Faster, higher, stronger, older: Relative age effects are most influential during the youngest age grade of track and field athletics in the United Kingdom

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Acknowledgements

The authors would like to thank Simon Northcott for his helpful comments on an earlier draft of this manuscript. In addition, the lead author acknowledges the support of the Institute of Sport at the University of Chichester where this research project was begun.

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Abstract

The relative age effect (RAE) is a common phenomenon in youth sport, whereby children born early in the selection year are more likely to experience success and to sustain participation. There is a lack of research investigating variables which influence RAEs within track and field athletics. Such information is vital to guide policies in relation to competition structure, youth development squads and coach education. A database of competition results was analysed to determine the extent to which RAEs were present in track and field athletics in the United Kingdom. Subsequent analyses examined whether age, sex, event and skill level influenced the RAE. Examination of 77,571 records revealed that RAEs were widespread, but most pronounced during Under 13 (U13) competitions; that is, during athletes' first exposure to formal track and field competition. Sex, event and skill level further influenced the existence and magnitude of RAEs at different age grades. Relative age is a key influencing factor within track and field athletics, especially at the youngest age category. Consequently, national governing bodies need to consider what administrative and stakeholder initiatives are necessary to minimise the effects of RAEs on young athletes' early experiences of competition.

Keywords: youth sport, talent, coaching

Introduction

Within youth sport, children and adolescents are often assigned to categories based upon chronological age with the intention of ensuring appropriate competition experiences (Cobley, Baker, Wattie, & McKenna, 2009). However, children of the same chronological age may show wide variation in biological development (Jones, Hitchen, & Stratton, 2000; Malina, 2011). This problem is compounded by the use of broad age categories in many sports, typically one or two years in span. Within such categories, the average child born shortly after the cut-off date is thought to possess a considerable physical and cognitive advantage relative to the average child born shortly before the cut-off date for that age group (Buchheit & Mendez-Villanueva, 2014; Nutton et al., 2012; Roberts, Boddy, Fairclough, & Stratton, 2012). This initial advantage is thought to be compounded as coaches may confuse this developmental advantage for a difference in potential and provide additional opportunities to relatively early born children in the form of supplementary coaching (e.g., selection to development squads) or access to higher levels of competition (Barnsley, Thompson, & Barnsley, 1985; Hancock, Adler, & Côté, 2013; Sherar, Bruner, Munroe-Chandler, & Baxter-Jones, 2007). As a result, relative age effects (RAEs) emerge, whereby an individual's age relative to their peers during youth sport exerts an influence on their progress and participation in later years (for a review see Cobley et al., 2009).

Pronounced RAEs have been identified in a number of track and field contexts (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Romann & Cobley, 2015). This finding is unsurprising given that there is a well-established relationship between chronological age and performance on tests of basic motor capabilities which underpin track and field events such as sprinting speed, endurance running, and jumping distance (Haubenstricker & Seefeldt, 1986; Ross, Dotson, Gilbert, & Katz, 1985; Veldhuizen, Wade, Cairney, Hay, & Faught, 2014), hence the use of age groups for competitions. However, at the end of adolescence and during adult competition, by which point maturation-related differences have largely dissipated (Malina, Rogol, Cumming, Coelho-e-Silva, & Figueirido, 2015), examinations of a number of track and field contexts have revealed persisting RAEs (Morris & Nevill, 2006; Saavedra-García et al., 2016); that is, the sample of top performers still contains a disproportionately high number of individuals born in the first quarter of the year. Furthermore, while research in other sports has investigated how RAEs are influenced by factors such as age, event, and skill level (Delorme, Boiché, & Raspaud, 2010a; Stenling & Hölmstrom, 2014; Till et al., 2010), limited research has investigated the effect of such factors on RAEs in track and field athletics. It is critically important for administrators and coach educators to understand the factors influencing RAEs so that they can deliver appropriate organizational and educational initiatives in response.

One framework which may be useful to stakeholders attempting to understand and address RAEs is Hancock, Adler, & Côté's (2013) Social Agent Model. The central point of the model is that social agents, such as parents, coaches or athletes, may all amplify RAEs by falsely conflating physical maturity with actual skill differences. Specifically, parents are proposed to initially influence RAEs by preferentially enrolling relatively older children in sport (Delorme, Boiché, & Raspaud, 2010b; Hancock, Ste-Marie, & Young, 2013). Subsequently, coaches are proposed to influence RAEs due to their greater expectations of relatively older athletes translating into changes in behaviour (e.g., more frequent feedback or praise; Solomon, DiMarco, Ohlson, & Reece, 1998). Athletes themselves are proposed to influence RAEs by acting congruently with the expectations placed upon them (e.g., increased diligence in training). Thus, interventions to address RAEs need to target multiple social agents. An in-depth assessment of the factors that influence RAEs (e.g., age grade, skill level) should be valuable in guiding such interventions. For example, such information could aid administrators in the design of competitions (e.g., individual versus team contests; at what age group to introduce national competitions) and national ranking systems (e.g., at what age group should rankings begin to be published; should athletes be ranked by year or by month). Furthermore, increased knowledge of factors influencing RAEs could guide regional development officers in recruitment to development squads (e.g., at what age to begin squads) and consideration of the curriculum offered (e.g., single or multi-event focus at different age grades), and for coach educators to design more relevant courses/guidance (e.g., including information on the influence of relative age on performance).

