of Limerick and University of Eastern Finland

Alan E. Donnelly
University of Limerick

**Purpose:** To examine the prevalence of and approaches to monitoring health-related physical fitness (HRPF) in secondary school-based physical education programs. **Methods:** Physical education teachers (N = 325; 56.6% females) from 235 secondary schools (33.1% of national total) in the Republic of Ireland completed a survey designed specifically for the purposes of this study. **Results:** HRPF tests were used by 95.3% of teachers. A significant decline in the testing frequency was observed from the junior grades (age 13–15 years) to the senior grades (age 16–18 years) (p < .001). Just over half (51.7%) of the teachers discuarted the test results after a single use. Less than one third (37.0%) of the teachers indicated that they shared the test results with the students’ parents. The vast majority (87.0%) of the teachers agreed that the development of a digital platform would facilitate monitoring test results over time. **Conclusions:** HRPF testing is highly prevalent in secondary schools. More actions are needed to ensure that teachers use pedagogically sound student-centered approaches toward monitoring HRPF, with a focus on learning that may lead to more positive testing experiences for students. Consideration should be given to the development of digital platforms to facilitate monitoring and reporting HRPF.

**Keywords:** adolescents, digital platform, fitness testing, tracking

The role of school-based physical education programs in monitoring and promoting health has been extensively debated in recent years (Alfrey & Garb, 2014; Cale, Harris, & Chen, 2014; Silverman, Keating, & Phillips, 2008). The unique position of physical education, as one of the primary vehicles to promote the importance of health and activity among young people (Pate et al., 2006), has been increasingly acknowledged by national (Department of Health, 2016) and international (Hallett et al., 2012) policy makers. Fitness testing has been part of school-based physical education programs for over half a century (Morrow, Zha, Franks, Meredith, & Spain, 2009) and has been reported as the most common form of assessment used in physical education in the state of California, United States (Ferguson, Keating, Bridges, Gau, & Li, 2007). Despite the prominence of fitness testing in physical education programs internationally (United Nations Educational, Scientific and Cultural Organization, 2014), calls for more extensive examinations of teachers’ use of fitness tests in school-based physical education programs have mostly gone unanswered (Mercur, Phillips, & Silverman, 2016). Therefore, little is known about teachers’ approaches to fitness testing in schools (Cale et al., 2014), particularly in countries where a standardized approach to health-related physical fitness (HRPF) monitoring does not exist.

Physical fitness is a complex and multifaceted construct that includes performance-related components and health-related components (Welk, Corbin, & Dale, 2000). In recent years, there has been a shift away from monitoring performance-related components of fitness to health-related components (Pilobaly, Oria, & Pate, 2013). Health-related components of fitness, including cardiorespiratory endurance (CRE), musculoskeletal fitness (muscular strength, endurance, and power), and body composition, have been identified as powerful markers of future health among children and adolescents (Ortega, Ruiz, Castillo, & Sjöström, 2008; Smith et al., 2014). Perhaps more importantly, positive changes to HRPF during adolescence can reduce the risk of negative health outcomes later in life (Ortega, Silventoinen, Tynelius, & Rasmussen, 2012). In addition, high levels of HRPF have been associated with higher academic achievement (Bzold et al., 2014). HRPF is often assessed in the form of a fitness test battery in schools (Bianco et al., 2015). A fitness test battery is a group of two or more tests that measure one or more components of fitness. Some countries have developed test batteries in an effort to establish a standardized approach to fitness testing. International examples include FitnessGram® (Cooper Institute, Dallas, TX), CNPPT (China), ALPHA (European Union), GTO (Russia), SLO-fit (Slovenia), NesFit (Hungary), and Move! (Finland). Indeed, several states in the United States and countries including Japan, China, Slovenia Hungary, and Finland have mandated monitoring...
Test–Retest Reliability of Student-Administered Health-Related Fitness Tests in School Settings

Brendan T. O’Keeffe, Alan E. Donnelly, and Ciaran MacDonncha
University of Limerick

