Examining the Role of Thoracic Kyphosis in Shoulder Pain

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Examining the Role of Thoracic Kyphosis in Shoulder Pain

Declaration

My submission as a whole is not substantially the same as any that I have previously made or currently am making, whether in published or unpublished form for a degree, diploma, or similar qualification at any university or similar institution. I am the author of this thesis and the principle author of the six studies which form its core.

Signature: __________________

EVA BARRETT
Abstract

Introduction: Shoulder pain is a common musculoskeletal condition that carries a substantial economic burden. Due to the challenges acknowledged with structural diagnoses, studies have labelled participants as having non-specific shoulder pain. Non-specific shoulder pain may be caused by several factors, including physical, psychological, lifestyle and cognitive factors. An increase in thoracic kyphosis is a physical factor which has been hypothesised to contribute to shoulder pain. While exercises to reduce thoracic kyphosis are a common component of the physiotherapy treatment of shoulder pain, the relationship between thoracic kyphosis and shoulder pain is unclear. The aim of this doctoral thesis was to examine the role of thoracic kyphosis in shoulder pain.

Methods: This doctoral thesis presents six studies. A systematic review examines the association between thoracic kyphosis and shoulder pain, function and range of motion (Chapter 2). Three methodological studies (systematic review, reliability study, validity study) investigate the reliability and validity of methods for measuring thoracic kyphosis clinically (Chapter 3). Chapter 4 presents two clinical studies. A case series evaluates pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain who receive two different types of shoulder exercise classes. A separate qualitative study of people with non-specific shoulder pain examines individual experiences of shoulder exercise classes.

Results: A systematic review (Study I) concluded that thoracic kyphosis was not significantly different in people with and without shoulder pain, suggesting that increased static thoracic kyphosis is not a consistent postural deviation in people with shoulder pain. The cross-sectional nature of these studies prevented analysis of a causal relationship between thoracic kyphosis and shoulder pain. A second systematic review (Study II) synthesised the evidence regarding the reliability and validity of non-radiographic thoracic kyphosis measurement methods. A reliability study (Study III) found that the Flexicurve and manual inclinometer demonstrated excellent intra- and inter-rater reliability for thoracic kyphosis measurement. In a validation study (Study IV), the manual inclinometer demonstrated good concurrent validity with the gold standard radiographic Cobb angle, in contrast to the Flexicurve angle which demonstrated poor validity. In Study V, people with non-specific shoulder pain who completed a six week group exercise class demonstrated significant and clinically meaningful improvements in shoulder pain and disability at six week and six month follow-up, without a change in thoracic kyphosis beyond measurement error. The separate qualitative study (Study VI) revealed that shoulder exercise classes provided an environment conducive to peer-learning, support and motivation, facilitation towards independent exercise and highlighted beliefs regarding pain and exercise.

Conclusion: Thoracic kyphosis can be measured with validity and good reliability using the manual inclinometer. However, static thoracic kyphosis, measured in relaxed standing, may not be strongly related to shoulder pain. This thesis provided preliminary quantitative and qualitative evidence to support group exercise classes for people with non-specific shoulder pain. However, a change in thoracic kyphosis was not the mechanism of clinical improvements. Future research should (i) compare the effectiveness of shoulder exercise classes, with and without thoracic extension exercises, for the treatment of non-specific shoulder pain, (ii) examine the effectiveness of group exercise classes compared to individual physiotherapy for this population and (iii) explore the mechanisms which underlie the improvements after exercise-based rehabilitation in people with non-specific shoulder pain.
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<tbody>
<tr>
<td>BMI</td>
<td>body mass index</td>
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<tr>
<td>CI</td>
<td>confidence interval</td>
</tr>
<tr>
<td>CLBP</td>
<td>chronic low back pain</td>
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<tr>
<td>Cm</td>
<td>centimetres</td>
</tr>
<tr>
<td>CNS</td>
<td>central nervous system</td>
</tr>
<tr>
<td>CoP</td>
<td>community of practice</td>
</tr>
<tr>
<td>C7</td>
<td>spinous process of 7th cervical vertebra</td>
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<tr>
<td>DASH</td>
<td>disabilities of the arm, shoulder and hand</td>
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<td>DOS</td>
<td>duration of symptoms</td>
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<td>EMG</td>
<td>electromyographic</td>
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<tr>
<td>F</td>
<td>female</td>
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<tr>
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<td>intraclass correlation coefficient</td>
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<tr>
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<td>kilogram</td>
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</tr>
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</tr>
<tr>
<td>MCID</td>
<td>minimum clinical importance difference</td>
</tr>
<tr>
<td>mm</td>
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<tr>
<td>NRS</td>
<td>numerical rating scale</td>
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<tr>
<td>OR</td>
<td>odds ratio</td>
</tr>
<tr>
<td>PRISMA</td>
<td>preferred reporting items for systematic reviews and meta-analyses</td>
</tr>
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<td>QAREL</td>
<td>quality appraisal of diagnostic reliability studies</td>
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<tr>
<td>QUADAS</td>
<td>quality assessment of diagnostic accuracy studies</td>
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<tr>
<td>RCT</td>
<td>randomised controlled trial</td>
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<tr>
<td>ROM</td>
<td>range of motion</td>
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<tr>
<td>r_s</td>
<td>spearman's rank correlation coefficient</td>
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<td>subacromial pain syndrome</td>
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<tr>
<td>SD</td>
<td>standard deviation</td>
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<tr>
<td>SEM</td>
<td>standard error of measurement</td>
</tr>
<tr>
<td>SHCI</td>
<td>subjective health complaints inventory</td>
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<td>SIS</td>
<td>subacromial impingement syndrome</td>
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<td>SNQ</td>
<td>standardised Nordic questionnaire</td>
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<tr>
<td>SPSS</td>
<td>statistical package for the social sciences</td>
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<td>shoulder symptom modification procedure</td>
</tr>
<tr>
<td>T1</td>
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<tr>
<td>T2</td>
<td>spinous process of 2nd thoracic vertebra</td>
</tr>
<tr>
<td>T11</td>
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<tr>
<td>T12</td>
<td>spinous process of 12th thoracic vertebra</td>
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<tr>
<td>VAS</td>
<td>visual analogue scale</td>
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<td>wall occiput test</td>
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<td>°</td>
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1. Chapter 1: Background

The aim of this chapter is to introduce the key areas of relevance to the thesis. The chapter will introduce shoulder pain, the challenges involved in shoulder diagnoses, the factors involved in shoulder pain and current intervention strategies. The chapter will then narrow to focus on the predominant theories underpinning posture and the role of thoracic kyphosis in shoulder pain. The potential to change thoracic kyphosis with exercise and to quantitatively measure thoracic kyphosis will be discussed. The chapter will then be summarised and the aims of the thesis will be provided.
1.1 Shoulder pain: prevalence and socioeconomic impact

Shoulder pain is a common musculoskeletal condition that is associated with substantial economic burden (Kooijman et al 2013). The point prevalence varies greatly from 7-27% (Luime et al 2004), according to the location of pain and duration of symptoms specified. Shoulder pain is the third most common musculoskeletal complaint presenting to physiotherapy (Kooijman et al 2011). For example, in the United Kingdom, shoulder pain represents 14% of annual referrals to physiotherapy outpatient services (May 2003). Moreover, in a community survey of 3,136 people in Ireland, 27% of chronic pain sufferers reported the shoulder as a site of ongoing pain (Raftery et al 2011). Shoulder pain has a substantial impact on an individual’s daily functioning, ability to work and utilisation of health services (Virta et al 2012). The prevalence of shoulder pain rises with age (Luime et al 2004) and as life expectancy is increasing, the physical and economic burden of shoulder pain is also likely to escalate (Cho et al 2013). Of concern, only 40-50% of people referred to primary care with their first episode of shoulder pain completely recover within two years (Winters et al 1999, van der Windt et al 1995, Croft et al 1996). The recurrent and persistent nature of shoulder pain highlights the need for research which examines the factors that contribute to its development, in order to inform more effective treatment.

1.2 Challenges involved in shoulder diagnoses

Shoulder pain has traditionally been explained in terms of local tissue based pathology (Neer 1983). The rotator cuff tendons have been heavily implicated as a predominant source of shoulder pathology and pain (van der Windt et al 1995), although signs and symptoms which are now considered not to have the specificity to diagnose rotator cuff tendon pathology (Hegedus et al 2012), were used in this study. The mechanisms of rotator cuff pathology have been described in terms of external mechanisms of compression/impingement (Neer 1983, Bigliani et al 1986) and internal mechanisms of tendon degeneration (Lewis et al 2010). Some of this research, however, is based on clinical experience and low quality evidence (Neer 1983, Bigliani et al 1986) and is regarded by many to be outdated (Littlewood et al 2013, Seitz et al 2011, Michener et al 2004, Cook and Purdham 2011). Similarly, a number of other structures in the shoulder joint have been associated with pathology and pain, including the glenohumeral labrum, the subacromial
bursa, the long head of biceps tendon, the glenohumeral capsule and the glenohumeral ligaments (Donatelli 1997). Terms such as ‘subacromial impingement syndrome’, ‘rotator cuff tendinopathy’ and ‘subacromial pain syndrome’ (Lewis 2011) are commonly used in practice. There is much debate regarding this terminology as it is not founded on any firm evidence base.

However, the relevance of diagnosing structural pathology in people with shoulder pain is challenged by findings that the extent of tissue damage observed on clinical imaging does not correlate with shoulder pain intensity (Miniaci et al 2002, Connor et al 2003). While many people with shoulder pain have structural pathology, 20-40% of the general population have asymptomatic rotator cuff tears (Templehof et al 1999, Worland et al 2003, Yamamoto et al 2010). This suggests that structural pathology may not fully explain the perception of shoulder pain and highlights the potential for diagnostic labels to mislead treatment.

Even if shoulder pain was closely correlated with structural pathology, the special tests for the shoulder are not currently able to identify the structures associated with shoulder pain, with the clinical confidence required (Lewis 2009). A large body of evidence, in the form of narrative and systematic reviews, indicates that the majority of special tests of the shoulder have limited diagnostic accuracy (Hegedus et al 2008, Hegedus et al 2012, Hughes et al 2008) and poor reliability (May et al 2010), thereby making them unsuitable for structural diagnoses (Hegedus et al 2012). A major limitation of these special tests is that they are based on the premise that structures in the shoulder can be provoked in isolation. However, due to the close anatomical relationship of the aforementioned structures within the shoulder, stretch/compression of a single structure is likely to elicit a response in surrounding structures (Lewis 2009). This clarifies why many special tests demonstrate a high sensitivity to detect pain but a low specificity to identify structural pathology (Hegedus et al 2012, Hughes et al 2008, Lewis and Tennent 2007).

As a result, research has been conducted without classifying participants according to structural diagnosis (Ginn and Cohen 2005, Chen et al 2009). Non-specific shoulder pain has been described as pain with no clearly defined pathology (van den Dolder et al 2015) upon the exclusion of specific causes of shoulder pain, including infection, trauma, dislocation, neoplasm, systemic inflammatory disorders and referred pain (Gemmell et al 2011, van den Dolder et al 2015). After ruling out these specific causes of shoulder pain, a transition away from structural diagnosis may help to improve evidenced-based treatment for the shoulder.
1.3 Factors involved in non-specific shoulder pain

Emerging evidence suggests that non-specific shoulder pain may be associated with many different factors across the biopsychosocial spectrum, including patho-anatomical (Bayam 2011), physical (Kibler et al 2013), psychological (Anderson et al 2002), lifestyle (Miranda et al 2001) and cognitive (Valencia et al 2011) factors. Previously, the cause of shoulder pain has been predominantly attributed to local tissue based pathology, caused by patho-anatomical and physical factors. The rotator cuff tendons are described as the most common source of structural pathology in the shoulder (van der Windt et al 1996). Neer (1983) hypothesised an external impingement model of the rotator cuff tendons, in which the upper portion of the tendons are irritated by abrasion from the acromion process. This model has been largely criticised by later evidence which supports a higher incidence of partial thickness tears in the lower, articular portion of the rotator cuff tendons compared to the upper, bursal portion of the tendon (Payne et al 1997, Ellman 1990).

More recently, research has focussed on the role of intrinsic degeneration of the rotator cuff tendons (Seitz et al 2011). Several factors have been discussed in the literature which may influence the mechanical properties of the tendon and its ability to sustain load, including age (Lake et al 2009), genetics (Tashjian et al 2009), lifestyle factors (Rechardt et al 2010) and tendon vascularity (Codman 1934). Lewis (2010) presented a continuum model of rotator cuff tendon pathology, with involvement of the subacromial bursa, which was based on a generic model originally described by Cook and Purdham (2009). This model acknowledged that tendon is highly adaptive to load, where both underloading (when the rotator cuff does not receive appropriate physiological stress) and overloading (when tensile loading exceeds the tendon’s internal capacity to repair) are suggested to bring about maladaptive responses in tendon structure, which may produce pathology and pain.

As well as patho-anatomical factors, physical factors which include posture (Kebaetse et al 1999), scapulohumeral rhythm (Ludewig and Cook 2000), muscle length (Borstad 2006), posterior capsule tightness (Tyler and Nicholas 2000) and shoulder and scapular strength (Burkhart et al 2000), have also been implicated in the pathogenesis and perpetuation of shoulder pain. The posture of the thoracic spine and scapula are of key relevance here, as increased thoracic kyphosis and alterations in scapular position and scapular kinematics are hypothesised to dynamically compromise the subacromial space and produce local pathology.

A contemporary understanding of pain suggests that psychological factors may be involved in shoulder pain. A recent study reported that mental health had a stronger correlation with shoulder pain intensity compared to tear severity observed on Magnetic Resonance Imaging in people with full-thickness rotator cuff tears (Wylie et al 2016). Furthermore, prognostic studies have emphasised the importance of psychological risk factors, including depression and anxiety, in the development of chronic shoulder pain (Horsley 2011, Struyf et al 2016, Reilingh et al 2008). Another study has shown that greater disability on the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire and higher pain intensity on the Brief Pain Inventory was associated with social factors (language, professional qualification) and psychological factors (catastrophising, depression) in people with chronic shoulder pain (Wolfensberger et al 2016). Lifestyle factors may also contribute to shoulder pain. For example, shoulder pain and disability, as measured on the Shoulder Disability Questionnaire, have been correlated with subjective measures of sleep (Tekeoglu et al 2013). Rechardt and colleagues demonstrated that weight-related factors, especially abdominal obesity, type 1 diabetes mellitus and smoking are associated cross-sectionally with shoulder pain (Rechardt et al 2010). Although cognitive factors have not yet been extensively researched with regard to shoulder pain, some studies have demonstrated catastrophising (George et al 2008) and fear-avoidance (van der Windt et al 2007) to be associated with shoulder pain intensity.