Cobley et al.'s (2009) meta-analysis suggested that RAEs are most prominent during late adolescence, however, the majority of sports included in this review were team sports. It is plausible that advantages due to physical development may peak earlier in track and field athletics due to the emphasis that these events place on a single attribute (e.g., speed in sprinting). There is a dearth of research investigating RAEs at younger ages of track and field competition, with the majority of previous research focusing on athletes who are Under 15 or older (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Morris & Nevill, 2006; Saavedra-García et al., 2016). Within track and field athletics, performances are judged on objective data (e.g., distance jumped), rather than on the subjective evaluation of an individual's contribution to a team performance. Athlete rankings, and selection to development squads is similarly based upon such performances. Understanding when RAEs are strongest would allow coaches, parents and administrators to interpret such performances more appropriately; that is, as indicative of short-term advantage rather than long-term potential (Güllich & Emrich, 2006; Moesch, Elbe, Hauge, & Wikman, 2011).

In addition to age, a number of factors have been demonstrated to influence RAEs in track and field athletics. Two studies have investigated the effect of skill level on RAEs in track and field; Brazo-Sayavera et al. (2016) examined athletes selected to Spanish national federation training camps, while Romann & Cobley (2015) divided athletes who had competed in the 60m sprint into groups on the basis of their seasonal best performance. In both cases, RAEs were higher when examining higher skill level athletes. Investigations of the influence of event on the existence or strength of RAEs have produced mixed results (Hollings et al., 2014; Saavedra-García et al., 2016). For example, Hollings et al. (2014) identified a smaller RAE in boys competing in middle distance events at the 2009 World Youth Championships (Under 18). For girls, the smallest RAE was observed in the jumping events. The authors suggested that as the various events rely on different gross motor abilities (i.e., strength, speed), it was likely that events would show RAEs at different points. Finally, and in contrast to the majority of research on RAEs (Cobley et al., 2009), mixed results have been reported in relation to the effect of sex on RAEs in track and field. Specifically, investigations of various female populations have found no effect (Romann & Fuchslocher, 2014), or else have identified an effect for female athletes competing in certain events or age groups, but not for others (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Saavedra-García et al., 2016). Thus, within track and field, it appears that sex might interact with age and event in determining where RAEs are most prominent.

It is clear from the above review that a more comprehensive analysis of RAEs within track and field athletics is warranted. Such an analysis should provide valuable information to coaches and administrators in relation to athlete selection and development policies. Based upon the findings of previous research, we hypothesised that RAEs would be stronger within male populations and in higher skill level populations. As the evidence relating to the effect of event is equivocal, no predictions were made as to how event might moderate RAEs. While we hypothesised that RAEs should be stronger at Under 15 than at subsequent age grades, given the absence of prior investigations no prediction could be made in relation to the Under 13 age grade.

Method

Data were acquired from a publicly-available website, www.powerof10.info, which hosts information on athlete track and field performances and rankings within the United Kingdom. All data used in this study are reported anonymously. Institutional ethical approval was obtained for the project.

Participants

All participants listed on www.powerof10.info in one of nine events (100m, 800m, 1500m, sprint hurdles, long jump, high jump, shot put, discus, javelin) between 2005 and 2015, and for whom a date of birth was available, were identified. These events were chosen as they represent the core athletic disciplines. More specialist events (e.g., pole vault, hammer) were not considered due to the lower number of participating athletes. Birthdates were available for 67% of athletes in the Under 13 (U13) category, 69% of U15s, 79% of U17s, 89% of U20s, and 99% of senior athletes. Senior athletes were defined as those aged between 20 and 35 (the entry point for masters competition) years. Within the United Kingdom, youth athletes are organized within two- (U13, U15, U17) or three-year (U20) age bands. So that each athlete was only counted once per age category, the analysis was restricted to those athletes who were in the senior year of each age category. To enable statistical comparisons across events, athletes who were ranked in multiple events were only counted within the event in which they were ranked most highly. Consequently, the final sample involved 77,571 records. These records were sorted into categories based on age grade (i.e., U13, U15, U17, U20, Senior), skill level (see data analysis section for details), event, and sex.