Purpose: To examine the test–retest reliability of student-administered (SA) health-related fitness tests in school settings and to compare indices of reliability with those taken by trained research-assistants. Methods: Participants (n = 86; age: 13.43 [0.31] y) were divided into 2 groups: SA (n = 45, girls = 26) or research-assistant administered (RA; n = 41, girls = 21). The SA group had their measures taken by 8 students (age: 15.59 [0.56] y, girls = 4), and the RA group had their measures taken by 8 research-assistants (age: 21.21 [1.38], girls = 5). Tests were administered twice by both groups, 1 week apart. Tests included body mass index, handgrip strength, standing broad jump, isometric plank hold, 90° push-up, 4 × 10-m shuttle run, back-saver sit and reach, and blood pressure. Results: Intraclass correlation coefficients for SA (≥79%) and RA (≥86%) groups were high, and the observed systematic error (Bland–Altman plot) between test 1 and test 2 was close to 0 for all tests. The coefficient of variation was less than 10% for all tests in the SA group, aside from the 90° push-up (24.3%). The SA group had a marginally lower combined mean coefficient of variation across all tests (6.5%) in comparison with the RA group (6.8%). Conclusion: This study demonstrates that, following familiarisation training, SA health-related fitness tests in school-based physical education programs can be considered reliable.

Keywords: adolescent, youth, physical fitness, physical education

Physical fitness is a complex and multifaceted construct integrating a wide range of bodily functions including morphological, muscular, motor, cardio-respiratory, and metabolic (32). Physical fitness is composed of performance-related components and health-related components. In recent years, there has been a shift away from monitoring performance-related components of fitness to health-related components (35). Health-related physical fitness (HRPF) is made up of multiple components, including cardiorespiratory endurance (CRE); muscular fitness (muscular strength, local muscular endurance, and power); and body composition that have been identified as important markers of current and future health among children and adolescents (20,32,47). Higher levels of CRE are associated with reduced risk of future cardiometabolic-related diseases (45), potentially higher levels of academic achievement (44) and better mental health (32). In addition, positive changes to HRPF during adolescence can reduce the risk of negative health outcomes later in life (31,34). There is also mounting evidence that associates higher levels of muscular fitness in youth with lower levels of cardiovascular risk factors in young adulthood, independent of CRE and adiposity (17). In a systematic review of the health benefits of muscular fitness for children and adolescents, Smith et al (47) concluded that there was strong evidence of an inverse association between muscular fitness, central adiposity, and metabolic risk factors. The growing evidence base supporting the predictive capacity of physical fitness as a marker of current and future health has important implications for health promotion practices and has resulted in calls for the development of population wide monitoring of fitness (21,40).

Health-related physical fitness can be objectively and accurately measured in laboratory settings by qualified technicians using sophisticated instruments. However, as indicated by Espana-Romero et al (13), such tests are not feasible for administration at population level. Field-based tests provide a suitable alternative since they are time efficient, low in cost, and can be easily administered to a large number of people simultaneously (40), and there have been increasing calls for the development of simple, accurate, and inexpensive methods to measure fitness in youth (42). In any testing situation, it is important that the results are derived from high-quality measurement techniques. Reliability and validity are essential for meaningful interpretation and inference of results (28). Reliability refers to the reproducibility of a test result in repeated tests on the same individual under the same conditions. Extensive research has been conducted on the reliability of field-based measures of physical fitness. However, the majority of research to date has used an intratester or intertester reliability methodological design in which reliability is established by experienced and highly trained test administrators in standardized and controlled settings (13). Validity, described by Mahar and Rowe (25) as the most important concept in testing, refers to the ability of a test to reflect what it is designed to measure. A number of systematic reviews have recently been published identifying the criterion related validity of commonly administered field-based tests in youth, including the 20-m shuttle run (43), handgrip strength and standing broad jump (1), and body mass index (BMI) (35). Furthermore, as previously detailed, there is increasing evidence to support the predictive validity of body composition, CRE, and muscular fitness as powerful indicators of health in later life (39,40). Different models of HRPF test administration exist in secondary schools including: trained research-assistants visiting the school to collect HRPF data; the physical education teacher as the test coordinator and administrator; the physical education
Students’ attitudes towards and experiences of the Youth-fit health-related fitness test battery

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Abstract
The aim of this study was to examine secondary school students’ attitudes towards and experiences of a student-centred health-related fitness test battery. A total of 795 adolescents (403 boys, 50.7%; 392 girls, 49.3%) aged 13.2 years (± 0.39) from 20 secondary schools in the Republic of Ireland participated in the study. Schools were stratified for gender, location and educational (dis)advantage. Students completed the test battery in small groups (n = ≤6) and each test item was administered by a trained senior student facilitator. Testing took place during physical education lessons. Test items included: body mass index; 20 m shuttle run; back-saver sit and reach; hand-grip strength; standing long jump; isometric plank-hold; 90° push-up; 4 × 10 m shuttle run; and blood pressure. Following participation in the test battery, students completed an instrument with valid scores for measuring attitudes towards fitness tests. Students’ experiences of each test item were also analysed. Overall, students had a positive attitude towards fitness testing (M = 3.9, ± 0.59) on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Although both positive, the mean attitude score for boys (M = 4.05, ± 0.59) was significantly higher than girls (M = 3.79, ± 0.59; p < 0.01, t-test). Most students (n = 690, 86.6%) agreed or strongly agreed that the senior student facilitator made it easier for them to perform the tests. In conclusion, students had positive attitudes towards and experiences of the Youth-fit test battery. Physical education teachers should consider implementing a small-group and senior student-facilitated approach when administering fitness tests.