The interplay of these factors may determine the dominant mechanism underlying an individual’s shoulder pain. Many people with shoulder pain present with localised pain, which is intermittent and aggravated and eased by specific movements and postures (Littlewood et al 2014a). This clinical profile may be indicative of peripheral nociception (Smart et al 2012a) and may be related to structural pathology driven by physical factors. However, some people may have widespread pain which is not localised to the shoulder, more constant in nature and follows an unpredictable pattern of pain provocation. This clinical picture is likely to reflect central sensitisation (Smart et al 2012b) and may involve additional or isolated psychological, cognitive and lifestyle factors.
1.4 Interventions for shoulder pain

1.4.1 Evidence for current management

Shoulder pain may be treated through conservative and/or surgical approaches. However, the evidence to support any one treatment approach above another is limited, as well as the strength of evidence for any one specific type of conservative (Green et al 2003) or surgical (Gebremariam et al 2011) intervention. Acromioplasty, with or without rotator cuff repair, is the most common surgical operation performed on the shoulder (Paloneva et al 2015), with a 254% increase in incidence from 1996 to 2006 in the USA (Vitale et al 2010) and a 746% increase from 2001 to 2010 in the UK (Judge et al 2014). Despite this, there is a substantial weight of high quality systematic reviews which demonstrate that long-term results of surgical approaches are not better than those of conservative management (Dorrestijn et al 2009, Coghlan et al 2008, Ketola et al 2009, Ketola et al 2013).

Less invasive treatments for shoulder pain include non-steroidal anti-inflammatory drugs, corticosteroids (oral or injection) and acupuncture. Cochrane reviews have provided some evidence to support the short-term effectiveness of these interventions in comparison to placebo, but the effects do not last in the long-term (Buchbinder et al 2003, Green et al 2005). Limitations including small sample sizes, weak methodological quality, heterogeneity in terms of populations studied and interventions and lack of long-term follow-up hinder the ability of these systematic reviews to draw valid conclusions.

Physiotherapy may consist of manual therapy (e.g. joint mobilisations, soft tissue massage), active or passive exercise and/or electrotherapeutic modalities (e.g. laser therapy, ultrasound). The efficacy of these interventions were reviewed by a previous Cochrane review which demonstrated a lack of long-term effectiveness of several electrotherapeutic modalities and no strong evidence to support any physiotherapeutic intervention above another (Green et al 2003). While previous systematic reviews and randomised controlled trials (RCTs) have supported a combination of exercise and manual therapy (Michener et al 2004, Faber et al 2006, Braun et al 2013), an equal weight of evidence has concluded that there is no difference in clinical outcome between structured exercise with or without manual therapy (Kachingwe et al 2008, Chen et al 2009, Trampios and Kitios 2006). Further, a previous RCT reported that a specific exercise regime was as effective as both corticosteroid
injection alone and exercise combined with physiotherapy modalities for people with non-specific shoulder pain (Ginn and Cohen 2005).

1.4.2 Evidence for exercise interventions

Shoulder exercise has emerged as the cornerstone of the physiotherapy treatment for shoulder pain (Hanchard et al 2004, Diercks et al 2014). There have been several systematic reviews which have synthesised the evidence regarding the effectiveness of exercise for the management of shoulder pain (Kuhn 2009, Abdulla et al 2015, Hanratty et al 2012, Braun and Hanchard 2010, Desmeules et al 2003, Kromer et al 2009) with varying conclusions. The majority of reviews, which included only RCTs, concluded a moderate to strong level of evidence supporting exercise interventions for shoulder pain (Kuhn 2009, Abdulla et al 2015, Hanratty et al 2012, Kromer et al 2009, Littlewood et al 2012), while others concluded that the evidence was limited or unclear (Braun and Hanchard 2010, Desmeules et al 2003). The conflicting results between systematic reviews may be due to the differences in search strategies and thus the articles obtained, differences in tools used to critically appraise studies and differences in approaches to data synthesis. The reviews appeared to be of satisfactory methodological quality, measured against the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) tool, as all but one (Kuhn 2009) performed a comprehensive search strategy using two reviewers and two data extractors, provided adequate detail of included studies and incorporated an assessment of quality into their conclusions. However, two reviews (Braun and Hanchard 2010, Desmeules et al 2003) included studies in which exercise formed one part of a multimodal intervention, which may lead to biased conclusions about the effectiveness of exercise. The largely supportive evidence of the effectiveness of exercise for people with shoulder pain is reflected in the building number of clinical practice guidelines which recommend exercise to be an integral component of treatment, both in the acute and chronic stages of shoulder pain (Albright et al 2001, Hopman et al 2013, Diercks et al 2014).

1.4.3 Rationale for focussing on thoracic kyphosis

Exercise programmes typically contain a number of exercises which target several physical factors, including shoulder and scapular strength, shoulder movement, muscle length and/or thoracic posture (Kuhn 2009, Hanratty et al 2012, Littlewood et al 2012). However,
the primary outcomes of shoulder pain interventions are usually self-report measures of pain and disability, with fewer studies using outcomes to measure physical impairments. Therefore, it is unclear which of these physical factors, if any, change in response to a shoulder exercise programme and are important drivers of the self-reported clinical improvements. Common outcome measures at impairment level tend to be shoulder range of motion (Senbursa et al 2007, Kachingwe et al 2008) and shoulder strength (Ginn and Cohen 2005, Lombardi et al 2008, Maenhout et al 2013). Recently, clinical intervention studies have taken pre and post measurements of scapular position (Struyf et al 2013, Roy et al 2009), in order to better understand the effects of the intervention. Treatment is commonly directed towards addressing thoracic spine posture in people with shoulder pain (Kachingwe et al 2008, Bennell et al 2010, Walther et al 2004, Engebretsen et al 2009, Conroy and Hayes 1998, Kuhn 2009, McClure et al 2004) and has been described as thoracic extension exercises (McClure et al 2004, Bang and Deyle 2000, Walther et al 2004, Bennell et al 2010, Kuhn 2009), postural correction exercises (Conroy and Hayes 1998, Kachingwe et al 2008) and taping to promote thoracic spine extension (Bennell et al 2010). Despite the perceived importance of thoracic spine posture in shoulder pain rehabilitation, it is unclear if exercises aimed to reduce thoracic kyphosis or improve postural awareness are creating alterations in resting thoracic kyphosis. To date, only one study (McClure et al 2004) has attempted to both modify and measure posture, including thoracic kyphosis, through exercise in people with shoulder pain and examine this in relation to clinical outcome. Therefore, relative to the other physical impairments, and despite the importance placed on thoracic spine posture in many exercise programmes, the measurement of thoracic kyphosis as an outcome of exercise interventions has received little research attention.

1.4.4 Mode of exercise delivery

A physiotherapist can deliver exercise to people with shoulder pain on an individual basis or within a group. Consensus is lacking as to the most effective mode of treatment delivery for people with non-specific shoulder pain (Klintberg et al 2015). Individual physiotherapy is the most widely adopted approach for musculoskeletal conditions (Tiffreau et al 2007). However, group exercise classes may be as effective, with the potential benefits of providing social support and potentially a lower cost compared to physiotherapy delivered individually (Toomey et al 2015). Two recent systematic reviews examined the effectiveness of group exercise classes for people with musculoskeletal pain (Toomey et al 2015, O’
Keeffe et al. 2016). Toomey et al. (2015) reported that interventions which included group education were as effective as individual physiotherapy and medical management in people with knee osteoarthritis and low back pain. Similarly, O’ Keeffe et al. (2016) concluded no clinically significant differences between group and individual physiotherapy and if small differences existed, they were in favour of the group intervention. This review included a range of musculoskeletal pain conditions including low back pain, neck pain, knee pain and shoulder pain. In addition to these systematic reviews, a recent RCT in people with frozen shoulder demonstrated that a group receiving a course of exercise classes demonstrated significantly greater functional gains compared to those receiving individual multimodal physiotherapy or home exercise alone (Russell et al 2014). Group exercise classes may also be a means of treating patients sooner. This is important as an increase in duration of symptoms of greater than three months is a strong prognostic indicator of poorer outcome in people with shoulder pain (Kuijpers et al 2004, Bot et al 2005, Reilingh et al 2008). However, research is needed to explore the effectiveness of group-based exercise classes in people with non-specific shoulder pain. Furthermore, as physiotherapy has been traditionally delivered on an individual basis, there is a lack of qualitative research which explores the participant’s experiences of group exercise classes for people with non-specific shoulder pain. This may potentially elucidate further mechanisms by which exercise appears to be effective.

1.5 Posture

1.5.1 References to an ideal posture

The concept of incorrect posture and associated musculoskeletal harm has been described for decades (Cureton 1941, Kendall et al 1952, Turner 1957, Horter 1978, Gray and Grimsby 2004). An ‘ideal’ postural alignment was proposed in relation to a vertical line passing through the body’s centre of gravity (Kendall and McCreary 1993), as demonstrated in Figure 1.1. Deviations from this ‘ideal’ posture were theorised to place the musculoskeletal system at risk of stress, strain, joint instability and muscular imbalance and have been regarded to precede musculoskeletal pathology and pain (Greigel-Morris et al 1992, Kuo et al 2009). However, this postural model is based on anecdotal evidence and clinical observations only. The cross-sectional research which supports the role of posture in pain (Greigel-Morris
et al 1992, Kuo et al 2009) can only describe associations and is unable to infer a cause and effect relationship.

Figure 1.1 A hypothesised ideal posture, assessed using the plumb line described previously (Kendall and McCreary 1993).

1.5.2 Deviations in thoracic spine posture

One such postural deviation described in the literature is an increase in thoracic kyphosis. Griegel-Morris et al. (1992) measured thoracic kyphosis visually in reference to the imaginary plumb line and categorised thoracic kyphosis as ‘within normal limits’, ‘moderate’ or ‘severe’. However, with the use of radiological methods to quantify thoracic kyphosis, Fon et al. (1980) proposed normative degrees of thoracic kyphosis according to age group and gender in 159 people without thoracic spine abnormalities on radiographic assessment, as described in Table 1.1. The most rapid rate of increase in thoracic kyphosis in females was observed in the 50 to 59 year age range, which may suggest the involvement of degenerative processes, including osteoporosis. Although the data presented by Fon et al. (1980) is useful to show a general trend of increasing thoracic kyphosis with age, the degrees of thoracic kyphosis presented here might be specific to the population and measurement procedure used in this study. Further, the small samples sizes, especially in the older age ranges, could produce biased estimates. It is possible that variations in these values may be demonstrated with the emergence of further research. Figure 1.2 provides a visual representation of a range of thoracic kyphosis angles in sitting.
<table>
<thead>
<tr>
<th>Age range (years)</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean (SD) thoracic kyphosis (degrees)</td>
</tr>
<tr>
<td>2-9</td>
<td>26</td>
<td>20.88 (7.85)</td>
</tr>
<tr>
<td>10-19</td>
<td>28</td>
<td>25.11 (8.16)</td>
</tr>
<tr>
<td>20-29</td>
<td>37</td>
<td>26.27 (8.12)</td>
</tr>
<tr>
<td>30-39</td>
<td>26</td>
<td>29.04 (7.93)</td>
</tr>
<tr>
<td>40-49</td>
<td>20</td>
<td>29.75 (6.93)</td>
</tr>
<tr>
<td>50-59</td>
<td>10</td>
<td>33 (6.46)</td>
</tr>
<tr>
<td>60-69</td>
<td>9</td>
<td>34.67 (5.12)</td>
</tr>
<tr>
<td>70-79</td>
<td>3</td>
<td>40.67 (7.57)</td>
</tr>
</tbody>
</table>

Table 1.1 Normative values of thoracic kyphosis as reported by Fon et al. (1980), who used the Cobb angle calculated from T2 to T12 vertebral endplates.

‘Thoracic hyperkyphosis’ is described as an abnormally accentuated thoracic spine curvature (Kado et al 2009a). In the presence of limited normative data, there are no uniform diagnostic criteria to define thoracic hyperkyphosis. However, based on the 95% upper percentiles derived from previous work (Fon et al 1980), normal degrees of thoracic kyphosis are generally considered to be 20-40° in adults (Kado et al 2014, Katzman et al 2010, Greendale et al 2011). Larger cohorts of community dwelling women in the Study of Osteoporotic Fractures (n = 944), the Fracture Intervention Trial (n = 6,459) and the Rancho Bernardo Study (n = 854) reported slightly greater mean thoracic kyphosis angles of 44° to 49° in women over 50 (Schneider et al 2004), 55 (Ensrud et al 1997) and 65 (Kado et al 2013) years of age respectively. However, these studies contained both people with and without osteoporosis, making it difficult to delineate thoracic kyphosis in people with and without this condition. The exact causes of thoracic hyperkyphosis are unclear, but may

![Figure 1.2](image-url)

Kado et al. (2014) suggested that a cut-off for a normal degree of thoracic kyphosis may not exist. Rather, thoracic kyphosis may need to be considered as a continuum, where the threshold for thoracic hyperkyphosis may be dependent on specific impairments (Kado et al 2014). As there has been no longitudinal research to associate variations in thoracic kyphosis as a risk factor for the development of shoulder pain, there is no definition of a threshold for thoracic hyperkyphosis in people with shoulder pain. Therefore, in order to consider the role of thoracic kyphosis in shoulder pain, this thesis will consider the mean and standard deviation angle of thoracic kyphosis for the sample studied.

1.6 The relationship between thoracic kyphosis and the shoulder

An increase in thoracic kyphosis in respect to an individual’s normal thoracic kyphosis has been considered by many to contribute to the development and maintenance of shoulder pain (Gray and Grimsby 2004, Sahrmann 2002, Kebaetse et al 1999, Gumina et al 2008). A biomechanical relationship between the thoracic spine and the shoulder is evident as the thoracic spine has been shown to actively extend during unilateral (Stewart et al 1995) and bilateral (Crawford and Jull 1993) shoulder elevation. However, as of yet, a direct relationship between thoracic kyphosis and shoulder pain has not been established. There has been some research which examines whether people with shoulder pain demonstrate higher degrees of thoracic kyphosis compared to healthy controls (Lewis et al 2005a, Theisen et al 2010, Greenfield et al 1995). However, a systematic review is needed to synthesise this evidence and to provide guidance to physiotherapists regarding the level of consensus in the literature. Chapter 2 provides a systematic review which examines the association between thoracic kyphosis and shoulder pain, function and range of motion (ROM).