Procedure

The cut-off date for the majority of youth age grades in the United Kingdom is August 31st. However, for U20 athletes, the cut-off date changes to the international cut-off date for track and field of December 31st. On visual inspection of the data, it was apparent that the August 31st cut-off date experienced during their initial years in the sport exerted the dominant influence on the U20 populations, rather than the December 31st cut-off date which the athletes had only lately experienced. Consequently, all athletes were classified into birth quartiles such that quartile one ranged from September 1st to November 30th, quartile two ranged from December 1st to February 28th/29th, quartile three ranged from March 1st to May 31st, and quartile four from June 1st to the August 31st.

Data Analysis

To analyse the data set for RAEs, the 77,571 records were processed using customised Microsoft Excel spreadsheets and IBM SPSS Version 24. For each combination of age grade, event, and sex, χ^2 Goodness of Fit tests were used to examine whether the distribution of births present within the sample differed from that of the general UK population for the relevant years, retrieved from http://data.un.org (Table 1).To examine whether RAEs were more pronounced for top ranked athletes, the analysis was repeated for the athletes ranked in the top 20 in each category. The top 20 was chosen as these athletes represented those who could reasonably be expected to make national semi-finals. Furthermore, as the top 20 has previously been used in analyses of athlete progression and retention within UK athletics populations (Morris & Nevill, 2006; Shibli & Barrett, 2011), using this category facilitated comparison with previous research. Due to the smaller sample size available for top 20 athletes, event groups (Sprints/Hurdles: 100m, hurdles; Middle Distance: 800m, 1500m; Jumps: high jump, long jump, Throws: shot, discus, javelin) were analysed rather than individual events. Cohen's w provided a measure of effect size, with values of 0.1, 0.3 and 0.5

indicating small, medium and large effect sizes, respectively (Cohen, 1992). Ninety-five percent confidence intervals for w were calculated following the procedure of Smithson (2003). Where significant chi-square results and at least a small effect size were found, standardized residuals (SR) provided a post-hoc test to identify where there were significant deviations from the expected frequencies (Hancock, Young, & Ste-Marie, 2011). SRs ≥ ±1.96 were deemed noteworthy.

[*Insert Table 1 about here*]

Consistent with Cobley et al. (2009), odds ratios (ORs) and 95% confidence intervals (95% CIs) were calculated for relative age quartile distributions using the observed number of athletes available from the website in quartile one, using quartile four as the reference quartile. This procedure allows an estimation of the odds or risk size of RAEs (Cobley et al., 2009; Till et al., 2010), and to evaluate the influence of sex, event, and skill level on RAEs (Cumming, 2012).

In order to interpret differences in ORs and 95% CIs, independent samples are required (Cumming, 2012). A comparison across age grades for the entire sample was not appropriate due to participants appearing at multiple age grades. To investigate how age grade moderated the strength of the RAE, a sample was formed from the years 2005-2006 and 2014-2015, in which independent samples existed across age grades (i.e., performers from 2005/06 would be too old for the U20 category in 2014). This reduced sample consisted of 27,676 records, and was analysed in the manner described above. Event groups (as described previously in relation to skill level) were analysed rather than individual events, due to the smaller sample sizes which existed for some events.

Results

A typical example of the RAEs observed is provided in Table 2 for women's high jump. A substantial bias in favour of the first quarter is evident within all age groups for this event. For efficiency, only the odds ratio (OR) calculations for the remaining RAE analyses are presented (Table 3). A detailed breakdown of RAEs within each event is available in supplementary file 1.

[*Insert Table 2 about here*]

The χ^2 tests revealed significant deviations from the pattern of births in the general population in all but four of the 90 samples examined (female U17 800m, 1500m and javelin; female U20 1500m). However, the 95% CIs around the ORs suggested caution in the interpretation of eight further cases (all female populations): 800m and 1500m at U15, shot at U17, 800m at U20, and 100m, 1500m, high jump and javelin at senior level (see Table 3).

[*Insert Table 3 about here*]

Inspection of 95% CIs in Table 3 suggested that at U13, U20 and Senior level, ORs were similar between males and females, but that RAEs are likely stronger in most male populations at U15 and U17. For example, U15 male 100m runners were 4.2 times more likely to be born in Q1 than Q4 (95% CI [3.5, 5.0]). While a RAE was still present in U15 female 100m runners, athletes were only 2.2 times more likely to be born in Q1 than Q4 (95% CI [1.8, 2.6]). Table 3 illustrates that sex differences in the size of the RAE were likely in most events at U15, and in running events (100m, hurdles, 800m, 1500m) at U17.