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**Abstract:**

*Aim:* The purpose of this study was twofold: 1) to examine the influence of school level characteristics on fitness test performance; 2) to compare Irish adolescents’ physical fitness to European norms. 

*Methods:* Adolescents (N= 1215, female = 609) aged 13.4 years (SD 0.41) from a randomised sample of 20 secondary schools, stratified for sex, location and educational (dis)advantage, completed a series of field-based fitness tests. Tests included: body mass index, 20m shuttle run test (20m SRT), hand-grip strength, standing broad jump (SBU), 4x10m shuttle run and back-saver sit and reach (BSR). 

*Results:* Overall, boys outperformed girls in all measured variables, aside from flexibility (BSR) (p < 0.005; t-test, Bonferroni correction). Participants in designated disadvantaged schools had significantly higher body mass index levels, and significantly lower cardiorespiratory endurance (20m SRT) and muscular strength (handgrip strength) levels compared to participants in non-disadvantaged schools (p < 0.005). When compared to European norms, girls in this study scored significantly higher in the 20m SRT, 4x10m shuttle run and SBU tests, while boys scored significantly higher in the BSR test (Cohen’s d 0.2 to 0.8; p < 0.01). However, European adolescents had significantly higher handgrip strength scores (Cohen’s d 0.6 to 0.8, p < 0.01). 

*Conclusion:* Irish adolescents compared favourably to European normative values across most components of HRPF, with the exception of muscular strength. School socioeconomic status was a strong determinant of performance among Irish adolescents. The contrasting findings for different fitness components reiterate the need for multi-component testing batteries for monitoring fitness in youth.
Appendix M. Conference proceedings (oral presentations)

Conference: International Association for Physical Education in Higher Education (AIESEP)

Location: New York, United Stated
Year: 2019
Format: Oral presentation

Title: Students’ attitudes towards and experiences of health-related physical fitness tests in secondary schools in the Republic of Ireland

Introduction: Despite the prominence of health-related physical fitness (HRPF) testing in secondary schools (O’Keeffe et al., 2020), little is known about how students perceive these tests (Cale et al., 2014; Mercier and Silverman 2014). The purpose of this investigation was to examine secondary school students’ attitudes towards and experiences of HRPF testing.

Methods: A randomised sample of 795 adolescents aged 13.2 years (SD = 0.39; 403 boys, 50.7%) from 20 schools in Ireland completed a series of field-based HRPF tests. Schools were stratified for sex, location and educational (dis)advantage. Following test administration, students completed the Students Attitudes towards Fitness Testing Scale (Mercier and Silverman 2014) which has four domains; cognitive, affect-enjoyment, affect-teacher and affect-feelings. Additional study-specific items were also included.

Results: Overall, students had a positive attitude towards fitness testing (M= 3.9, SD .59) on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Males had significantly more positive attitude toward fitness testing in comparison to females across all domains (Bonferroni adjusted p-value of p < 0.01, t-test), with the exception of affect-teacher. A one-way ANOVA revealed that students in single-sex boys and mixed-sex schools had significantly more positive attitudes towards fitness testing in comparison to students in single-sex girls’ schools (F (2, 795) = 9.4, p = 0.001). The majority of students (n = 636, 81.3%) agreed or strongly agreed that they would like to track their HRPF while in secondary school. Students (n = 301, 39.6%) indicated that they would be most in favour of a peer or self-test format in comparison to an external expert (27.0%) or their teacher (20.2%) recording test scores.