1.6.1 Effect of thoracic kyphosis on scapular position and scapular kinematics

According to Sahrmann (2002), the thoracic spine may influence the shoulder joint through an alteration in scapular position and scapular kinematics. Two studies, which used a
repeated-measures design, compared scapular resting position and kinematics in slouched and erect thoracic postures in relatively small samples of healthy subjects (Kebaetse et al 1999, Finley and Lee 2003). Both studies demonstrated significantly more anterior tilt and internal rotation of the scapula in a maximally slouched posture, at rest and during shoulder abduction (Finley and Lee 2003) and flexion in the scapular plane (Kebaetse et al 1999). Contrary to popular belief, however, both studies demonstrated increased upward rotation of the scapula at rest in a slouched posture, which in theory creates a potential increase in the subacromial space. Both studies reported comparable degrees of upward rotation between postures when elevating the shoulder as far as 90°. Although Finley and Lee (2003) did not measure movement above 90° abduction, Kebaetse et al. (1999) demonstrated less upward rotation during flexion in the scapular plane above 90° in a slouched posture compared to an upright posture. The methodological differences between these studies may help to explain the variability in results. Both studies used different techniques to measure scapular kinematics, namely an electromagnetic sensor device, in which the acromion was the only scapular site placed with a sensor (Finley and Lee 2003) and an electronic system in which measurement was based on the examiner moving a probe over three points on the scapula (Kebaetse et al 1999). In addition, the samples sizes were very small, which might expose the results to individual variation between people. The contradictory findings of these studies indicate a lack of evidence at present to suggest a consistent and detrimental effect of increased thoracic kyphosis on scapular position and scapular kinematics.

1.6.2 Effect of thoracic kyphosis on acromiohumeral distance

Hypotheses regarding the influence of the thoracic spine on scapular position also implicate the thoracic spine in influencing acromiohumeral distance, i.e. linear representation of the subacromial space. Grimsby and Gray (1997) suggested that increased thoracic kyphosis may lower the acromion process in relation to the humerus. Hence, some research has measured the direct effect of changing thoracic kyphosis on acromiohumeral distance (Kalra et al 2010, Gumina et al 2008). Unfortunately, the level of experience of the investigators who undertook the imaging was not stated in these studies. One of these studies compared the effect of neutral, slouched and erect thoracic posture on ultrasound acquired acromiohumeral distance in people with rotator cuff tendinopathy and healthy controls, with the arm at rest and at 45° active abduction (Kalra et al 2010). No significant differences in acromiohumeral distance were reported throughout the thoracic postures while the shoulder
was at rest and the majority of postures at 45° shoulder abduction. The authors did note a statistically significant increase in acromiohumeral distance in an upright posture compared to a normal posture in the full group at 45° shoulder flexion (mean difference 1.2mm). However, as displayed in Table 1.2, the mean acromiohumeral distance in all groups was smaller in the normal thoracic posture when compared to the slouched posture. Secondly, in most cases, the symptomatic group demonstrated a larger mean acromiohumeral distance compared to the control group who did not have shoulder pain. These findings highlight the discrepancies in the hypotheses that an increased thoracic kyphosis reduces the subacromial space and that a reduced subacromial space is a consistent feature of shoulder pain. However, a criticism of this study is that the postures used were artificially induced and may not truly reflect how a person moves. Additionally, although this study achieved statistical power, the sample size was small.

<table>
<thead>
<tr>
<th>Group</th>
<th>Upright posture</th>
<th>Normal posture</th>
<th>Slouched posture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest</td>
<td>Abduction</td>
<td>Rest</td>
</tr>
<tr>
<td>All</td>
<td>12.6 (2.5)</td>
<td>9.8 (2.0)</td>
<td>12.1 (2.6)</td>
</tr>
<tr>
<td>Rotator cuff tendinopathy</td>
<td>12.7 (2.6)</td>
<td>9.9 (2.1)</td>
<td>12.5 (2.6)</td>
</tr>
<tr>
<td>Control</td>
<td>12.5 (2.3)</td>
<td>9.6 (1.9)</td>
<td>11.8 (2.5)</td>
</tr>
</tbody>
</table>

Table 1.2 Mean (SD) ultrasound measured acromiohumeral distance (mm) in upright, normal and slouched thoracic postures, at rest and 45° shoulder abduction, in people with rotator cuff tendinopathy and healthy controls, as reported by Kalra et al. (2010).

In contrast, Gumina et al. (2008) provided a radiographic comparison of acromiohumeral distance in people with a thoracic kyphosis of greater than 40° compared to controls. Within the hyperkyphotic group, this study also analysed the acromiohumeral distance in people with thoracic kyphosis of greater than and less than 50°. The study reported that people with thoracic kyphosis of greater than 40° had significantly reduced mean acromiohumeral distance compared to those with a normal thoracic kyphosis (p<0.01). Also, the individuals with thoracic kyphosis greater than 50° had a smaller acromiohumeral distance than those with thoracic kyphosis between 40-50° (p<0.01). However, a power calculation was not carried out in this study. Further, a large confounding factor was that the thoracic kyphosis of the control group was not described and it may not have been measured. Therefore, it cannot be assumed that the control group had a smaller mean angle of thoracic kyphosis. Furthermore, there were large mismatches between the samples sizes in all groups analysed, with the more kyphotic groups being considerably smaller. Therefore, the values obtained may have reflected individual variation.
1.6.3 Effect of thoracic kyphosis on shoulder muscle activity

It has also been hypothesised that increased thoracic kyphosis can affect muscle activity around the shoulder girdle (Ludewig and Cook 2000). Anecdotal evidence suggests that increased thoracic kyphosis causes the anterior muscles of the shoulder including pectoralis major and minor and serratus anterior to shorten, while the posterior muscles such as the erector spinae, rhomboids and trapezius become stretched and weakened, thereby influencing length tension relationships around the shoulder girdle (Grimsby and Gray 1997, Borstad 2006). Furthermore, Greig et al. (2008) attempted to compare upper and lower trapezius electromyographic (EMG) activity between normal thoracic kyphosis and a reduced thoracic kyphosis with postural tape, during balance tasks in standing. This study reported no statistical difference in EMG activity of these muscles between thoracic postures. However, the change in thoracic kyphosis of approximately 3° reported in this study was arguably small and is within measurement error of the manual inclinometers used (Barrett et al 2013).

1.6.3.1 Summary of the relationship between thoracic kyphosis and the shoulder

These studies clearly demonstrate the weak and often contradictory evidence regarding the effect of thoracic kyphosis on scapular position, scapular kinematics, acromiohumeral distance and shoulder muscle activity. Of concern, much of this evidence regarding the effect of thoracic kyphosis on shoulder mechanics is carried out in people without shoulder pain. Importantly, exercises which aim to reduce thoracic kyphosis and return posture to an ‘ideal’ alignment are invested in by patients and physiotherapists without any concrete evidence that (i) the patient’s thoracic kyphosis differs from those without pain, (ii) the exercises can modify thoracic kyphosis and (iii) a change in thoracic kyphosis causes clinical improvements. The next step to better understand the role of thoracic kyphosis in shoulder pain may be to measures if changes in thoracic kyphosis occur alongside changes in pain and disability following variations in exercise programmes in people with non-specific shoulder pain. It is first important to introduce the potential for thoracic kyphosis to be reduced using targeted exercise and to be measured clinically.
1.7 Is thoracic kyphosis modifiable and measurable?

Edmondston and Singer (1997) suggested that thoracic kyphosis is characterised by the morphology of the vertebral elements and is largely unmodifiable due to the limited capacity of the thoracic spine to actively extend. This has been supported by an earlier study which demonstrated that increased EMG activity of the thoracic extensors, brought about by carrying a load in front of the body, produced changes in lumbar curvature but not thoracic kyphosis (Klausen 1965). This suggests that muscle activity in the thoracic extensors may have little effect on reducing thoracic kyphosis, whereas it may produce postural changes elsewhere in the spinal column. This seems plausible as the cervical and lumbar spinal segments are much more mobile than the thoracic spine (Oda et al 2002, Panjabi and White 1980).

However in recent years, several studies have emerged which have reported changes in thoracic kyphosis after exercise-based physiotherapy interventions. A systematic review synthesised the evidence from 13 studies examining the effectiveness of targeted exercise on reducing thoracic hyperkyphosis in people over 45 years with thoracic hyperkyphosis (Bansal et al 2014). Although a clinically meaningful change in thoracic kyphosis has not been determined, the majority of studies under review reported a mean reduction in thoracic kyphosis of 2-6° (Bansal et al 2014). There was considerable heterogeneity between studies regarding the duration of treatment, which most commonly ranged from 8 to 12 weeks, and specific exercises used. However, an exercise component aimed to increase back extensor strength using thoracic extension exercises was used by all studies under review.

As the studies under review were predominantly carried out in older populations, the effect of thoracic extension exercises on reducing thoracic kyphosis in younger populations is not yet clear. Hinman (2004) reported that pre-menopausal women demonstrated nearly a three times greater range of thoracic extension compared to older, post-menopausal women, suggesting a potential loss of modifiability of thoracic kyphosis with increasing age. Further to this, some studies under review (Bansal et al 2014) specifically included people with osteoporosis and vertebral compression fractures (Renno et al 2005, Abreu et al 2012, Bennell et al 2010, Schuerman 1998). Therefore, the effect of thoracic exercises for reducing thoracic kyphosis in people without osteoporosis is also unclear. This systematic review must also be critiqued for its exclusion of non-English studies and the largely low quality studies which were not homogenous enough to conduct a meta-analysis.
1.7.1 Measurement of thoracic kyphosis

Radiographic imaging of the spine in the sagittal plane, which provides a Cobb angle, is recognised as the gold standard for thoracic kyphosis measurement (Briggs et al 2007). The Cobb angle is the angle formed between a line drawn from the superior endplate of the upper thoracic vertebra and the inferior endplate of the lower thoracic vertebra (Harrison et al 2001), although there is variation between studies regarding the specific vertebral levels used (Azadinia et al 2014, Briggs et al 2007, Greendale et al 2011).

However, the use of the Cobb angle has limitations. Difficulty in visualising the desired endplates on X-ray images has been reported, especially in subjects with osteoporosis or scoliosis (Singer et al 1994). Previously, different spinal levels have been used to provide either a global degree of thoracic kyphosis from T1-T12 or a regional degree of thoracic kyphosis from T3–T11 (Jackson et al 1988), T3–T12 (Singer et al 1994), T4–T11 (Itoi 1991) and T4-T9 (Goh et al 2000). The reliability of using these levels has not yet been compared. The Cobb method has also been criticised for its dependence on an upper and lower thoracic spinal segment for an accurate representation of thoracic kyphosis (Harrison et al 2001). In this way, the Cobb method only provides information limited to the chosen vertebrae and fails to identify regional changes within the curve, such as the presence of vertebral compression fractures. Alternative radiographic measurement methods have been suggested, such as the vertebral centroid method (Chen 1999) and the posterior tangent method (Harrison et al 2001). However, a repeated measures study has shown that all three of these radiographic measurement techniques have similar levels of inter-rater and intra-rater reliability, with ICCs in the good and excellent ranges (0.59–0.75 and 0.75–1.0, respectively) (Harrison et al 2001).

The limited accessibility to spinal radiographs in clinical practice as well as their unsuitability for regular assessment has encouraged a range of non-invasive methods to be adopted for use in clinical settings. Measurement of thoracic kyphosis from the skin surface presents particular challenges to clinicians, including accurate palpation, the intervening soft tissues between the vertebrae and the skin and potential variability in the handling of the instrument. At present, there is very little guidance as to the most appropriate method for clinicians to measure thoracic kyphosis with good reliability and validity. Chapter 3 of this thesis will synthesise the current evidence regarding the reliability and validity of methods for measuring thoracic kyphosis, as well as presenting both a reliability and validity study of two specific instruments.
1.8 Chapter 1: Summary

1.8.1 Summary of key points

- Shoulder pain is a common musculoskeletal complaint associated with a substantial economic burden.
- Clinically, determining the source of shoulder pain using special tests or clinical imaging remains a considerable challenge, with a growing number of studies labelling participants as having non-specific shoulder pain.
- A range of factors have been implicated in non-specific shoulder pain, including physical, psychological, lifestyle and cognitive factors. Thoracic kyphosis is one of the physical factors proposed as contributing to the development of shoulder pain.
- Shoulder exercise is recognised as the hallmark of evidence-based treatment for people with shoulder pain and may be as effective when delivered through an exercise class. Although thoracic extension exercises are typically included in shoulder exercise programmes, it is not clear if thoracic kyphosis is modifiable in response to exercise and is important for changing shoulder pain and disability.
- Studies have attempted to determine the effect of thoracic kyphosis on the scapula, acromiohumeral distance and shoulder muscle activity and have provided conflicting results. A systematic review which synthesises the evidence regarding the association between thoracic kyphosis and shoulder pain, function and ROM is justified in order to further evaluate the role of thoracic kyphosis in shoulder pain.
- One explanation for the high levels of disagreement between studies which attempt to measure thoracic and scapular posture is their use of different measurement devices, which lack reliability and validity. A systematic review which details the reliability and validity of thoracic kyphosis measurement methods is required in order to provide guidance to researchers and clinicians who wish to measure thoracic kyphosis.
- Clinical hypotheses suggest that thoracic kyphosis may be reduced after a structured exercise programme. In order to further examine the relationship between thoracic kyphosis and non-specific shoulder pain, it may be of benefit to investigate the outcomes of an intervention aimed to reduce thoracic kyphosis through an exercise class in this population. A qualitative evaluation of participant’s experiences of shoulder exercise classes is also warranted.
1.8.2 Aims of thesis

A review of the literature indicates that the role of thoracic kyphosis in the development of non-specific shoulder pain is poorly understood. As the assessment and treatment of thoracic spine posture is commonly addressed by physiotherapists treating the shoulder, the evidence base to support this practice needs to be clearer. This focus of this thesis is to contribute to the understanding of the role of thoracic kyphosis in shoulder pain.

The aims of this doctoral thesis are:

**Aim 1: To review the literature which investigates an association between thoracic kyphosis and shoulder pain, function and range of motion.**

In order to address the gap in the literature regarding the role of thoracic kyphosis in shoulder pain, a systematic review is required to establish the current level of evidence on the topic. The specific objective, which will be achieved in Chapter 2 (Study I), is to conduct a systematic review of the evidence relating to the association between thoracic kyphosis and shoulder pain, function and range of motion.