Further inspection of ORs and 95% CIs in Table 3 suggested that differences between events in the size of RAEs were relatively rare. However, analysis of the ORs suggested consistently smaller RAEs for the 1500m than for the other events for females at the U13, U15, U17 and U20 age categories, and for males at the U13, U15, U17 and Senior age categories.

The only other event-related differences appeared at U13, where for both males and females, larger ORs were observed for the 100m (male OR 6.3, 95% CI [4.9, 8.2]; female OR 4.4, 95% CI [3.7, 6.7]) and shot (male OR 5.5, 95% CI [3.9, 7.8]; female OR 5.0, 95% CI [3.7, 6.7]) relative to other events.

Table 4 illustrates the RAEs for athletes ranked within the top 20 in their age grade. For male athletes, it is clear from an inspection of the 95% CIs that ORs are likely substantially larger for top 20 ranked athletes at the U13 and U15 age grades relative to their lower ranked peers. For example, male U13 athletes competing in the 100m sprint or hurdles events who are ranked in the top 20 are 14.8 times more likely to have been born in Q1 than Q4 (95% CI [7.4, 29.6]). While a pronounced RAE still exists for those athletes ranked outside the top 20 (OR 3.6, 95% CI [3.0, 4.3]), it is markedly lower than the effect for their top ranked peers. At U20 and Senior level, there are no longer any skill level-related differences in RAEs for male athletes. For female athletes, the only skill-related differences in the strength of RAEs appear at U13 level (all event groups), and for jumps at U15, where RAEs are stronger amongst top 20 ranked athletes.

[*Insert Table 4 about here*]

Inspection of the ORs and 95% CIs in Table 5 reveals that, for both male and female athletes, RAEs tended to be largest at the U13 age category. For both male and female athletes, this difference was most pronounced in the sprints/hurdles event group. In contrast, examining the ORs and 95% CIs for male middle distance runners revealed a relatively consistent RAE across age grades. For female middle distance runners, ORs indicated that there was no RAE from U15 through to Senior level.

[*Insert Table 5 about here*]

Discussion

The results of the current study provide valuable insight for administrators, regional development officers and coach educators into the factors which influence RAEs. It is clear that variations in relative age are a central factor contributing to success at different age grades of track and field competition in the United Kingdom. The existence of RAEs is consistent with most previous investigations of track and field athletics (Brazo-Sayavera et al., 2016; Hollings et al., 2014; Saavedra-García et al., 2016), however the larger sample size within the present study allowed for the investigation of individual events and a broader range of age categories within the same national system. In particular, by examining younger age groups than previous research, this study suggests that RAEs are most pronounced in early rather than late adolescence. The existence of RAEs is a serious problem for youth sport, due to the well-established connection between RAEs and dropout (Delorme, Boiché, & Raspaud, 2010b; Lemez, Baker, Horton, Wattie, & Weir, 2014).

In contrast to Cobley et al.'s (2009) meta-analysis, RAEs were generally largest in the youngest population examined (U13). Cobley et al.'s (2009) analysis focused predominantly on complex team sports. The earlier peak in RAEs within track and field athletes is likely due to the greater importance of basic physical (e.g., height) and physiological characteristics (e.g., speed) to performance differences amongst relatively untrained athletes (Brazo-Sayavera et al., 2016), and the wide variation in physical development present at this age (Malina, 2011). Thus, athletes are being introduced to formal competitions at precisely that point when their performances are most subject to differences in maturation. Consequently, administrators and coaches need to critically reflect upon the structure of the youth athletic experience at this age grade. Such reflections could consider what level of regional competition is appropriate, the extent to which athletes engage in team or individual competitions, and the emphasis placed on single versus multi-event (e.g., pentathlon) competitions.

While the most obvious finding in this analysis is a large benefit of being among the relatively oldest at U13, it is also important to consider how the effect changes across age grades. The continued existence of a biased distribution of births in many events at Senior level suggests that the large initial benefit has a long-lasting effect. However, the markedly reduced size of the RAE at Senior level in comparison to U13 suggests that in the latter stages of their development, the advantage shifts to those relatively late born athletes. An inspection of female 100m sprinters illustrates this point; at U13 the ratio of athletes born in Q1:Q4 was 42.4%:9.7%, but by senior level this ratio was 31.3%:22% (Supplementary file 1). This shift in the distribution back towards (but not completely attaining) an even distribution is consistent with what has been observed in rugby league within a UK context (Cobley & Till, 2017). Thus, our data emphasises the need to minimise the relative age-related loss of athletes throughout development, both in terms of Q4 athletes during early adolescence, and Q1 athletes during later adolescence.