Conclusion: The results suggest that students have a positive attitude towards fitness testing. However, girls, and girls in single-sex girls’ schools in particular, have significantly less positive attitudes towards fitness testing. Further research is needed on effective methods to integrate fitness testing in these settings. Physical education teachers should adopt student-centred approaches when administering HRPF tests.
**Conference:** All Ireland Postgraduate Conference in Sport Sciences, Physical Activity and Physical Education

**Location:** Athlone I.T., Ireland  
**Year:** 2019  
**Format:** Oral presentation

**Title:** Health-related physical fitness levels among Irish adolescents: The Youth-fit study.

**Award:** Best oral presentation in health and exercise category

**Introduction:** Health-related physical fitness (HRPF) in childhood and adolescence is a powerful marker of future health (1). The aim of the present investigation was to profile the HRPF levels of a randomised and stratified sample of Irish adolescents.

**Methods:** A total of 1215 adolescents (female = 608; male = 607) aged 13.4 years (SD.41) from a randomised sample of 20 schools in the south-west and mid-west regions of Ireland completed a series of field-based HRPF tests. Schools were stratified for sex, location and socioeconomic status. Tests included; body mass index (BMI), 20m shuttle run, hand-grip strength, standing broad jump (SBJ), isometric plank hold, 90° push-up, 4x10m shuttle run, modified sit and reach test, and blood pressure. Test protocol and administration training was provided to PE teachers and eight senior cycle student facilitators in each school. Means and standard deviations were calculated for all scale scores, with independent or one sample t-tests testing for differences by selected demographics.

**Results:** Boys had higher cardiorespiratory endurance (CRE), muscular fitness levels compared to girls, while girls had higher flexibility (both significant using Bonferroni adjusted p-value of P < 0.005). Boys and girls in designated disadvantaged schools had significantly higher BMI levels, and significantly lower CRE and muscular fitness levels compared to those in non-designated disadvantaged schools (all P < 0.005). When compared with age-matched European normative values, participants in the Youth-fit study had significantly lower BMI and higher CRE (P < 0.005, one sample t-test with Bonferroni corrected p-value). However, European adolescents had significantly higher muscular strength levels (SBJ and handgrip strength) across both sexes (p < 0.005).

**Conclusion:** Future interventions designed to promote healthy lifestyle behaviours among adolescent populations should give special consideration to targeting students in designated disadvantaged schools. In addition, health based interventions aimed at adolescent populations should include a muscular strength focus.
Title: Post-primary students’ attitudes towards and experiences of health-related physical fitness tests in school-based physical education programmes.

Introduction: There is a paucity of research on students attitudes towards fitness tests (Cale, Harris, & Chen, 2014; Mercier & Silverman, 2014). The purpose of this investigation was to examine post-primary students’ attitudes towards and experiences of HRPF testing in school-based physical education programmes.

Methods: First year students (N=111; 50.5% female) from four post primary schools (mixed urban; mixed rural; single sex boys; single sex girls) completed the validated Students Attitudes towards Fitness Testing Scale (SAFTS) (Mercier & Silverman, 2014). The scale comprises of 18 items divided in to four domains (cognitive; affective teaching; affective feelings; affective enjoyment). Mean (M) and standard deviations (SD) were calculated for all scale scores, with t-tests and ANOVAs testing for differences by selected demographics.

Results: Overall, students had a slightly positive attitude towards fitness testing (M= 3.4, SD=.35) on a five point Likert scale ranging from 1 strongly disagree to 5 strongly agree. The cognitive (perceived usefulness) domain had the highest mean score (M= 4.3, SD=.55). The affective-feelings domain had the lowest mean score (M=2.8, SD =.56). No significant differences in attitude were found for the demographic variables gender and school type. The majority of students (75.7%, n= 81) agreed or strongly agreed that they would like to track their HRPF across year groups. Students were more in favour of a self or peer test format (M= 3.3, SD=1.1) than their teacher recording test scores (M= 2.7, SD=1.2).

Conclusion: The results of this investigation indicate that physical education teachers should consider student centred approaches to administering HRPF tests. Further research is needed on mechanisms to enhance students perceived feelings towards HRPF testing and methods to facilitate teachers in tracking students results over time.
Conference: Health Research Institute Inaugural Research Day

Location: University of Limerick, Ireland   Year: 2018   Format: Oral presentation

Title: A comparison of Health-related Physical Fitness Levels of Irish Adolescents with European Norms: Preliminary findings from the Youth-fit Study.

Award: Best overall oral presentation

Introduction: Health-related physical fitness (HRPF) in childhood and adolescence is a powerful marker of future health (1). Despite WHO recommendations (2), the Republic of Ireland (RoI) lacks a clearly specified national strategy for testing and monitoring physical fitness in children and adolescents. The main objectives of the present investigation were to assess health-related physical fitness levels in a randomised sample of Irish adolescents and compare them with European norms (3).