**Aim 2: To review the reliability and validity of non-radiographic methods of thoracic kyphosis measurement.**

In order to establish the most reliable and valid method for the measurement of thoracic kyphosis, a systematic review is required to synthesise the current available evidence. The specific objective, which will be achieved in Chapter 3 Study II, is to conduct a systematic review which synthesises the evidence regarding the reliability and validity of currently established methods to measure thoracic kyphosis.

**Aim 3: To determine the reliability and validity of the Flexicurve and manual inclinometer for the measurement of thoracic kyphosis.**

In order to build on the evidence found in the systematic review in Aim 2, two clinically useful measurement tools, the Flexicurve and manual inclinometer, will be investigated further. The specific objectives, which will be achieved in Chapter 3, are to examine the inter-rater and intra-rater reliability of the Flexicurve and manual inclinometer (Study III) and the concurrent validity of the Flexicurve and manual inclinometer (Study IV) for the measurement of thoracic kyphosis.
**Aim 4:** To evaluate the effect of two different exercise interventions on pain, disability and thoracic kyphosis among two groups of people with non-specific shoulder pain.

As described previously, there is a lack of research which measures thoracic kyphosis in response to exercise based interventions in people with shoulder pain. The specific objective, in Chapter 4, Study V, is to conduct a case series in which shoulder pain, disability and thoracic kyphosis will be measured in two groups of people with non-specific shoulder pain at baseline, six weeks and six months following the start of two different group exercise class interventions.

**Aim 5:** To examine the experiences of people who participated in physiotherapy group exercise classes for the treatment of non-specific shoulder pain.

Currently, little is known about the experiences of participating in an exercise class for people with non-specific shoulder pain. Qualitative research has the ability to enrich quantitative findings and provide important insights into patient experiences. The specific objective, which will be achieved in Chapter 4, Study VI, is to conduct a qualitative study examining the experiences of people with non-specific shoulder pain who participated in a group exercise class. This study is independent of Study V, with the use of different participants.

This thesis is presented in a research publication format. There are six studies presented in the thesis. Three studies are published in a peer-reviewed journal and three studies are being prepared for publication. All papers have been formatted in terms of referencing styles, table layout and numbering to provide uniformity across the thesis. The text remains unchanged other than the minor changes requested by examiners.
2 Chapter 2: Introductory Systematic Review

This chapter presents Study I. This is a systematic review which examines the association between thoracic kyphosis and shoulder pain, function and range of motion. Specifically, the studies under review compare thoracic kyphosis between groups with and without shoulder pain and examine the effect of changing thoracic kyphosis on shoulder pain and range of motion. This study has been published in Manual Therapy.
2.1 Study I: Is thoracic spine posture associated with shoulder pain, function and range of motion? A systematic review.


2.1.1 Abstract

Introduction: Increased thoracic kyphosis is considered a predisposing factor for subacromial impingement syndrome (SIS), though there is uncertainty about the nature of the relationship between SIS and thoracic spine posture. The aim of this systematic review was to investigate the relationship between thoracic kyphosis and shoulder pain, function and shoulder range of motion (ROM).

Methods: Two reviewers independently searched eight electronic databases and identified relevant studies by applying eligibility criteria. Sources of bias were assessed independently by two reviewers using a previously validated tool (Ijaz et al 2013). Data were synthesised using a level of evidence approach (van Tulder et al 2003).

Results: Ten studies were included. Four studies were rated as low risk of bias, three at moderate risk of bias and three at high risk of bias. There is a moderate level of evidence of no significant difference in thoracic kyphosis between groups with and without shoulder pain (p>0.05). One study at high risk of bias demonstrated significantly greater thoracic kyphosis in people with shoulder pain (p<0.05). There is a strong level of evidence that maximum shoulder ROM is greater in erect postures compared to slouched postures (p<0.001), in people with and without shoulder pain.

Conclusions: Thoracic kyphosis may not be an important contributor to the development of shoulder pain. While there is evidence that reducing thoracic kyphosis facilitates greater shoulder ROM, this is based on single-session studies in which the long-term clinical relevance is unclear. Higher quality research is warranted to fully explore the role of thoracic posture in shoulder pain.
2.1.2 Introduction

Shoulder pain is a common musculoskeletal condition and is often associated with substantial morbidity, with a third of patients demonstrating persisting restriction of movement, loss of function and/or pain after one year (Reilingh et al 2008, Greving et al 2012). The most common source of shoulder pain reported in clinical practice is subacromial pain (van der Windt et al 1995). Subacromial pain syndrome (SAPS) has been described as non-traumatic shoulder pain, localised around the acromion, which worsens during or subsequent to lifting the arm (Lewis 2011). Due to the limited diagnostic accuracy of clinical tests (Lewis 2009), SAPS has been adopted as an overarching term encompassing subacromial impingement, bursitis, supraspinatus tendinopathy and rotator cuff tendinopathy (Lewis 2011, Diercks et al 2014, Engebretsen et al 2009). The pain and limitation of shoulder movement associated with shoulder pain may reduce shoulder function and health-related quality of life (Duckworth et al 1999, MacDermid et al 2004, Smith et al 2000).

The role of the thoracic spine in shoulder function has been investigated. Previous studies have demonstrated that approximately 15° of thoracic extension mobility is required for full bilateral shoulder flexion, in both younger and older populations (Crawford and Jull 1993). Other research suggests that full unilateral shoulder elevation requires approximately 9° of thoracic extension (Stewart et al 1995). Thoracic hyperkyphosis, an angulation of the thoracic spine of greater than 40° (Greendale et al 2011) or 50° (Willner 1981, Teixeira and Carvalho 2007), has been implicated as a contributing factor to shoulder pain (Grimsby and Gray 1997). Crawford and Jull (1993) demonstrated that older adults with a large thoracic kyphosis had reduced arm elevation. A recent cross-sectional study involving 525 volunteers compared the prevalence of rotator cuff tears across four postural classifications; ideal alignment, kyphotic-lordotic posture, flat-back posture and sway-back posture (Yamamoto et al 2015). This study reported that the prevalence of rotator cuff tears, diagnosed using ultrasound, was lowest in the ideal posture at 2.9% and highest in the kyphotic-lordotic posture at 65.8%, which points towards a posture-impairment model.

Several hypotheses have been proposed to describe the mechanisms by which thoracic hyperkyphosis effects the shoulder and may lead to shoulder pain. Firstly, it has been reported that an increase in thoracic kyphosis is associated with a more elevated and anteriorly tilted resting position of the scapula in pain-free participants (Kebaetse et al 1999, Culham and Peat 1993). As a result, the acromion may be in a more inferior and anterior position, hypothetically reducing the subacromial space (Solem-Bertoft et al 1993, Borstad et
Participants with thoracic hyperkyphosis have been reported to have a smaller acromiohumeral distance as measured on radiographic images compared to non-kyphotic participants (Gumina et al 2008). However, a larger study reported no difference in acromiohumeral distance between induced slouched and normal postures with the arm in the neutral position (Kalra et al 2010). Gray and Grimsby (2004) reported that these potential change in scapular position, as a result of increased thoracic kyphosis, result in shoulder pain as the supraspinatus tendon and/or the subacromial bursa become impinged against the anterior edge of the acromion process during shoulder elevation. It is hypothesis that the compression and irritation of the upper portion of the supraspinatus tendon manifests in a nociceptive input which initiates symptoms of shoulder pain (Gray and Grimsby 2004).

An additional hypothesis suggests that thoracic spine curvature may influence the shoulder girdle through muscular attachments (Michener et al 2003). Again, the evidence to support this is scant and the data are largely based on pain-free populations. It is acknowledged that the thoracic spine shares supporting musculature with the scapula, humerus and thoracic cage (Culham and Peat 1993). Increased thoracic kyphosis is hypothesised to change the length-tension relationship of the muscles attached to the scapula (Grimsby and Gray 1997). In pain-free people, adopting a slouched posture was reported to decrease maximal glenohumeral abduction strength (Kebaetse et al 1999), although this posture was fixed. A mechanical disadvantage may reduce the capacity of the rotator cuff to stabilise the humeral head during glenohumeral elevation (Michener et al 2003).

The impingement model of SAPS has been widely challenged in recent research with a variety of other mechanisms such as mechanical overload or lifestyle factors purported to be important in the development of shoulder pain (Lewis 2011, Lewis et al 2015). In addition, a recent systematic review concluded that there is insufficient evidence for the role of scapular orientation in SAPS (Ratcliffe et al 2014). This leaves considerable uncertainty concerning the relationship between spinal posture and shoulder pain. The aim of this systematic review is to establish the current level of evidence regarding the relationship between thoracic kyphosis and shoulder pain, function and range of motion (ROM). The specific research questions are:

1. Is there a difference in thoracic kyphosis between groups with and without shoulder pain?
2. What is the effect of changing thoracic kyphosis on shoulder pain, function and ROM in people with or without shoulder pain?
2.1.3 Methods

This review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Liberati et al 2009) and was registered with PROSPERO (ID: CRD42015024834).

2.1.3.1 Identification and selection of studies

An electronic search was conducted by two reviewers (EB, MOK) in July 2015 using the following databases: Medline, CINAHL, AMED, SPORTDiscus, PsycINFO, PsycARTICLES, General Science and Biomedical Reference Collection. A combination of three search lines was used;

("shoulder" OR "glenohumeral") [Title/Abstract] AND (“range” OR “movement” OR “motion” OR “pain” OR “function*” OR “disability” OR “symptom*” OR "dyskinesi*”) [Title/Abstract] AND (“spin*” OR "alignment" OR "hyperkypho*" OR "kypho*" OR "postur*" OR “orientation” OR “biomechanic*” OR “curv*” OR "thora*") [Title/Abstract].

Two reviewers (EB, MOK) independently screened the title and abstract of each article, followed by the full texts of those deemed potentially relevant, applying the eligibility criteria. Inclusion and exclusion criteria are displayed in Table 2.1. Both observational and experimental studies were eligible for inclusion. The reference lists of the included studies were manually searched for other relevant studies.

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic posture is examined in relation to shoulder pain, function or range of motion.</td>
<td>The study does not specifically examine shoulder pain in isolation, but includes other pain regions, e.g. cervical spine.</td>
</tr>
<tr>
<td>Studies must have (i) a control group without pain or (ii) involve two different positions/postures involving more/less thoracic kyphosis.</td>
<td>Spinal posture as a whole is considered without commenting specifically on thoracic posture.</td>
</tr>
<tr>
<td>The study is published in English.</td>
<td>Studies not available in the English language.</td>
</tr>
<tr>
<td>Experimental studies must compare the effect of an intervention directly aimed at changing posture, e.g. postural advice.</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1 Eligibility criteria for the inclusion of studies in systematic review.
2.1.3.2 Assessment of risk of bias

Sources of bias were assessed independently by two reviewers (EB, MOK) using a standardised checklist of 10 criteria (Ijaz et al 2013) which was validated for use in observational studies (Shamliyan et al 2010). Each item was rated as a low, high or unclear risk of bias. The 10 items were divided into two hierarchical groups (Ijaz et al 2013). The group with the major items of bias included: exposure definition, exposure assessment, reliability of exposure assessment, analysis bias and confounding factors. The remaining five items were considered as minor domains: attrition, blinding of assessors, selective reporting, funding described and conflict of interest. Studies were considered as low risk of bias if they had low risk in all major domains and ≥2 of the minor domains, moderate risk of bias if they had low risk of bias in ≥4 major and 2 minor domains, or high risk of bias if they had low risk of bias in <4 major domains (Ijaz et al 2013).

For the purpose of this review, the exposure was considered to be thoracic kyphosis. Therefore, to be scored as a low risk of bias in the domain of exposure definition, the level of spinous processes where measurement was taken was required to be stated. To be scored as a low risk of bias in the domain of exposure assessment, the study must have used an objective measurement of thoracic kyphosis, thereby providing a thoracic kyphosis angle. To be scored as low risk of bias in the domain of reliability exposure assessment, the reliability of the measurement tool must have been stated, either by measuring the tool’s reliability in a pilot study or providing reference to its previously established level of reliability. To be scored as low risk of bias in the domain of confounders, between group comparisons of thoracic kyphosis must contain samples of similar gender and age, as these variables influence thoracic kyphosis angle (Fon et al 1980). The remaining six domains were rated as previously recommended (Ijaz et al 2013).

2.1.3.3 Data analysis

One reviewer (EB) extracted data relating to the study design, study population, postures used and outcome measures related to shoulder pain, function and/or range of motion. Variation in the study designs, study population and outcome measures used did not permit the pooling of data in a meta-analysis. Data were synthesised using a level of evidence approach (van Tulder et al 2003), taking into account the risk of bias, the design of the study
and the outcomes of the included studies. Definitions for levels of evidence are outlined in Table 2.2.

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Consistent findings among multiple high quality studies</td>
</tr>
<tr>
<td>Moderate</td>
<td>Consistent findings among multiple low quality studies and/or one high quality study</td>
</tr>
<tr>
<td>Limited</td>
<td>Consistent findings in one low quality study or only one study available</td>
</tr>
<tr>
<td>Conflicting</td>
<td>Inconsistent evidence in multiple studies irrespective of study quality</td>
</tr>
</tbody>
</table>

Table 2.2 Levels of evidence approach used in the systematic review (van Tulder et al 2003).

2.1.4 Results

2.1.4.1 Flow of trials through the review

Figure 1.1 details the flow of studies through the review process. A total of ten studies involving 2,794 participants were included in the review.

Figure 2.1 PRISMA flow diagram
2.1.4.2 Characteristics of the included studies

2.1.4.2.1 Design

Six studies utilised a cross-sectional design which compared thoracic kyphosis between groups with and without shoulder pain (Lewis et al 2005a, McClure et al 2006, Otoshi et al 2014, Lewis and Valentine 2010, Theisen et al 2010, Greenfield et al 1995). Four studies used a same-participant repeated measures design to examine whether different thoracic spine postures influence shoulder ROM. Two of these studies involved a pain-free population (Kanlayanaphotporn 2014, Kebaetse et al 1999), one study included participants with SAPS (Bullock et al 2005) and one used a group with and a group without SIS (Lewis et al 2005b). Two studies that met the eligibility criteria for this review used the same participants to investigate different outcomes of relevance to the review (Lewis et al 2005a, Lewis et al 2005b). One of these studies compared thoracic kyphosis in people with and without shoulder pain (Lewis et al 2005a) and one compared shoulder ROM in different thoracic postures (Lewis et al 2005b). Study characteristics are displayed in more detail in Table 2.3.