RAEs were found to be stronger in males at U15 and U17. Furthermore, sex interacted with skill level. Specifically, RAEs were more prominent amongst athletes ranked in the top 20 for an age grade relative to their lower ranked peers at U13 and U15 for male athletes, and predominantly at U13 for female athletes. That is, high performing athletes in the youngest age category are more likely to be relative older, and therefore there is a higher probability that they are biologically more developed. That sex was found to interact with skill level is consistent with previous research within athletics (Brazo-Sayavera et al., 2016; Hollings et al., 2014) and is likely to be due to female athletes maturing faster than their male counterparts (Cumming, Standage, Gillison, & Malina, 2008). If clubs, counties, or regions are recruiting development squads at U13, then these results suggest that coaches should reflect on whether decisions relating to selection and content are being biased by athletes' current level of development at the cost of the long term development of the broader athlete pool.

Few differences between events emerged, but RAEs were generally weaker for the 1500m than for the other events examined at U13, U15 and U17, while both middle distance events showed no RAE in several female samples. Competition has been noted as an important pre-requisite for RAEs (Musch & Grondin, 2001), however, the sample sizes within the current study for the 1500m were equivalent to those for other events. While Saavedra-Garcia et al. (2016) reported less consistent RAEs across events than reported here, the sample sizes in that study (average N = 110 for youth samples) was far fewer than the current study (average N = 862). These findings reinforce the conclusion of Hollings et al. (2014) that RAEs are likely to be largest in events with a greater emphasis on speed and/or strength.

Despite the change in cut-off date from August 31st to December 31st, and a three year age category, the U20 samples were still biased towards the August cut-off date. Previous studies which have investigated the effect of a system-wide shift in cut-off date on RAEs have consistently found that the RAE shifts to the new date (Helsen, Starkes, & Van Winckel, 2000; Musch & Hay, 1999), however there is a lack of research on the effect of a shift in cut-off date between age groups. Till et al. (2010) included Under 18 community-level rugby league players within their analysis, for whom the cut-off date had shifted to December 31st from August 31st. No RAE was found for these players, possibly due to their age and their playing at the club level only, but Till et al. did not comment on the effect of the shift in cut-off date. Within track and field, our results suggest that the RAE from earlier age grades has already influenced participation, and that maturation-related differences are too low at U20 for any new effect to emerge.

Numerous solutions have been proposed to address RAEs, including rotating cut-off dates from year to year (Barnsley et al., 1985), longer (Grondin et al., 1984) or shorter age-group bandwidths (Boucher & Halliwell, 1991), implementing player quotas/average age schemes (Barnsley & Thompson, 1988), physical classification schemes (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017), and educating stakeholders regarding RAEs (Andronikos et al., 2015; Musch & Grondin, 2001). Specific to sprinting, Romann and Cobley (2015) have demonstrated how corrective adjustments could be applied to youth results to remove RAEs from top rankings, however additional research is required to determine if this strategy would work for other athletic disciplines. Furthermore, it is important to emphasise that relative age is a proxy measure for development, which is only accurate at the population level. Thus, while relative age has the advantage of being easily accessible and non-invasive, any correction factor based on regression analysis will always contain error at the level of the individual athlete.

Methods for rotating the cut-off date have been proposed to provide all athletes with an advantage at different time points in development (e.g., the Novem system; Boucher & Halliwell, 1991). Rotating the cut-off dates on an annual basis would be a considerable administrative challenge. Publishing additional rankings based upon month of birth may be a more feasible solution. Taking the boys U15 100m rankings from 2015 as an extreme example, such an approach would see the sprinter who was ranked 697th out of all boys born in that selection year also ranked 10th out of all August-born U15s; an altogether more encouraging prospect for a young athlete. However, while such alternative rankings would present a better picture for those relatively few late-born athletes whose performances appear on the national rankings, only a small minority of late-born athletes achieve the necessary performances to be ranked. Consequently, for an additional month-based ranking to be effective, administrators also need to consider the criteria for inclusion within the rankings. In light of the dramatic effect that relative age has on rankings at U13, particularly top 20 rankings, and the weak relationship between performances at U13 and later age grades (Kearney & Hayes, 2018), it is worth considering whether publishing national rankings for U13 performances is beneficial.