Methods: A total of 671 adolescents (Male = 391; Female = 280) aged 13.1 year (SD .42) from the south-west and mid-west regions of Ireland completed a series of field-based HRPF tests. Tests included body mass index, 20m shuttle run, Hand-grip strength, Standing broad jump and 4x10m shuttle run. PE teachers and 8 senior student facilitators administered the test during timetabled physical education in the school’s sports hall. Mean (M) and standard deviations (SD) were calculated for all scale scores, with t-tests and ANOVAs testing for differences by selected demographics.

Results: Boys had higher fitness levels compared to girls across all components with the exception of flexibility. When compared with European normative values, participants in the Youth-fit study had lower mean scores for BMI and had a higher mean distance covered in the 20m SRT. However, participants had lower mean scores for handgrip strength and standing broad jump.

Conclusion: Preliminary data from the Youth-fit study indicated that adolescents from the mid-west and south-west region of Ireland have higher cardiorespiratory fitness and lower body mass index scores when compared to their European peers. However, consideration should be given to developing the muscular strength component for future interventions for an adolescent population.
Introduction: Health-related Physical Fitness (HRPF) in childhood and adolescence is a powerful marker of future health (Ortega et al. 2008b). Despite WHO recommendations (Hallal et al. 2012), and unlike the US, Australia, Canada, New Zealand and several European countries (Cvejić et al. 2013), the Republic of Ireland (ROI) lacks a clearly specified strategy for testing and monitoring physical fitness in children and adolescents. The aim of this study was twofold. Firstly, to review physical health and fitness monitoring practices in secondary schools in the ROI. Secondly, to determine the perceived need for the development of a web based solution to host, evaluate and compare HRPF levels at a national level.

Methods: An email containing a link to an online questionnaire was sent to all secondary schools (N=714) in the ROI. 336 physical education (PE) teachers initiated a 39-item questionnaire, of which 323 responses from 235 schools (32.0%) were eligible for analysis. Questionnaire items were generated in part from the cross validated ‘Physical Education Teachers Attitudes Towards Fitness Testing Scale’ (PETAFTS) (Keating et al. 2008) and a ‘Health, Activity and Fitness Monitoring’ questionnaire (Cale and Harris 2009). Descriptive statistics were calculated for all variables.

Results: 92.6% of teachers used fitness testing in their physical education programme. Student health was not monitored outside of physical education in 86.4% of schools. Only 11.6% of physical education teachers tracked students HRPF for the duration of their time in second level education. Teachers had positive attitudes towards the role of HRPF monitoring in physical education (M=5.8; SD = .66) on a 7 point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Teachers were in favour of developing a web based solution to facilitate monitoring health measures across year groups (M=6.4; SD = .94).

Conclusions: Levels of HRPF testing in the ROI are in line with international practice (Keating and Silverman 2004a; Cale and Harris 2009). However, a minority of PE teachers track students’ results as they move through school years. PE teachers are strongly in favour of the development of a web-based platform to monitor students HRPF levels as they progress through secondary school. There is a need to develop a standardised method and platform for schools to record and track student HRPF.
Title: Preliminary findings from a national survey of health-related physical fitness monitoring practices in Irish secondary schools.

Methods: Physical education teachers (N=323) from 235 secondary schools (31.97%) in the Republic of Ireland completed a 39 item questionnaire. Questionnaire items were generated in part from the cross validated ‘Physical Education Teachers Attitudes Towards Fitness Testing Scale’ (PETAFTS) (Keating et al. 2008) and the ‘Health, Activity and Fitness Monitoring’ questionnaire (Cale and Harris 2009). Descriptive statistics were calculated for all variables using IBM SPSS Version 19.

Results: 94.39% (N = 286) of teachers incorporated some element of fitness testing in to their physical education programme. Student health was not monitored in anyway outside of physical education in 86.36% of schools. While 93.45% of teachers indicated they keep a record of students’ measurements, only 12.68% of teachers track HRPF for the duration of a student’s time in second level education. 90% of physical education teachers agreed that fitness testing should form some element of a physical education curriculum. Results also indicated that boys (69.83%) respond more positively to fitness tests than girls (40.51%). 85% of those surveyed agreed that Ireland should have some form of standardised national fitness test battery.