2.1.4.2.2 Risk of bias

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Recruitment, setting</th>
<th>Design</th>
<th>n</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanlayanaphotporn 2014</td>
<td>Participants were recruited by convenience sampling, Thailand.</td>
<td>Same-participant repeated-measures design.</td>
<td>30</td>
<td>Pain-free males aged 18-35 years, mean age 20 years. <strong>Exclusion criteria:</strong> history of shoulder problems within the last 6 months, positive signs on the Neer and Hawkins-Kennedy Tests, pain on palpation of the rotator cuff tendons.</td>
</tr>
<tr>
<td>Kebaetse et al 1999</td>
<td>Participants were recruited by convenience sampling, USA.</td>
<td>Same-participant repeated-measures design.</td>
<td>34</td>
<td>Pain-free (18F, 16M, mean age 30.2 (8.7)) <strong>Exclusion criteria:</strong> a history of shoulder pain or shoulder injury, pain with active or resisted isometric shoulder abduction.</td>
</tr>
<tr>
<td>Bullock et al 2005</td>
<td>Participants were recruited from a hospital physiotherapy department, UK.</td>
<td>Same-participant repeated-measures design.</td>
<td>28</td>
<td>28 participants with SIS (14M, 14F, mean age 48.2 (13.9)) <strong>DOS:</strong> mean 3.6 (4.7) years <strong>Diagnostic criteria:</strong> at least 3 of following: positive Neer test, positive Hawkins test, painful arc with active shoulder flexion or abduction, pain with palpation of the rotator cuff tendons, anterior or lateral shoulder pain, pain with resisted isometric abduction.</td>
</tr>
<tr>
<td>McClure et al 2006</td>
<td>Shoulder patients were recruited from university based orthopaedic practice, controls were recruited from the university, surrounding community and contacts of investigators, USA.</td>
<td>Observational, cross-sectional comparison group study.</td>
<td>90</td>
<td>45 participants with SIS (21F, 24M, mean age 45.2 (12.8)) 45 control participants (21F, 24M, mean age 43.6 (12.4)) <strong>DOS:</strong> 2&lt; 1 month, 14= 1-3 months, 12= 3-6 months, 17 &gt; 6 months <strong>Diagnostic criteria:</strong> at least 3 of following: positive Neer test, positive Hawkins impingement test, pain with active shoulder elevation, pain with palpation of the rotator cuff tendons, pain with isometric resisted abduction, and pain in the C5 or C6 dermatome region.</td>
</tr>
<tr>
<td>Lewis et al 2005a, Lewis et al 2005b</td>
<td>Participants were recruited by a specialised shoulder therapist, UK.</td>
<td>This investigation was carried out as part of a placebo-controlled crossover design</td>
<td>120</td>
<td>60 participants with SIS (25F, 35M, mean age 48.9 (15.2)) 60 pain-free participants (31F, 29M, mean age 34.1 (9.9)) <strong>DOS:</strong> mean 1.1 years (SD 2.5 years), range 2 weeks to 22 years <strong>Diagnostic criteria:</strong> at least 4 of the following: positive Neer impingement test, positive Hawkins test, positive empty-can test, painful arc between 60° and 120°, pain with palpation on the greater tuberosity of humerus.</td>
</tr>
<tr>
<td>Study</td>
<td>Recruitment Method</td>
<td>Study Design</td>
<td>Participants</td>
<td>DOS</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------</td>
<td>--------------</td>
<td>------</td>
</tr>
</tbody>
</table>
| Lewis and Valentine 2010      | Participants were recruited through orthopaedic and physical therapy outpatient departments, personal and public advertisements, UK. | This investigation was carried out as part of a test-retest reliability study. | 90           |      | 45 participants with pain (23F, 22M, mean age 43) 45 participants without pain (24F, 21M, mean age 32) DOS: not stated.  
Diagnoses: non-specific shoulder pain (n = 21), rotator cuff tendinopathy (n = 12), frozen shoulder (n = 2), acromioclavicular joint pain (n = 2), glenohumeral instability (n = 2), stable humeral fractures (n = 1), stable scapular fractures (n = 1) |
| Otoshi et al 2014             | People aged over 40 years who attended a local health check-up, Japan.            | This study is part of a cardiovascular case series. | 2144         |      | 95 participants with SIS (64F, 31M, mean age 69.6 (8.6)) 2049 participants without SIS (1221F, 828M, mean age 67.9 (9.0)) DOS: not stated.  
Diagnostic criteria for SIS: shoulder pain during shoulder elevation and a positive Neer or Hawkins impingement test. |
| Greenfield et al 1995          | Participants were recruited by convenience sampling, USA.                        | Observational, cross-sectional comparison group study. | 60           |      | 30 participants with shoulder pain (13F, 17M, mean age 39 (13.9). 30 participants with pain-free shoulders (13F, 17M, mean age 39 (13.7). DOS: Not stated.  
Diagnostic criteria for pain group: 2 out of 4 positive tests: Neer Impingement, Supraspinatus Resisted, Locking and Quadrant tests. |
| Theisen et al 2010             | Participants were recruited from an outpatient orthopaedic and rheumatology clinic, Germany. | Observational, cross-sectional comparison group study. | 78           |      | 39 participants with SIS (16F, 23M, mean age 56.6 (10.2)) 39 participants with no shoulder pain (16F, 23M, mean age 56.1 (10.3)) DOS: Greater than 3 months.  
Diagnostic criteria: diagnosis based on Neer test, Hawkins-Kennedy test, Speed test, and supraspinatus muscle test, also osteophytes on the coracoacromial arch confirmed using X-ray imaging. |

Table 2.3 Descriptive characteristics of studies included in the systematic review.

DOS=duration of symptoms, F=female, M=male, SIS=subacromial impingement syndrome.
Table 2.4 Risk of bias of the studies included in the review.

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Exposure definition</th>
<th>Exposure assessment</th>
<th>Reliability of exposure assessment</th>
<th>Analysis bias</th>
<th>Confounding factors</th>
<th>Attrition</th>
<th>Blinded assessors</th>
<th>Selective reporting</th>
<th>Funding described</th>
<th>Conflict of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanlayanaphotporn 2014</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>UR</td>
<td>LR</td>
</tr>
<tr>
<td>Kebaetse 1999</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>UR</td>
<td>LR</td>
</tr>
<tr>
<td>Bullock 2005</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>UR</td>
<td>UR</td>
</tr>
<tr>
<td>McClure 2006</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>UR</td>
<td>UR</td>
</tr>
<tr>
<td>Lewis 2005a</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>UR</td>
</tr>
<tr>
<td>Lewis 2005b</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>UR</td>
</tr>
<tr>
<td>Otoshi 2014</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>HR</td>
<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>UR</td>
</tr>
<tr>
<td>Lewis and Valentine 2010</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
</tr>
<tr>
<td>Theisen 2010</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
</tr>
<tr>
<td>Greenfield 1995</td>
<td>LR</td>
<td>LR</td>
<td>LR</td>
<td>HR</td>
<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>LR</td>
<td>HR</td>
<td>HR</td>
</tr>
</tbody>
</table>

HR=high risk of bias; LR=low risk of bias; UR=unclear risk of bias.
2.1.4.2.3 Outcome measures

A variety of methods were used for thoracic kyphosis measurement. Three studies used the Flexicurve ruler, measuring from T12 to either T2 (Greenfield et al. 1995, Bullock et al. 2005) or C7 (Kanlayanaphotporn 2014). Four studies used a gravity-dependant manual inclinometer, one measured at T3 (McClure et al. 2006) and three from T1/T2 to T12/L1 (Lewis et al. 2005a, Lewis et al. 2005b, Lewis and Valentine 2010). Both the Flexicurve and the manual inclinometer have been previously shown to have excellent levels of intra-rater and inter-rater reliability (Barrett et al. 2014). One study measured thoracic kyphosis using the Metrecom Skeletal Analysis System which digitised landmarks two inches above and below both T2 and T11 (Kebaetse et al. 1999). The reliability of this method for thoracic kyphosis measurement was previously reported to range from an intraclass correlation coefficient of 0.72 to 0.83 (Fiebert et al. 1993). One study used the wall occiput test (WOT) in which a positive or negative result was obtained based on the participant’s ability to touch a wall behind them with their occiput (Otoshi et al. 2014). However, this measures the extent of thoracic kyphosis while the person tries to press their head back against a firm surface, it could be argued this measures thoracic mobility rather than thoracic curvature. One study used ultrasound topography (Theisen et al. 2010), for which the reliability of static thoracic kyphosis measurement was not reported.

2.1.4.3 The effect of thoracic kyphosis on shoulder pain

Six studies (Lewis et al. 2005a, McClure et al. 2006, Otoshi et al. 2014, Theisen et al. 2010, Greenfield et al. 1995, Lewis and Valentine 2010) compared resting thoracic kyphosis in groups with and without shoulder pain. Values for these are shown in Table 2.5. In comparing a group with SIS to those without shoulder pain, Lewis and colleagues reported that there were no significant differences in resting standing thoracic kyphosis (Lewis et al. 2005a). While this study did not meet adequate statistical power and was rated at a moderate risk of bias, a later study by the same research group was at low risk of bias and reported no significant differences in resting standing thoracic kyphosis between groups with and without shoulder pain (Lewis and Valentine 2010). Similarly, two further studies which compared a group with SIS to an age- and gender-matched control group reported no significant difference in resting thoracic posture (McClure et al. 2006, Theisen et al. 2010). However, these were considered to be at a moderate (McClure et al., 2006) and high (Theisen et al.,
2010) risk of bias. A study with a high risk of bias which compared thoracic kyphosis in a group of people with mixed shoulder diagnoses to a pain-free control group demonstrated no significant difference between groups (Greenfield et al 1995). In contrast, one study with a high risk of bias (Otoshi et al 2014) reported that there was a significant association between a positive WOT and the diagnosis of SIS (OR 1.65, 95% Confidence Interval 1.02-2.64).
<table>
<thead>
<tr>
<th>Study, year</th>
<th>Mean (SD) thoracic kyphosis in degrees (pain group)</th>
<th>Mean (SD) thoracic kyphosis in degrees (control group)</th>
<th>p value</th>
<th>Shoulder ROM in degrees (pain group)</th>
<th>Shoulder ROM in degrees (control group)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>McClure et al 2006</td>
<td>69.4 (6.4)</td>
<td>70.5 (6.0)</td>
<td>p=0.415</td>
<td>Active flexion: 144.6 (17.4), active IR: 50.1 (19.5), active ER: 90.9 (17.0), passive IR: 28.4 (12.5)</td>
<td>Active flexion: 163.5 (6.0), active IR: 70.0 (12.6), active ER: 111.9 (10.0), passive IR: 163.5 (6.0)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Lewis et al 2005a</td>
<td>37.1 (7.1)</td>
<td>35.7 (8.2)</td>
<td>p&gt;0.05</td>
<td>Shoulder flexion: 120.5 (30.9), shoulder abduction: 111.3 (31.8)</td>
<td>Shoulder flexion: 157.3 (11.9), shoulder abduction: 156.1 (12.1)</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Lewis and Valentine 2010</td>
<td>37.6 (9.5)</td>
<td>35.5 (6.0)</td>
<td>p&gt;0.05</td>
<td>Not stated</td>
<td>Not stated</td>
<td>Not stated</td>
</tr>
<tr>
<td>Otoshi et al 2014</td>
<td>Positive WOT: 31.6%</td>
<td>Positive WOT: 20%</td>
<td>p&lt;0.05</td>
<td>Positive RSE: 34.3%</td>
<td>Positive RSE: 7.7%</td>
<td>p&lt;0.05</td>
</tr>
<tr>
<td>Greenfield et al 1995</td>
<td>38 (10.7)</td>
<td>34 (11.5)</td>
<td>p&gt;0.05</td>
<td>Not stated</td>
<td>Not stated</td>
<td>Not stated</td>
</tr>
<tr>
<td>Theisen et al 2010</td>
<td>45.9 (10.8)</td>
<td>44.8 (10.6)</td>
<td>p=0.66</td>
<td>Not stated</td>
<td>Not stated</td>
<td>Not stated</td>
</tr>
</tbody>
</table>

Table 2.5 Comparison of thoracic kyphosis and shoulder range of motion in groups with and without impingement.

WOT=wall-occiput test, RSE=restricted shoulder elevation (measured as maximum active shoulder range of motion below 150°), IR=internal rotation, ER=external rotation.
2.1.4.4 *The effect of changing thoracic kyphosis on shoulder function*

No studies were found that investigated the effect of changing thoracic kyphosis on the outcome of shoulder function.