There are a number of limitations with this study. Due to the potential for a biased distribution to exist within the entire population of registered players, RAEs should be calculated relative to all registered players rather than to national statistics (Delorme, Boiché, & Raspaud, 2010c). Indeed, such a biased distribution with the general population has previously been demonstrated in Spanish track and field athletics at U15 level (Brazo-Sayavera et al., 2016). Unfortunately statistics on all registered athletes were not available for this study. However, inspection of the top ranked athletes in this study did reveal substantially higher ORs relative to all athletes at younger age grades, supporting the likelihood of a genuine effect. The selection of the top 20 as representing highly skilled, although consistent with previous research (Morris & Nevill, 2006; Shibli & Barrett, 2011), is somewhat arbitrary, as the depth of performances may not be consistent across events. Future research should consider whether standards based upon the International Association of Athletics Federations scoring tables (Spiriev & Spiriev, 2017) might provide more appropriate criteria. A final limitation arose due to a recent change in the weight of the shot and javelin implements thrown by female athletes at U15 and U17. All records of performances with the previous weight implements were not available from the database. The sample sizes for these categories were considerably lower than for the other events, and consequently, these specific results should be treated with caution.

In conclusion, RAEs were evident within the majority of subpopulations of track and field athletes examined. Unlike team sports, where RAEs are typically more pronounced during late adolescence, in this study RAEs were found to be strongest at U13, particularly amongst top ranked U13 athletes. Consequently, national governing bodies need to consider what administrative and stakeholder initiatives are necessary to minimise the effects of RAEs on young athletes' initial experiences of formal competition.

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Table 1

Distribution of births within the general population of the United Kingdom matched to participants within the sample

Category	**Relevant years for sample matching**	**% in quartile 1**	**% in quartile 2**	**% in quartile 3**	**% in quartile 4**
Under 13	1993-2003	24.4	25.1	25.9	24.7
Under 15	1991-2001	24.6	25.2	25.8	24.4
Under 17	1989-1999	24.5	25.3	25.8	24.4
Under 20	1986-1996	24.4	25.4	25.8	24.4
Senior	1970-1985	25.0	25.5	25.5	24.0

Table 2.

Relative age effects for women's high jump

Category	**N**	**% Q1**	**% Q2**	**% Q3**	**% Q4**	χ^2	***P***	**w [95% CI]**	**SRq1**	**SRq2**	**SRq3**	**SRq4**
Under 13	1665	40.6	27.2	19.8	12.4	306.8	<0.001	0.43 [0.38, 0.48]	13.4	1.7	-4.8	-10.1
Under 15	1343	36.0	26.2	20.9	16.8	116.6	<0.001	0.29 [0.24, 0.35]	8.5	0.8	-3.5	-5.6
Under 17	671	31.0	24.6	23.4	21.0	16.5	<0.001	0.16 [0.09, 0.23]	3.4	-0.3	-1.2	-1.8
Under 20	234	36.8	27.4	17.5	18.4	24.6	<0.001	0.32 [0.21, 0.46]	3.8	0.6	-2.5	-1.9
Senior	229	34.5	22.7	20.1	22.7	11.8	0.008	0.23 [0.13, 0.36]	2.9	-0.8	-1.6	-0.4

Note: N = number of athletes; Q = quarter of the year, with Q1 Sep-Nov, Q2 Dec-Feb, etc; w = Cohen's w; 95% CI = 95% confidence interval; SR = standardised residual, with SRq1 referring to the standardised residual for quarter 1. The χ^2 tests have 3 degrees of freedom.

Table 3.
Relative age effects as identified by the odds ratio (OR) for the entire population by sex, event, and age group.