Conclusion: HRPF testing remains a very prominent component of physical education programmes in Ireland. However, physical health monitoring outside of physical education class does not take place in the vast majority of schools. Despite the popularity of fitness testing in physical education settings, a minority of teachers track students’ results across year groups. Teachers are strongly in favour of the development of a standardised fitness test battery for implementation during physical education class.
Appendix N. Conference proceedings (poster presentations)

Conference: Health Research Institute Inaugural Research Day

Location: University of Limerick, Ireland  Year: 2019  Format: Poster presentation

Title: ‘Profiling the health-related fitness levels of Irish adolescents: An educational (dis)advantage divide.’

Introduction: Adolescents (N= 1215, female = 609) aged 13.4 years (SD.41) from a randomised sample of 20 schools, stratified for sex, location and educational (dis)advantage, completed a series of field-based fitness tests.

Methods: Tests included; body mass index, 20m shuttle run test (20m SRT), hand-grip strength, standing broad jump (SBJ), isometric plank-hold, 90° push-up, 4x10m shuttle run, back-saver sit and reach, and blood pressure.

Results: Participants in designated disadvantaged schools had significantly higher body mass index levels, and significantly lower cardiorespiratory endurance and muscular fitness levels compared to participants in non-designated disadvantaged schools (p= < 0.005, t-test, Bonferroni correction), running on average 20 fewer shuttles (20m SRT) and jumping on average 10.9cm less (SBJ). When compared to European norms, girls in this study scored significantly higher in the 20m SRT, 4x10m shuttle run and SBJ tests, while boys scored significantly higher in the back-saver sit and reach test (Cohen’s d ranging from 0.2 to 0.6, p= < 0.01, Bonferroni correction). However, European adolescents had significantly higher handgrip strength scores (Cohen’s d ranging from 0.6 to 0.8, p= < 0.01).

Conclusion: Streamlining the use of funds to promote healthy lifestyle behaviours in designated disadvantaged schools may represent a more efficient and effective use of government resources aimed at improving health among school going populations. Furthermore, future interventions designed to promote healthy lifestyle behaviours in Irish adolescents should include a muscular fitness focus.
PROFILING THE HEALTH RELATED FITNESS LEVELS OF IRISH ADOLESCENTS: AN EDUCATIONAL (DIS)ADVANTAGE DIVIDE?

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INTRODUCTION

Health related physical fitness (HRPF) in childhood and adolescence is a powerful marker of future health (1). Despite WHO recommendations (2), the Republic of Ireland lacks a clearly specified national strategy for testing and monitoring physical fitness in children and adolescents. The aim of the present investigation was to assess health-related physical fitness levels in a randomised and stratified sample of Irish adolescents and compare them with European norms (3).

METHODS

Adolescents (n=1225, female = 609) aged 13.4 years (SD=2.4) from a randomised sample of 20 schools, stratified for sex, location and educational (dis)advantage as per DEIS status (4), completed a series of field-based fitness tests.

- Tests included: body mass index, 20m shuttle run test (20m SRT), hand-grip strength, standing broad jump (SBJ), isometric plank-hold, 90° push-up, 4x30m shuttle run, back-saver sit and reach, and blood pressure.

- A linear mixed model analysis was conducted to examine the differences between designated disadvantaged and non-designated disadvantaged schools for key health related fitness outcome variables, controlling for age and gender as fixed effects, and school as a random effect.

Participants physical fitness scores were also expressed using a quintile classification framework based on European normative values (5), corresponding to "very low," "low," "moderate," "high," and "very high" levels as recommended by Tomlinson et al. (5).

RESULTS

Participants in designated disadvantaged schools had significantly higher body mass index levels, and significantly lower cardiopulmonary endurance and muscular fitness levels compared to participants in non-designated disadvantaged schools (p < 0.05, t-test, Bonferroni correction), running an average 30m fewer shuttle test (20m SRT) and jumping an average 10.9cm less (SBJ) (Figures 1 to 4).

When compared to European norms, girls in this study scored significantly higher in the 20m SRT, 4x30m shuttle run and SBJ tests, while boys scored significantly higher in the back-saver sit and reach test (Cohen’s d ranging from 0.2 to 0.6, p < 0.05, Bonferroni correction). However, European adolescents had significantly higher handgrip strength scores (Cohen’s d ranging from 0.6 to 0.8, p < 0.05) (Figures 5 and 6).

Conclusions

1. Prioritise funding to promote healthy lifestyle behaviours in designated disadvantaged schools.
2. Future interventions designed to promote healthy lifestyle behaviours in Irish adolescents should include a muscular fitness focus.
3. Establish a national strategy for monitoring multiple components of physical fitness in Irish youth on an annual basis.

REFERENCES:

Title: ‘A Web-based Solution to Monitor the Health-related Physical Fitness Levels of Adolescents’ in Schools.’