2.1.4.5 *The effect of changing thoracic kyphosis on shoulder ROM*

Two studies, of low (Kanlayanaphotporn et al 2014) and moderate (Kebaetse et al 1999) risk of bias, reported that erect thoracic postures increased shoulder ROM when compared to a slouched thoracic posture in pain-free participants. One of these compared three different sitting postures (erect, comfortable slouched and maximum slouched) and found that reduced thoracic kyphosis significantly improved shoulder flexion, abduction and external rotation (Kanlayanaphotporn 2014). Conversely, mean shoulder internal rotation ROM increased by approximately 20% from the erect to maximum slouched posture. Kebaetse et al. (1999) also reported significantly more maximum active shoulder abduction ROM in an erect posture compared to a slouched posture. A further study of low risk of bias reported similar findings people with SAPS, demonstrating a statistically significant improvement in mean angle of shoulder flexion in an erect posture in comparison to a slouched posture in people with SAPS (Bullock et al 2005). Additionally, this study recorded pain intensity during shoulder flexion in both postures. The mean pain intensity on a 100mm visual analogue scale (VAS) was reported as 38.89 when sitting slouched and 34.39 when sitting erect (mean difference=4.50±17.93mm), indicating no statistically significant difference in pain intensity between postures (Bullock et al 2005). One study, of low risk of bias, reported that in people with SIS, significantly greater shoulder ROM to the point of onset or worsening of shoulder pain was achieved following scapular and thoracic taping aimed at thoracic extension compared to normal resting posture (p<0.001) (Lewis et al 2005b). However, no significant differences were found on VAS pain rating for shoulder flexion (p=0.14) or scapular plane abduction (p=0.11) between postures. In the group who did not have shoulder pain, thoracic extension using taping significantly increased maximum shoulder ROM compared to resting thoracic posture (p=0.001). Data relating to posture and shoulder ROM are displayed in Table 2.6. All four studies checked that the mean thoracic kyphosis angle significantly changed between postures (Lewis et al 2005b, Kanlayanaphotporn 2014, Kebaetse et al 1999, Bullock et al 2005).
Two of the studies which measured the relationship between thoracic kyphosis and shoulder pain (Lewis et al 2005a, Otoshi et al 2014) also investigated the association between shoulder ROM and thoracic kyphosis. Lewis and colleagues reported a poor association between resting thoracic kyphosis and shoulder flexion (Kendall coefficient for participants without SIS= –0.173, p=0.057 and with SIS= –0.016, p= 0.858) or abduction ROM (Kendall coefficient for participants without SIS= –0.146, p=0.110 and with SIS= –0.005, p= 0.959) (Lewis et al 2005a). In contrast, one study reported a significant, positive association between a positive WOT (increased thoracic kyphosis) and restricted shoulder flexion ROM (OR 2.50, 95% CI 1.80, 3.46), based on splitting shoulder ROM among participants as greater than or less than 150º (Otoshi et al 2014).
<table>
<thead>
<tr>
<th>Study, year</th>
<th>Population</th>
<th>Mean (SD) thoracic kyphosis in degrees (erect)</th>
<th>Mean (SD) thoracic kyphosis in degrees (slouched)</th>
<th>p value</th>
<th>Shoulder in degrees ROM (erect)</th>
<th>Shoulder ROM in degrees (slouched)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kanlayanaphotporn 2014</td>
<td>30 pain-free males, mean age 20.5 years</td>
<td>21.5 (9.7)</td>
<td>C.S: 28.5 (9.5) M.S: 38.0 (9.8)</td>
<td>p&lt;0.001</td>
<td>Shoulder flexion: 168.0 (8.0)</td>
<td>Should flexion: CS: 152.4 (13.9) MS: 132.5 (16.6)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shoulder abduction: 175.7 (6.8)</td>
<td>Should abduction: CS: 159.8 (16.0), MS: 135.1 (20.7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shoulder ER: 90.7 (11.5)</td>
<td>Should ER: CS: 78.9 (10.9) MS: 64.7 (9.8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shoulder IR: 55.3 (11.0)</td>
<td>Should IR: CS: 60.3 (12.8) MS: 65.6 (14.0)</td>
<td></td>
</tr>
<tr>
<td>Kebaetse et al 1999</td>
<td>34 pain-free participants, mean age 30.2 years</td>
<td>26.4 (11.5)</td>
<td>38.5 (10.8)</td>
<td>p&lt;0.001</td>
<td>Shoulder abduction: 157.5 (10.8)</td>
<td>Should abduction: 133.9 (13.7)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Bullock et al 2005</td>
<td>28 patients with SIS, mean age 48.2 years</td>
<td>35.61 (13.70)</td>
<td>53.46 (12.02)</td>
<td>p&lt;0.0001</td>
<td>Shoulder flexion: 127.32 (25.81)</td>
<td>Shoulder flexion: 109.65 (25.53)</td>
<td>p=0.0001</td>
</tr>
<tr>
<td>Lewis et al 2005b</td>
<td>60 people with SIS, 60 healthy controls</td>
<td>Mean change (SE) from normal to erect posture: Symptomatic: −5.8 (0.66) Asymptomatic: −6.4 (0.72)</td>
<td></td>
<td>p&lt;0.001</td>
<td>Mean change (SE) from normal to erect posture: Symptomatic: 16.2 (2.70) (flexion), 14.7 (2.92) (scapula plane abduction) Asymptomatic: 8.2 (0.69) (flexion), 7.0 (.65) (scapula plane abduction)</td>
<td></td>
<td>p&lt;0.001</td>
</tr>
</tbody>
</table>

Table 2.6 Comparison of thoracic kyphosis and shoulder ROM in erect and slouched sitting postures.

CS=comfortable slouched, MS=maximum slouched, SE=standard error.
2.1.5 Discussion

2.1.5.1 Main findings

The most important finding of the review indicates that there is moderate evidence (one study at low risk of bias, two at moderate risk of bias and two at high risk of bias) of no association between increased thoracic kyphosis and shoulder pain. Although one other study did report a significant association between thoracic kyphosis and shoulder pain, this study was at high risk of bias. Further, there is strong evidence (three studies at low risk of bias, one at moderate risk of bias) that slouched postures, which increase thoracic kyphosis, are associated with reduced shoulder flexion and abduction ROM in participants with and without shoulder pain. None of the eligible studies investigated the association between thoracic posture and shoulder function.

2.1.5.2 The effect of thoracic kyphosis on shoulder pain

Five studies of varying risk of bias reported that there was no significant difference in static resting thoracic kyphosis between groups with and without shoulder pain (Lewis et al 2005a, McClure et al 2006, Theisen et al 2010, Greenfield et al 1995, Lewis and Valentine 2010). However, this should be viewed in light of the methodological weaknesses of these studies, which include insufficient power to detect between group differences and lack of assessor blinding. While acknowledging these limitations, the findings of the studies pose some challenge to the role of thoracic kyphosis in the development and maintenance of shoulder pain. Lewis and colleagues, who measured resting thoracic kyphosis, forward head posture and scapula position, demonstrated that neither groups with or without shoulder pain conformed to a specific posture (Lewis et al 2005a). The findings challenge the hypothesis that an ideal spinal posture exists from which deviation causes or contributes to shoulder pain. The etiology of shoulder pain is still debated and may be multi-factorial in nature, potentially influenced by mechanical overload (McClure et al 2006), degenerative changes (Seitz et al 2011), genetics and lifestyle factors (Tashjian et al 2009, Rechardt et al 2010).

In addition to these potential sources of nociception, the potential role of the central nervous system (CNS) in maintaining shoulder pain has also been recognised (Littlewood et al 2013). Of the studies included in this review which have provided information of the duration of symptoms of their participants, all have indicated symptoms of greater than three
months duration (Lewis et al 2005a, McClure et al 2006, Theisen et al 2010, Bullock et al 2005) which suggests that chronic pain processes are likely to be involved. In light of this, the relative role of thoracic hyperkyphosis as a driver of pain may be reduced in the presence of heightened CNS sensitivity and it highlights that CNS factors may sometimes have a greater role.

One study demonstrated that a positive WOT was more prevalent in a group with SIS compared to pain-free participants (Otoshi et al 2014). Caution must be taken when interpreting the implications of this as this study had several aforementioned methodological weaknesses. In addition to indicating the extent of thoracic kyphosis, the authors suggest that the WOT also measures thoracic mobility, where a positive WOT may indicate a restriction in thoracic spine mobility (Otoshi et al 2014). Therefore, its potential for comparison to the five other studies which measure a static degree of thoracic kyphosis is debatable.

The suggestion that thoracic mobility may be a contributing factor in the development of SIS has also been evaluated by other research. It has been reported that thoracic mobility was significantly less in patients with SIS compared with a control group (Meurer et al 2004). It has also been reported that greater restriction of segmental mobility of the thoracic spine was present in a group of people with SIS compared with pain-free controls, whereas static kyphosis did not differ between groups (Theisen et al 2010). While this review focuses on the role of static thoracic posture, it would be valuable to further examine the influence of thoracic mobility on shoulder pain, function and ROM as this was outside the scope of this review.

2.1.5.3 The effect of thoracic kyphosis on shoulder ROM

This review found strong evidence that increasing thoracic kyphosis through slouched sitting reduces maximum shoulder ROM. The reduced shoulder ROM in slouched sitting may be explained by positional changes of the scapula into a more protracted, anteriorly tilted and medially rotated position, potentially acting as a mechanical block to shoulder elevation (Donatelli 1997). It is also worth considering that the change in thoracic kyphosis with slouched sitting is likely to be accompanied by changes in cervical and lumbar lordosis (Bullock et al 2005, Lewis et al 2005b), as well as changes in the activation of a range of scapulothoracic muscles (Claus et al 2009). Therefore, the specific mechanisms through which a change in thoracic kyphosis alters shoulder ROM are unclear.
Three studies that compared shoulder ROM between postures in this review used the extremes of sitting postures, which may not reflect how people move in a real life scenario. Only one study compared shoulder movement between a normal and erect thoracic posture (Lewis et al 2005b), demonstrating that a smaller change in thoracic kyphosis can also improve shoulder ROM. However, both studies which assessed shoulder pain intensity during shoulder movement reported that pain intensity was not changed between postures (Bullock et al 2005, Lewis et al 2005b).

2.1.5.4 Implications for future research

All eligible studies were either cross-sectional studies or involved repeated-measures on a single day. These approaches provide limited information to detect whether thoracic hyperkyphosis leads to shoulder pain and shoulder ROM deficits over time. Even if the studies had reported significant differences in thoracic kyphosis between groups, it would not have been possible to establish whether the thoracic hyperkyphosis preceded the shoulder symptoms or if the thoracic hyperkyphosis was a postural adaptation to shoulder pain. The scope of these designs can only provide evidence on the immediate effects of changing thoracic kyphosis on shoulder symptoms and/or provide information regarding the prevalence of thoracic hyperkyphosis in groups with and without pain. Therefore, a case series where thoracic kyphosis and shoulder outcomes (pain, function and ROM) are monitored and compared longitudinally may progress our understanding of the role of the thoracic spine in the development of shoulder pain. This could entail a cohort of healthy adults without shoulder pain, being monitored over a 10 year period, which is sufficient time for thoracic kyphosis to naturally progress (Fon et al 1980). The manual inclinometer, which is a reliable tool for measuring thoracic kyphosis (Barrett et al 2013, Barrett et al 2014), may be suitable for this purpose. This could provide useful information regarding if a change in thoracic kyphosis is associated with the development of shoulder symptoms. Furthermore, studies which compare the treatment of shoulder pain with and without the inclusion of a thoracic posture rehabilitation component would provide clarity on the usefulness of altering thoracic posture in this patient group.
2.1.5.5 Implications for clinical practice

A limitation of this review is the relatively low number of included studies and the methodological weaknesses of the studies. However clinicians should be cautious when attempting to change thoracic kyphosis among people with shoulder pain, until the emergence of higher quality research to support this practice. One option is to examine whether patient symptoms are immediately modifiable by altering thoracic kyphosis, as this might partially justify such an approach. The Shoulder Symptom Modification Procedure (SSMP) (Lewis, 2009) uses such a model, where the immediate effect of changing thoracic kyphosis, among a range of other postural variables, on the patient’s symptoms is investigated. However, this model was developed based on clinical experience and has not yet undergone empirical testing. As described previously, another important consideration is the likelihood that a patient’s symptoms are related to nociceptive input, given what is now known about the role of central pain mechanisms in the maintenance of chronic pain conditions (Butler and Moseley 2003). Using the history and clinical examination to gauge the degree to which central pain mechanisms are involved in shoulder pain, may also allow for a more patient specific approach to the assessment and rehabilitation of shoulder pain.

2.1.6 Conclusion

There is a moderate level of evidence of no association between increased thoracic kyphosis and shoulder pain. Strong conclusions cannot be made due to the methodological weaknesses of many of the included studies. There is strong evidence that erect sitting postures which reduce thoracic kyphosis are associated with an immediate improvement in shoulder flexion and abduction ROM in participants with and without shoulder pain, although this has only been examined in a single session. There is a need for further research in the form of case series studies to investigate any potential relationships between thoracic hyperkyphosis and shoulder pain as well as studies examining the specific value of thoracic postural rehabilitation in populations with painful shoulders.
2.1.7 Chapter 2: Summary of key points

The aim of this chapter was to examine the association between thoracic kyphosis and shoulder pain, function and ROM. This was conducted through a systematic review which aimed to include both observation and experimental studies. The main findings of the review demonstrated that thoracic kyphosis was very similar when comparing groups with and without shoulder pain. The review provides moderate evidence that thoracic kyphosis is not a consistent postural deviation in people with shoulder pain. The review also indicated that significantly greater shoulder ROM was demonstrated when participants were asked to assume an extended thoracic posture, in comparison to a normal or flexed thoracic posture. This may be due to the natural extension of the thoracic spine required for full shoulder elevation. This review did not identify any studies which considered the association between thoracic kyphosis and shoulder function.

The cross-sectional research designs of these studies limit their ability to fully elucidate the role of thoracic kyphosis in shoulder pain. Therefore, it is important for this thesis to explore the role of thoracic kyphosis in shoulder pain by attempting to change thoracic kyphosis in a clinical population. However, in order for accurate conclusions to be drawn from this study, it is important to first identify a reliable and valid method for measuring thoracic kyphosis.
3 Chapter 3: Methods

Chapter 3 includes three studies. These are the methods studies of the thesis, which involve exploring the reliability and validity of thoracic kyphosis measurement techniques.

- **Study II** is a systematic review which examines the reliability and validity of non-radiographic methods of thoracic kyphosis measurement. This is published in Manual Therapy.
- **Study III** investigates the inter-rater and intra-rater reliability of two instruments, the Flexicurve and manual inclinometer, for the measurement of thoracic kyphosis. This is published in Rehabilitation Research and Practice.
- **Study IV** investigates the concurrent validity of the Flexicurve and manual inclinometer for the measurement of thoracic kyphosis. This is under review for publication.
3.1 Study II: Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: A systematic review

3.1.1 Abstract

Background: A wide array of instruments are available for non-invasive thoracic kyphosis measurement. Guidelines for selecting outcome measures for use in clinical and research practice recommend that properties such as validity and reliability are considered. This systematic review reports on the reliability and validity of non-invasive methods for measuring thoracic kyphosis.

Methods: A systematic search of 11 electronic databases located studies assessing reliability and/or validity of non-invasive thoracic kyphosis measurement techniques. Two independent reviewers used a critical appraisal tool to assess the quality of retrieved studies. Data was extracted by the primary reviewer. The results were synthesised qualitatively using a level of evidence approach.

Results: Twenty-eight studies satisfied the eligibility criteria and were included in the review. The reliability, validity and both reliability and validity were investigated by seventeen, two and nine studies respectively. Eighteen out of twenty-eight studies were deemed to be of high quality. In total, 15 methods of thoracic kyphosis were evaluated in the retrieved studies. All investigated methods showed high (ICC≥.7) to very high (ICC≥.9) levels of reliability. The validity of the methods ranged from low to very high.