		Under 13		Under 15		Under 17		Under 20		Senior	
Sex	**Event**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**
Male	100m	1335	6.3 [4.9, 8.2]	2544	4.2 [3.5, 5.0]	2110	2.6 [2.2, 3.1]	966	2.1 [1.6, 2.7]	1246	1.8 [1.4, 2.3]
	Hurdles	1249	2.7 [2.1, 3.4]	1028	3.6 [2.8, 4.7]	587	3.4 [2.4, 4.8]	250	3.4 [2.0, 5.8]	370	2.3 [1.5, 3.5]
	800m	1383	3.0 [2.4, 3.8]	1834	3.0 [2.5, 3.6]	1385	2.4 [1.9, 3.0]	801	2.1 [1.6, 2.8]	1168	1.7 [1.3, 2.1]
	1500m	1936	1.5 [1.3, 1.8]	2126	2.1 [1.8, 2.5]	1551	1.7 [1.4, 2.1]	850	1.8 [1.4, 2.4]	1407	1.3 [1.1, 1.6]
	High Jump	1234	3.4 [2.7, 4.3]	1298	3.3 [2.6, 4.2]	781	2.2 [1.7, 2.9]	322	2.0 [1.3, 3.1]	368	1.8 [1.2, 2.7]
	Long Jump	1124	3.1 [2.4, 4.0]	1104	3.6 [2.8, 4.7]	974	2.7 [2.1, 3.5]	421	2.0 [1.3, 3.0]	553	2.1 [1.5, 2.9]
	Discus	791	2.7 [2.0, 3.6]	847	3.5 [2.6, 4.7]	555	2.2 [1.6, 3.1]	222	2.8 [1.6, 4.8]	365	1.8 [1.2, 2.7]
	Shot	655	5.5 [3.9, 7.8]	691	4.5 [3.2, 6.3]	480	3.9 [2.7, 5.7]	234	3.2 [1.9, 5.5]	316	2.5 [1.6, 4.0]
	Javelin	1034	2.2 [1.7, 2.8]	824	2.7 [2.0, 3.6]	625	2.0 [1.5, 2.7]	304	2.0 [1.3, 3.1]	535	1.8 [1.3, 2.5]
Female	100m	1719	4.4 [3.6, 5.5]	1943	2.2 [1.8, 2.6]	1019	1.7 [1.3, 2.2]	398	1.9 [1.3, 2.8]	718	1.4 [1.0, 1.9]
	Hurdles	1558	3.1 [2.5, 3.8]	1381	2.3 [1.9, 2.9]	655	1.7 [1.3, 2.3]	217	2.4 [1.4, 4.1]	309	2.2 [1.4, 3.5]
	800m	1645	2.8 [2.3, 3.4]	1462	1.8 [1.5, 2.2]	788	1.2 [0.9, 1.6]	304	1.5 [1.0, 2.3]	523	1.5 [1.1, 2.1]
	1500m	1532	1.6 [1.3, 2.0]	1571	1.2 [1.0, 1.5]	872	1.1 [0.8, 1.4]	372	1.3 [0.9, 1.9]	891	1.2 [0.9, 1.6]
	High Jump	1665	3.3 [2.7, 4.1]	1343	2.1 [1.7, 2.6]	671	1.5 [1.1, 2.0]	234	2.0 [1.2, 3.3]	229	1.5 [0.9, 2.5]
	Long Jump	1343	3.2 [2.5, 4.0]	1330	2.5 [2.0, 3.1]	762	1.9 [1.4, 2.5]	299	3.2 [2.0, 5.1]	339	1.8 [1.2, 2.7]
	Discus	865	2.8 [2.1, 3.7]	1139	2.1 [1.7, 2.7]	667	1.5 [1.1, 2.0]	224	2.3 [1.4, 3.9]	250	1.8 [1.1, 3.0]
	Shot	998	5.0 [3.7, 6.7]	218	2.2 [1.3, 3.8]	84	2.1 [0.9, 5.0]	184	2.0 [1.1, 3.5]	268	2.2 [1.3, 3.6]
	Javelin	960	2.1 [1.6, 2.7]	242	2.1 [1.3, 3.5]	97	1.8 [0.8, 4.0]	211	2.3 [1.3, 4.0]	289	1.6 [1.0, 2.5]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus birth quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI); shaded cells indicate no relative age effect observed.

Table 4.

Relative age effects as identified by the odds ratio (OR) in male and female athletes of differing skill levels.