Introduction: The need for efficient, user friendly and low cost instruments to monitor HRPF levels of youth has been highlighted recently (3). The aim of this study was to pilot a web-based solution to facilitate monitoring HRPF levels in school physical education (PE) settings.

Method: 12 PE teachers (Female (F) = 6, Male (M) = 6), from 4 schools administered a 10 item HRPF test battery to 151 students (Age = 13.05 ± .47; F = 92, M = 59). HRPF test battery measures included the 20m SRT, height, weight, sit and reach, blood pressure, standing long jump, handgrip strength, plank hold, push-up and 4x10m SRT. PE teachers received training on standardised protocols for administering the HRPF test battery and uploading results to a centrally hosted web based platform. All participating teachers (n=12) and a sub-sample of students (n=106, F = 61) completed a 12 item process evaluation questionnaire developed specifically for this study. Mean (x̅) and standard deviations (±) were calculated for all scale scores with t-tests testing for differences by selected demographics.

Results: On a five point Likert scale ranging from 1 strongly disagree to 5 strongly agree, both female (M=4.03 ± .83) and male (x̅=4.00 ± .75) students agreed it was a worthwhile experience. 9 teachers indicated that additional help from senior students or staff would contribute to the reliability of the test measures. 4 teachers indicated that the process of entering results to the web based application was overly complicated and required streamlining. 76% (n=78) of students and all cooperating teachers (n=12) agreed that they would like to use the Youth-fit HRPF test battery and web-based monitoring application to track HRPF measures on an annual basis.

Conclusion: An expansion of the system is required to determine the feasibility of the Youth-fit test battery and monitoring software on a larger, randomised sample of schools in the Republic of Ireland. Streamlining data monitoring mechanisms for use in school settings will be imperative to the success of the national roll out. In addition, researchers need to consider ways to optimise the reliability and external validity of HRPF test results in order to facilitate comparisons of HRPF data from surveys internationally.
A Web-based Solution to Monitor Health Related Physical Fitness Levels of Adolescents in Schools.

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2Health Research Institute, University of Limerick, Ireland.

Introduction

Health related physical fitness (HRPF) in childhood and adolescence is a powerful marker of future health [1]. Despite WHO recommendations [2], the Republic of Ireland (RoI) lacks a clearly specified national strategy for testing and monitoring physical fitness in children and adolescents. The need for efficient, user friendly and low cost instruments to monitor HRPF levels of youth has been highlighted recently [3]. The aim of this study was to develop a web-based solution to facilitate monitoring HRPF levels in school physical education (PE) settings. This novel approach will allow data on key indicators of students’ health from participating schools to be available for analysis for relevant stakeholders, showing trends in real time, and informing interventions to improve current and future health among school-going populations.

Methods

- 11 PE teachers (female [F] = 6, male [M] = 5), from 4 school administrations, a total of 220 students (6th year) = 110 F, 110 M.
- HRPF test battery measures included the 20m SRT, height, weight, sit and reach, blood pressure, standing long jump, handgrip strength, plank hold, push-ups, and 400m SRT.
- Following test administration, teachers uploaded students results to a specially designed web based platform, developed by project partner, Infospire.
- Infospire have developed a radical new technology (Atmolytics™) to simplify the integration of data from multiple sources and streamline data discovery for both specialists and non-specialists.
- All participating teachers (n=11) and a sub-sample of students (n=106, F = 61) completed a 12 item process evaluation questionnaire developed specifically for this study.

Results

- On a five point Likert scale ranging from 1 strongly disagree to 5 strongly agree, both female (F) = 4.50 (±.48) and male (M) = 4.50 (±.75) students agreed or strongly agreed participating in the Youth-fit was a worthwhile experience.
- 76% (78) of students agreed or strongly agreed that they would like to track HRPF while in secondary school.
- 84% (87) agreed or strongly agreed that the Youth-fit report made them more aware of the importance of HRPF.

Discussion & Conclusions

- Rule et al. [4], among others, have called for the development of efficient systems for large scale collection of health-related fitness data, and the transfer of data to centrally located databases. The Youth-fit test battery and web-based software represents a positive step towards the creation of such a platform.
- An expansion study, involving a simplified software package, is required to determine the feasibility of the test battery and monitoring software on a larger randomised sample of schools in the RoI.
- Researchers need to consider ways to optimise the reliability and external validity of HRPF data gathering is school settings in order to facilitate international comparisons.