Conclusion: The strongest levels of evidence for reliability exists in support of the Debrunner kyphometer, Spinal Mouse and Flexicurve index, and for validity supports the arcometer and Flexicurve index. Further reliability and validity studies are required to strengthen the level of evidence for the remaining methods of measurement. This should be addressed by future research.
3.1.2 Introduction

Thoracic kyphosis is the sagittal curvature between T1 and T12 vertebral bodies (Perriman et al 2010). Increased thoracic kyphosis has a range of negative consequences. These include shoulder symptoms such as subacromial impingement syndrome (Gray and Grimsby 2004), cervical pain (Calliet 1991, Horter 1978, Ayub 1991), headaches (Watson and Trott 1993), impaired respiratory function (Murray et al 1993, Di Bari et al 2004), injurious falls (Kado et al 2007a) and reduced mortality (Milne and Williamson 1983, Kado et al 2004, Kado et al 2009b). It can also have severe functional influences such as decreased mobility and loss of independence (Lydick 1997). The measurement of thoracic kyphosis is therefore an essential aspect to musculoskeletal assessment, helping clinicians to adequately screen for increased kyphosis, determine baseline data, monitor progress and guide appropriate implementation of treatment strategies (Chaise et al 2011).

The current gold standard for the quantification of thoracic kyphosis is the lateral radiograph, a method which provides a Cobb angle (Harrison et al 2001, Briggs et al 2007). While this is routinely used for the diagnosis and monitoring of conditions such as idiopathic scoliosis and hyperkyphosis (Saad et al 2012), it has significant limitations. Radiographic methods are generally inconvenient in a clinical setting, involve high costs and expose the patient to high doses of potentially harmful radiation (Korovessis et al 2001, Kellis et al 2008). Furthermore, the validity of the Cobb angle has been criticised, particularly in osteoporotic individuals, as it predominantly reflects endplate tilt of vertebrae between selected limits of the curve and fails to represent the full contour of the thoracic spine (Goh et al 1999, Briggs et al 2007, Harrison et al 2001).

Alternatively, several non-invasive, skin-surface methods have been adopted for clinical use including the Debrunner kyphometer (Ohlen et al 1989), the Flexicurve (Milne and Williamson 1983), the Spinal Mouse (Mannion et al 2004) as well as technology based methods including rasterstereography (Melvin et al 2010) and 3D ultrasound (Folsch et al 2012). Guidelines for selecting outcome measures for use in clinical and research practice recommend that properties such as validity and reliability should be considered (Lohr 2002, Terwee et al 2007). Validity is an evaluation of whether an instrument measures a construct or variable that it is intended to measure (Carmines and Zeller 1979, van de Ven-Stevens et al 2009). For a non-invasive tool to be considered accurate enough to measure thoracic kyphosis in practice and research, it must display adequate criterion validity when compared to the gold standard, i.e. the radiographic Cobb angle. Reliability is defined as the extent to which a
measurement is consistent and free from error, when used by the same rater (intra-rater reliability) or when used by different raters (inter-rater reliability) (Portney and Watkins 2000). In practice, to state that a patient’s clinical status has changed since the last measurement, the measured change is required to be larger than the error associated with the measurement (Wright and Feinstein 1992). Therefore, the reporting of Standard Error of Measurement is an important element of reliability studies as it aids clinical interpretability of results (van de Ven-Stevens et al 2009).

Since numerous studies on the psychometric properties of these instruments have been published, an evaluation of the literature is required. Therefore, the purpose of this systematic review is to report on the reliability and validity of methods of non-invasive thoracic kyphosis measurement.

3.1.3 Methods

3.1.3.1 Search strategy

A systematic search was performed on 1st October 2012 by the primary reviewer (EB). Searches of the following databases were performed: MEDLINE, AMED, CINAHL, Pubmed, Biomedical Reference Collection: Expanded, SportDiscus, ScienceDirect, Cochrane Library, Web of Science (1960-Oct 2012). The search was conducted using search terms from three subject areas: thoracic kyphosis (“thoracic kyphosis”, “spinal curvature”, “thoracic curvature”, kyphosis), psychometric properties (reliability, validity, sensitivity, responsiveness, properties) and physical tests (instrument, tool, test, measure*, inclinometer, flexicurve, kyphometer, radiograph, Cobb). The Boolean Operators “Or” and “And” were used to combine the search terms within and between each of the three subject areas respectively. A word from each area was required to be in the Title or Abstract of the study. An additional search of Google Scholar search engine was also performed. These searches were supplemented by hand-searching the reference lists of the final articles found from the above searches.

3.1.3.2 Eligibility criteria

A meeting between two reviewers (EB, KMC) was convened to decide on selection criteria.
3.1.3.2.1 Inclusion criteria

- Articles available in full text.
- Articles available in English.
- A neutral thoracic kyphosis value angle was recorded.
- Measurement of validity and/or reliability was the primary aim of the study.
- Studies on human participants were included for review. No restrictions were made with regard to populations.

3.1.3.2.2 Exclusion criteria

- Full text in English could not be located.
- Thoracic kyphosis angle reported in thoracic flexion or extension only.
- Radiographic measurement techniques only.

Initially, article titles and abstracts were screened by the primary reviewer (EB). Any title and abstract which was not clearly investigating a psychometric property of a thoracic kyphosis measurement method was discarded as being not relevant. In cases of uncertainty about eligibility of a study abstract, the full text was explored. When the original search was narrowed down to relevant articles only, a second reviewer independently applied the selection criteria to the full text of the articles to ensure all were suitable for review (KMC). There were no disagreements between reviewers regarding the eligibility of chosen articles.

3.1.3.3 Quality assessment

The critical appraisal tool used was a relatively new checklist (Brink and Louw 2011) which was designed for testing combined reliability and validity studies or validity and reliability on their own. The checklist, which is comprised of 13 items, does not report a quality score. This tool was developed from two existing tools, the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) and the Quality Appraisal of Diagnostic Reliability Studies (QAREL). As some of the included studies assess both reliability and validity of the instrument, this checklist was more convenient than using the QUADAS or QAREL separately. The criteria are provided as a footnote to Table 3.2. The studies were considered

Quality assessment was performed independently by two reviewers on each paper. In the pilot stage, each reviewer independently rated two non-included articles using the checklist, in order to identify any difference in interpretations of the items. This process recorded an agreement score of 88.4%, which was regarded as acceptable to continue. Disagreements were resolved by discussion and all items were clarified.

### 3.1.3.4 Data analysis

Meta-analysis was not attempted due to the heterogeneity of tests, participants and analyses. Also, a subgroup analysis could not be performed due to the limited number of studies evaluating the same thoracic kyphosis measurement technique. Hence a descriptive analysis was conducted and data were synthesised using a level of evidence approach (van Tulder et al 2003), displayed in Table 3.1.

The Intraclass Correlation Coefficient (ICC) and Pearson’s correlation coefficient were interpreted as follows: 0.00-0.29 as very low correlation, 0.30-0.49 as low correlation, 0.50-0.69 as moderate correlation, 0.70-0.89 as high correlation and 0.90-1.00 as very high correlation (Munro and Visintainer 2005).

<table>
<thead>
<tr>
<th>Level of Evidence</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Consistent findings from at ≥ 3 high quality studies</td>
</tr>
<tr>
<td>Moderate</td>
<td>Consistent findings from at least 1 high quality and 1 low quality studies</td>
</tr>
<tr>
<td>Limited</td>
<td>Consistent findings in 1 low quality studies or only 1 study available</td>
</tr>
<tr>
<td>Conflicting</td>
<td>Inconsistent evidence in multiple studies irrespective of study quality</td>
</tr>
</tbody>
</table>

Table 3.1 Levels of evidence approach used in systematic review (van Tulder et al 2003).

### 3.1.4 Results

#### 3.1.4.1 Selection of studies

Figure 3.1 presents a flow diagram, based on the PRISMA guidelines (Liberati et al 2009), which details the movement of articles through the review process. Twenty-eight articles were included for review under the outlined selection criteria. Of these studies, two investigated validity only, 17 investigated reliability only and nine investigated both
reliability and validity. Of the 17 included reliability studies, one investigated inter-rater reliability, seven investigated intra-rater reliability and nine investigated both intra- and inter-rater reliability.

**Electronic databases (560):** Web of Science (204), Pubmed (180), Medline (118), CINAHL (42), Science Direct (23), SportsDiscus (11), AMED (5), PsycInfo (5), Cochrane Library (4), Biomedical Reference Collection: Expanded (3)

**Supplementary search (50):** Google scholar

**Total number of articles obtained=610**

Excluded:
- 205 Duplicates
- 258 Not Relevant
- 75 Not reliability/validity study
- 38 Radiographic
- 9 Not English

**Retained after duplicates =405**

- 1 Reliability/validity not primary aim
- 1 Radiographic
- 3 Kyphosis value unreported

**Retained after title and abstract screening=25**

**Retained after full text screening=20**

Included:
- 8 Hand searching reference lists

**Final number of articles included=28**

- Validity alone=2
- Reliability and Validity=9
- Reliability alone=17

Figure 3.1 PRISMA flow diagram.
3.1.4.2 Methodological quality

Eighteen out of twenty-eight studies were deemed to be of high quality (score ≥60%). The full scoring process is displayed in Table 3.2. The two reviewers initially disagreed on 12 items across all studies (kappa score 0.94). The disagreement between the two reviewers was then resolved by discussion. A third reviewer was available to moderate disagreement but was not required. Both of the included validity studies were of high quality (Leroux et al 2000, Gravina et al 2012). Five out of nine combined reliability and validity studies were of high quality (Chaise et al 2011, de Oliveira et al 2012, Greendale et al 2011, Ripani et al 2008, Teixeira and Carvalho 2007). Eleven out of seventeen reliability studies were of high quality (Czaprowski et al 2012, Folsch et al 2012, Hinman 2004, Kellis et al 2008, Lewis and Valentine 2010, Mannion et al 2004, Melvin et al 2010, Purser et al 1999, Sheeran et al 2010, Lundon 1998, Ohlen et al 1989, van Blommestein et al 2012).

The main areas of weakness found were inadequate description of the raters, insufficient between-rater and within-rater blinding, lack of variation in testing order and inappropriate or insufficiently described statistical analyses.
<table>
<thead>
<tr>
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<td>Within-rater blinding</td>
<td>Variation of testing order</td>
<td>Time period between index test and reference standard</td>
<td>Time period between repeated measures</td>
<td>Independency of reference standard from index test</td>
<td>Adequate description of index test procedure</td>
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Table 3.2 Methodological quality of studies included in the systematic review.

3.1.4.3 Study characteristics

A total of 15 methods for thoracic kyphosis measurement were found within reviewed articles. The Flexicurve index and the Debrunner kyphometer were the most commonly studied, in terms of both reliability and validity. A list of all methods is below.

- Arcometer (Chaise et al 2011, D’Osualdo et al 1997)
- Flexicurve angle (de Oliveira et al 2012, Greendale et al 2011)
- Digital inclinometer (Czaprowski et al 2012)
- Rasterstereography (Goh et al 1999, Melvin et al 2010)
- Stereovideography (Leroux et al 2000)
- Goniometer (Gravina et al 2012)
- Electrogoniometer (Perriman et al 2010)
- Spinal wheel (Sheeran et al 2010)
- Pantograph (Willner 1981)

3.1.4.4 Types of participants

Twenty-one out of twenty-eight studies used a healthy sample of participants. Only seven studies included subjects with any degree of pathology, with four involving postmenopausal, osteoporotic women (Yanagawa et al 2000, Lundon et al 1998, Greendale et al 2011, Purser et al 1999) and three studies of subjects with scoliosis (Willner 1981, Saad et al 2012, Leroux et al 2000). The subject body mass index (BMI) was unreported in 15 studies, while five studies reported an average BMI $\geq 25$ kg/m$^2$ (Greendale et al 2011, Chaise et al 2011, Mannion et al 2004, Sheeran et al 2010, de Oliveira et al 2012) and three studies

3.1.4.5 Reliability and validity

All reliability studies showed high to very high levels of reliability. The validity of the methods was more diverse and ranged from low to very high. This is shown in more detail in Table 3.3.
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<th>High quality?</th>
<th>Reliability (ICC/Cronbach alpha)</th>
<th>SEM (degrees)</th>
<th>Validity (correlation coefficient)</th>
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Table 3.3 Reliability and validity data for all methods. Each study is described in terms of its quality, the reliability (measured using Intraclass Correlation Coefficient or Cronbach alpha) of the method investigated, the Standard Error of Measurement derived from the reliability coefficient, and/or the validity of the method investigated. The method investigated in each study is listed in Section 3.1.4.3.
3.1.4.6 Level of Evidence

Table 3.4 details the accumulated level of evidence found for all methods. For the majority, there is a limited or inconsistent level of evidence for the reliability and validity of methods. Strong and moderate levels of evidence have been found for a small selection of methods.

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<td>Spinal Mouse</td>
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</tbody>
</table>

Table 3.4 Level of evidence for thoracic kyphosis measurement methods. These have been synthesised using the van Tulder et al 2003 level of evidence approach, as described in Section 3.1.3.4.
3.1.5 Discussion

3.1.5.1 Main findings

This review highlighted 15 methods for the non-invasive measurement of thoracic kyphosis, ranging from simple, skin-surface measures to computerised postural analysis systems. In general, high to very high levels of reliability were found for all investigated measurement techniques. The validity of these techniques was less commonly studied and ranged from low to very high. On observation of the data, the more technological methods (e.g. rasterstereography, 3D ultrasound, stereovideography) did not appear to offer greater reliability or validity than the simpler methods. In fact, the strongest level of evidence was in support of the high to very high levels of reliability of the Flexicurve index, Debrunner kyphometer and Spinal Mouse, which are simple, hand-held tools.

3.1.5.2 Validity

Significant barriers to validity testing are the limited accessibility and the ethical issues regarding the use of spinal X-rays (Greendale et al 2011). This is likely to be a large contributing factor to the retrieval of only two studies which exclusively examined the validity of a non-invasive instrument for thoracic kyphosis measurement (Perriman et al 2010, D’Osualdo et al 1997). Other methods have been suggested as alternates to the Cobb angle, such as the centroid method (Chen 1999) and posterior tangent method (Harrison et al 2001). However, these are all still radiographically based.