Sex	Event	Ranking	Under 13		Under 15		Under 17		Under 20		Senior	
			N	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**
Male	Sprints/Hurdles	Top 20	283	14.8 [7.4, 29.6]	366	7.2 [4.4, 11.9]	296	3.5 [2.2, 5.7]	185	2.5 [1.4, 4.6]	117	2.3 [1.1, 4.8]
		Rank 21+	2301	3.6 [3.0, 4.3]	3206	3.8 [3.3, 4.4]	2401	2.7 [2.3, 3.2]	1031	2.3 [1.8, 3.0]	1499	1.8 [1.5, 2.2]
	Middle distance	Top 20	289	4.0 [2.4, 6.6]	316	4.2 [2.6, 6.8]	269	4.1 [2.4, 7.0]	193	1.5 [0.8, 2.7]	132	1.1 [0.6, 2.2]
		Rank 21+	3030	1.8 [1.6, 2.1]	3644	2.4 [2.1, 2.7]	2667	1.9 [1.6, 2.2]	1458	2.0 [1.6, 2.5]	2443	1.5 [1.3, 1.8]
	Jumps	Top 20	324	11.7 [6.4, 21.5]	332	6.6 [4.0, 11]	307	3.9 [2.4, 6.4]	181	1.8 [1.0, 3.3]	106	1.9 [0.9, 4.1]
		Rank 21+	2034	2.8 [2.3, 3.4]	2070	3.1 [2.6, 3.7]	1448	2.2 [1.8, 2.7]	562	2.1 [1.5, 2.9]	815	1.9 [1.4, 2.5]
	Throws	Top 20	377	6.3 [3.9, 10.1]	438	7.6 [4.7, 12.2]	367	3.5 [2.3, 5.4]	212	2.7 [1.5, 4.7]	141	2.8 [1.4, 5.6]
		Rank 21+	2103	2.6 [2.2, 3.1]	1924	2.9 [2.4, 3.5]	1293	2.3 [1.8, 2.9]	548	2.5 [1.8, 3.5]	1075	1.8 [1.4, 2.3]
Female	Sprints/Hurdles	Top 20	297	6.0 [3.5, 10.3]	303	2.4 [1.5, 3.8]	206	1.9 [1.1, 3.3]	119	1.7 [0.8, 3.4]	90	2.7 [1.1, 6.5]
		Rank 21+	2980	3.5 [3.0, 4.1]	3021	2.2 [1.9, 2.5]	1468	1.6 [1.3, 2.0]	496	2.2 [1.5, 3.1]	937	1.5 [1.2, 1.9]
	Middle distance	Top 20	277	3.6 [2.2, 6.0]	247	2.2 [1.3, 3.7]	185	1.2 [0.7, 2.2]	114	1.1 [0.5, 2.3]	111	1.2 [0.6, 2.5]
		Rank 21+	2900	2.0 [1.7, 2.3]	2786	1.4 [1.2, 1.6]	1475	1.2 [1.0, 1.5]	562	1.4 [1.0, 1.9]	1303	1.4 [1.1, 1.7]
	Jumps	Top 20	341	6.7 [4.0, 11.3]	276	4.2 [2.5, 7.1]	204	2.3 [1.3, 4.0]	131	1.8 [0.9, 3.6]	85	1.9 [0.8, 4.4]
		Rank 21+	2667	3.0 [2.6, 3.5]	2397	2.2 [1.9, 2.6]	1229	1.6 [1.3, 2.0]	402	2.9 [1.9, 4.3]	483	1.6 [1.1, 2.3]
	Throws	Top 20	394	4.7 [3.0, 7.3]	205	3.3 [1.8, 5.9]	150	1.6 [0.9, 3.0]	195	2.1 [1.2, 3.7]	108	1.5 [0.7, 3.3]
		Rank 21+	2429	2.8 [2.4, 3.3]	1394	2.0 [1.6, 2.5]	698	1.6 [1.2, 2.2]	424	2.3 [1.6, 3.4]	699	1.9 [1.4, 2.6]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus birth quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI). Sprints/hurdles: 100m, hurdles; Middle distance: 800m, 1500m; Jumps: long jump, high jump; Throws: shot, discus, javelin.

Table 5.

Variation in relative age effects across age categories in male and female athletes.

		Under 13		Under 15		Under 17		Under 20		Senior	
Sex	**Event Group**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**	**N**	**OR [95% CI]**
Male	**Sprints/Hurdles**	772	10.5 [7, 15.7]	1194	3.7 [2.9, 4.7]	887	3.0 [2.3, 4.0]	412	2.8 [1.9, 4.2]	693	2.0 [1.5, 2.7]
	Middle distance	1189	1.8 [1.4, 2.3]	1413	2.2 [1.8, 2.7]	960	1.9 [1.5, 2.5]	564	2.3 [1.6, 3.2]	1158	1.4 [1.1, 1.8]
	Jumps	791	4.6 [3.3, 6.3]	867	3.9 [2.9, 5.2]	558	2.4 [1.7, 3.4]	226	1.5 [0.9, 2.5]	378	2.0 [1.3, 3.0]
	Throws	799	5.7 [4.1, 8.0]	754	4.0 [2.9, 5.5]	522	2.5 [1.8, 3.5]	247	2.7 [1.6, 4.5]	515	2.1 [1.5, 3.0]
Female	**Sprints/Hurdles**	1190	6.9 [5.2, 9.2]	1055	2.2 [1.7, 2.8]	493	1.5 [1.1, 2.1]	193	2.7 [1.5, 4.8]	339	2.1 [1.4, 3.2]
	Middle distance	1197	2.3 [1.8, 2.9]	1094	1.3 [1.0, 1.6]	560	1.1 [0.8, 1.5]	230	1.7 [1.0, 2.8]	641	1.4 [1.0, 1.9]
	Jumps	1150	3.8 [2.9, 4.9]	949	2.6 [2.0, 3.4]	473	1.7 [1.2, 2.4]	213	2.2 [1.3, 3.7]	252	1.6 [1.0, 2.6]
	Throws	1031	5.0 [3.7, 6.7]	793	2.3 [1.7, 3.1]	351	1.5 [1.0, 2.3]	207	1.9 [1.1, 3.3]	366	1.7 [1.1, 2.5]

Note: N = number of participants; OR = odds ratio birth quartile 1 versus quartile 4; values in square brackets indicate the lower and upper limits of the 95% confidence intervals (CI). Sprints/hurdles: 100m, hurdles; Middle distance: 800m, 1500m; Jumps: long jump, high jump; Throws: shot, discus, javelin.