References

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[2] An expansion study, involving a simplified software package, is required to determine the feasibility of the test battery and monitoring software on a larger randomised sample of schools in the RoI.

[3] Researchers need to consider ways to optimise the reliability and external validity of HRPF data gathering in school settings in order to facilitate international comparisons.
**Conference:** All Ireland Postgraduate Conference in Sport Sciences, Physical Activity and Physical Education  
**Location:** Carlow I.T., Ireland  
**Year:** 2017  
**Format:** Poster presentation

**Title:** ‘The development of an online database to record, monitor and evaluate health-related physical fitness levels of Irish adolescents in post-primary schools: A prospective study’.

**Introduction:** Recent Irish cross-sectional data found that one in four children are unfit, overweight or obese and have high blood pressure (Woods et al. 2010). However, current research evidence is based on small sample sizes. The aim of this study is to develop a system including an online database to record, monitor and evaluate health-related physical fitness (HRPF) levels of Irish adolescents between the ages of 12 and 19 in secondary schools. This research project will also involve the development of Ireland’s first evidenced based health-related fitness test battery (FTB).

**Methods:** Boys and girls in 1st year of second level education in the Limerick city and county region will be recruited from 4 schools in September 2017. Cooperating Physical Education (PE) teachers will be responsible for implementing a 10 item FTB during timetabled PE lessons. The FTB comprises of 5 compulsory items (20 MST; Hand-Grip Strength; Standing Broad Jump; Weight; Height) and 5 optional items (Blood pressure; Max Press Up; Plank Hold; Sit and Reach; 4x10m SRT). An online database system will be designed in collaboration with health informatics company ‘iMosphere’ to enable data collection in schools. Data entry to the web based system will be completed by the PE teachers. Data will be inputted using individualised identification codes to allow subsequent tracking and facilitate longitudinal analysis. Cooperating PE teachers will attend a one hour upskilling workshop on test administration and software familiarisation prior to administering the FTB.

**Results:** Approximately 200 students from the 4 schools will be recruited. Data exploration will establish descriptive statistics for the parameters. Regression analyses will be used to explore relationships between the variables measured, with a focus on relationships between aerobic fitness, strength, and body mass and body mass index. Further analysis will determine the influence of age and sex on the parameters.

**Conclusion:** This study will involve the creation of Ireland’s first standardised FTB for implementation in schools. This novel project is a pilot for a larger scale live database which will make Ireland the first country where data on key predictors of adolescent health is available annually for analysis, showing trends in real time, and aiding interventions to improve current and future health among school going populations.
The development of an online database to monitor adolescents’ health related physical fitness in post-primary schools: 
A Prospective Study
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Department of Physical Education and Sport Sciences and Centre for Physical Activity and Health Research, University of Limerick.

Introduction:
Health related physical fitness (HRPF) of children and adolescents is a proven indicator of health in later life (Ruiz et al. 2009). According to the World Health Organisation (WHO) measuring, assessing and monitoring HRPF should be considered a public health priority (Hallal et al. 2012). Despite WHO recommendations, and unlike the US, Australia, Canada, New Zealand and most European countries (Cevjic et al. 2013), Ireland lacks a clearly specified and well defined strategy for testing and monitoring HRPF in children and adolescents. The aim of this study is to pilot a web-based HRPF surveillance system for use in Physical Education (PE) settings with approximately 800 adolescents. HRPF measures will be generated from a 10 item standardised fitness test battery (FTB) and uploaded to an online database. The web-based reporting platform will be developed using Atmolitics® health informatics software developed by project partner iMosphere.

Methods:
Participants
80 min P.E. Lesson
Guiding Principles
Sports Hall Layout

The Youth-Fit FTB

Compulsory Unit
Optional Unit
FTB Protocol
Software Application

Results:
• Data exploration will establish descriptive statistics for the parameters, and whether they are normally distributed.
• Regression analysis will be used to explore relationships between the variables measured, with a focus on relationships between aerobic fitness, strength, body mass and body mass index.
• Further analysis will determine the influence of age and sex on the parameters.
• A process evaluation review will take place at the conclusion of the pilot with cooperating PE teachers and students.

Conclusion:
• Recent Irish cross-sectional data found that 1 in 4 children are unfit, overweight and have high blood pressure (Woods et al. 2010). However, current research evidence is based on small sample sizes.
• A national roll out of the FTB will make Ireland one of the first countries where data on key predictors of adolescent health are available for analysis, showing trends in real time, and aiding interventions to improve current and future health among adolescents.

References:

All Ireland Postgraduate Conference, IT Carlow 2017