There are several reasons as to why skin-surface devices may falter in validity. Skin-surface techniques follow the line of the spinous processes and not that of the vertebral bodies, as done radiographically (Mannion et al 2004). Secondly, the varying distribution of adipose tissue overlying the spine imposes on the accuracy obtained (Mannion et al 2004). This may have been influential as only one retrieved validity study reported a BMI<25 kg/m² (Ripani et al 2008), whereas two studies reported BMI>25 kg/m² (Greendale et al 2011, Chaise et al, 2011) and the remaining eight validity studies had unreported BMI. As detailed by reviewed studies, other sources which were likely to lower the validity scores included incorrect landmark palpation (Greendale et al 2011, Leroux et al 2000), measurement error in calculating the Cobb angle (Greendale et al 2011, Ripani et al 2008) and the operation of the device (Korovessis et al 2001, Ripani et al 2008).
The Debrunner kyphometer, arcometer, inclinometry, goniometry and electrogoniometry attain a kyphosis value from placing the instrument on selected limits of the curve, a method which is similar to the calculation of the Cobb angle. Alternatively, the Flexicurve, Spinal Mouse, Spinal Wheel and pantograph provide a representation of spinal curvature continuously throughout the thoracic spine. By observing the validity data, there appears to be no obvious trend in higher or lower validity scores by using either method. However, over time, relying on selected limits of the curve may fail to reveal changes regionally within the thoracic curvature. This may create a discrepancy for populations with osteoporosis or Scheuermann’s disease where single vertebral wedging is common (Briggs et al 2007, Czaprowski et al 2012, Gravina et al 2012). Therefore, the latter techniques may be more sensitive and robust over time (Greendale et al 2011) and thus may be more appropriate for ongoing assessment.

3.1.5.3 Reliability

The variable nature of thoracic kyphosis poses a potential challenge to reliability studies (D’Osualdo et al 1997). Included studies have acknowledged the postural variability both from session to session as a result of sporting, vocational or routine activity (Lewis and Valentine 2010, D’Osualdo et al 1997), fatigue from repeated measures (Hinman 2004, Kellis et al 2008) and repositioning errors (Sheeran et al 2010, van Blommestein et al 2012). However, some studies attempted to control this by re-testing within the same session (Goh et al 1999, Melvin et al 2010, Leroux et al 2000, Chaise et al 2011, Greendale et al 2011, de Oliveira et al 2012, Teixeira and Carvalho 2007, D’Osualdo et al 1997, Lewis and Valentine 2010) or re-testing at the same time of day (Saad et al 2012, Mannion et al 2004, Folsch et al 2012, Korovessis et al 2001, de Oliveira et al 2012, Kellis et al 2008). Others used techniques such as using the same light and temperature conditions (Saad et al 2012) and restricting sporting activities between measurement days (Folsch et al 2012). As reliability data was largely positive, these controls appeared to be sufficient to stabilise the thoracic kyphosis between measurements.


3.1.5.4 Methodological considerations

There were some methodological limitations of the reviewed studies. Firstly, the majority of studies investigated a healthy sample, of mean age between 20-65 years and of unreported BMI. A healthy population of this age bracket is not necessarily representative of a clinical population (Whiting et al 2003) and so the results cannot be generalised to the clinical population. However, both studies which contributed to the strong level of evidence for the very high inter-rater reliability of the Flexicurve index used a postmenopausal, osteoporotic sample (Yanagawa et al 2000, Greendale et al 2011), which increases the clinical applicability of the Flexicurve. BMI is an important sample characteristic as, in reality, the bony landmarks may be more difficult to palpate in people with high BMI leading to higher measurement errors (Langendefer et al 2009, Greendale et al 2011). Secondly, a description of the raters was only sometimes described, further limiting the generalisability of the results. Thirdly, some studies did not describe their statistical methods sufficiently and others used inappropriate analyses. The lack of measures of precision by some studies limits the clinical applicability of their results. Lastly, some studies did not perform (Chaise et al 2011, Perriman et al 2010, Folsch et al 2012, de Oliveira et al 2012, Dunk et al 2004, Dunk et al 2005, Sheeran et al 2010) or did not detail (Hinman 2004, Saad et al 2012, Mannion et al
controls to ensure between-rater and within-rater blinding. The lack of blinding in inter-rater and intra-rater reliability studies may have inflated the agreement between raters or between measures respectively.

3.1.5.5 Limitations of review

The strengths of the present review are its systematic nature, the comprehensive search strategy based on PRISMA guidelines, its use of multiple reviewers and its inclusion of all populations. However, only articles in English were included. During the title/abstract screening, nine articles were excluded due to their unavailability in English. As there were so few studies found investigating each thoracic kyphosis measurement technique, these articles could have made a significant difference to the overall conclusions of the review. Secondly, the two reviewers assessing the methodological quality of the studies were not blinded to the results of the studies. While this may have produced an opportunity for reviewer bias (Stochkendahl et al 2006), the stringent criteria of the critical appraisal tool and the use of multiple reviewers reduced the likelihood of bias. Thirdly, the findings of the included studies were synthesised qualitatively using the level of evidence approach. This would have concealed the wide level of heterogeneity amongst study populations, procedures and testers (Stochendahl et al 2006).

3.1.5.6 Clinical and research implications

The 15 methods highlighted in this systematic review indicate that clinicians have a wide scope of options for thoracic kyphosis measurement. For the present, clinicians must choose a method using their best judgment of the reliability and validity data presented in this review. The Flexicurve index, Debrunner kyphometer and the Spinal Mouse have the strongest evidence base in terms of their reliability and the Flexicurve index and arcometer have the strongest level of evidence in terms of validity. Factors such as low cost, ease of use for entry level clinicians and short measurement time have been previously considered to argue for the use of the Flexicurve (Greendale et al 2011). However, the absence of evidence does not mean an outcome measure is not suitable, only that no data has yet been published to verify validity and reliability. Clinicians must also be mindful of the populations in which these measures were tested and the expertise of the raters testing them.
This systematic review identified the strong need for further research into the psychometric properties of thoracic kyphosis measurement methods, especially methods with limited and inconsistent levels of evidence. The early research appears promising, but a true representation of the reliability and validity cannot be made until further studies emerge. It is recommended that future research should include representative samples of patients, incorporate adequate measures to ensure subject and examiner blinding and consider the use of clinically relevant statistical analyses accompanied by estimates of precision.

3.1.6 Conclusion

A wide range of thoracic kyphosis measurement techniques have been reviewed. However, there are few studies investigating each technique. Overall, reliability data for investigated techniques is very positive but generally remains limited. The validity of the techniques was lower than their reliability but information on validity is lacking for many measures. The strongest levels of evidence for reliability exists in support of the Debrunner kyphometer, Spinal Mouse and Flexicurve index and for validity supports the arcometer and Flexicurve index. Future research should concentrate on methods with limited and inconsistent levels of evidence as identified by this review.
3.2 Study III: Intra-rater and inter-rater reliability of the Flexicurve index, Flexicurve angle and manual inclinometer for the measurement of thoracic kyphosis


3.2.1 Abstract

Objective: This study aimed to describe the inter-rater and intra-rater reliability of the Flexicurve index, Flexicurve angle and manual inclinometer in swimmers. A secondary objective was to determine the level of agreement between the manual inclinometer angle and the Flexicurve angle and to provide an equation to approximate one angle from the other.

Methods: Thirty swimmers participated. Thoracic kyphosis was measured using the Flexicurve and the manual inclinometer. Intraclass correlation coefficient, 95% confidence interval and standard error of measurement were computed.

Results: The Flexicurve angle and index showed excellent intra-rater (ICC = 0.94) and good inter-rater (ICC = 0.86) reliability. The manual inclinometer demonstrated excellent intra-rater (ICC = 0.92) and inter-rater (ICC = 0.90) reliability. The Flexicurve angle was systematically smaller and correlated poorly with the manual inclinometer angle ($R^2$=0.38). The following equations were used for approximate conversions: Flexicurve angle = (0.275 $\times$ inclinometer angle) + 8.478; inclinometer angle = (1.396 $\times$ Flexicurve angle) + 8.694.

Conclusion: The manual inclinometer and Flexicurve are both reliable instruments for thoracic kyphosis measurement in swimmers. Although the Flexicurve and manual inclinometer angles are not directly comparable, the approximate conversion factors provided may permit translation of Flexicurve angle to inclinometer angle and vice versa.
3.2.2 Introduction

Thoracic kyphosis is the sagittal plane curvature between the T1 and T12 vertebral bodies (Perriman et al 2010). Normal thoracic kyphosis ranges from 20-50° when assessed radiographically (Willner 1981) and non-radiographically (Mannion et al 2004, Saad et al 2012). Increased thoracic kyphosis has been linked with a range of musculoskeletal complaints including shoulder pain (Gray and Grimsby 2004) and cervical pain (Calliet 1991, Horter 1978, Ayub 1991).

Previous research has consistently reported high incidences of shoulder pain in competitive swimmers, with rates of 53% (McMaster and Troup 1993), 54% (Sein et al 2010) and 80% (McMaster et al 1998) amongst those documented. The increased thoracic kyphosis of swimmers is a postural adaptation to altered spinal forces experienced in swim training (Wojtys et al 2000) and is proposed as being a large contributing factor to the development of shoulder pain (Bedi 2011, Lewis et al 2005b). The simple and safe assessment of thoracic kyphosis is therefore of value to physiotherapists involved in treating high level swimmers.

The gold standard for the measurement of thoracic kyphosis is a radiograph, which provides a Cobb angle (Harrison et al 2001). While this method is noted to reveal the true position of the vertebrae (Chaise et al 2011), it is not always accessible in a clinical setting, involves high costs and exposes the patient to potentially harmful radiation (Korovessis et al 2001, Kellis et al 2008). Consequently, a wide range of non-invasive instruments have been developed for the clinical measurement of thoracic kyphosis. These methods include the arcometer (Chaise et al 2011, D’Osualdo et al 1997), 3D ultrasound (Folsch et al 2012), Debrunner’s kyphometer (Greendale et al 2011, Korovessis et al 2001), Spinal Mouse (Mannion et al 2004, Kellis et al 2008), photogrammetry (Saad et al 2012, Dunk et al 2005) goniometry (Gravina et al 2012) and electrogoniometry (Perriman et al 2010). Currently, there is no conclusive evidence regarding which of these tools is the most reliable or valid (Barrett et al 2014). The Flexicurve and manual inclinometer are two hand-held tools which are commonly used by physiotherapists for the measurement of thoracic kyphosis. These are simple, quick and cost-effective, making them suitable to use poolside.

The primary output of the Flexicurve is the kyphosis index. Previously, the Flexicurve index has shown very high inter-rater and intra-rater reliability in a healthy population (Teixeira and Carvalho 2007, Hinman 2004) and an osteoporotic population (Greendale et al 2011, Yanagawa et al 2000). However, the reliability of the Flexicurve index in swimmers has not yet been investigated. The Flexicurve does not provide an immediate angle which
limits its clinical interpretation. Recently, Greendale et al (2011) introduced a geometric formula to translate the Flexicurve index into an approximate Cobb angle. As access to radiological assessment is sometimes limited, it would be of value to compare the Flexicurve angle to another commonly used clinical tool like the inclinometer. Similar to the Flexicurve index, very high intra-rater reliability has been reported for the manual inclinometer in non-athletic subjects (Lewis and Valentine 2010, van Blommestein et al 2012). To the knowledge of the investigators, the inter-rater reliability of the manual inclinometer has not yet been reported in the literature in any population, which is a significant gap in the literature.

The primary purpose of this study was to investigate the intra- and inter-rater reliability of the manual inclinometer, Flexicurve index and Flexicurve angle in a population of swimmers. The secondary purpose was to compare the manual inclinometer angle and the Flexicurve angle obtained using the method presented previously (Greendale et al 2011).

3.2.3 Methods

3.2.3.1 Subjects

For a significance level of 5% and a power of 80, the suggested adequate number of subjects required is 19 (Walter et al 1998, Sim and Wright 2000). Thirty subjects (18 male, 12 female) participated in this study. This is an equal sample size to that used in a previous similar reliability study (van Blommestein et al 2012). Subjects were recruited by email to local swimming clubs. Inclusion criteria were as follows: member of a swimming club, swimming at least twice per week and aged at least 18 years. Subjects with and without shoulder pain were accepted for participation. Clinical tests were not used to identify the source of shoulder pain due to the low level of validity and reliability of diagnostic shoulder tests (Green et al 2008, May et al 2010). Thus this study examined individuals with non-specific shoulder pain. Permission to conduct this study was granted by the University of Limerick Research Ethics Committee. All subjects signed a witnessed informed consent form and were aware of their rights including the right to withdraw from the study at any stage. Each participant completed a questionnaire detailing swim training and shoulder pain history.
3.2.3.2 **Raters**

To evaluate inter-rater and intra-rater reliability of the instruments, two raters were used. Both raters were qualified physiotherapists, with one and 15 years of experience in the use of the instruments for clinical and research purposes. The raters also had a practice session with both instruments prior to commencement of the study. This included a review of basic spine anatomy, instruction in how to find landmarks by palpation and practice with the use of both instruments and how to take readings from them. This ensured a good level of familiarity with both techniques.

3.2.3.3 **Procedure**

This study was conducted alongside other investigations which assessed other components of upper body posture and strength. At first, the subject was asked to lie prone and the spinous processes of C7, T1, T2, T12 and L1 were identified by palpation and marked with an easily removable marker. The interspinous space of L3/4 was identified at the level of the iliac crests and the L1 and T12 spinous processes were marked by palpatating superiorly from this reference point (Palastanga et al 2002). The 7th cervical vertebra was designated to have the most prominent spinous process (Palastanga et al 2002). Palpating inferiorly from this reference point, the T1 and T2 spinous processes were identified and marked (Lewis and Valentine 2010).

The subject then assumed a standing position and was instructed to “adopt a comfortable position that felt natural to them” (van Blommestein et al 2012). Standardised instructions reduced the possibility of the subject assuming different postures for the test and re-test. The thoracic kyphosis was first measured using the Flexicurve. As depicted in Figure 3.2, the tip of the Flexicurve was placed over the C7 spinous process and the ruler was moulded to the contour of the thoracic spine as far as T12. The Flexicurve was carefully transferred to paper and the curve was outlined. The Flexicurve was moulded to the spine three times, being flattened between each measurement. The kyphosis index was later calculated using the formula displayed in Figure 3.3. Calculations were undertaken in a separate session to ensure rater one was blind to measures during the second testing session. The average of the three measurements of each subject was later used for analysis. Using geometric formulae, the Flexicurve kyphosis angle was also calculated from the Flexicurve tracing, as outlined in Figure 3.3.
Figure 3.2 Application of Flexicurve for thoracic kyphosis measurement.

Figure 3.3 Method of Flexicurve kyphosis index and angle calculation for thoracic kyphosis.

These are computed using measurements taken from the Flexicurve tracing, represented here by the curve from C7 to T12. To calculate the Flexicurve kyphosis index, the apex kyphosis height (B) is divided by the length of the entire thoracic curve (X) and then multiplied by 100 (B/X x 100). The Flexicurve angle or theta (θ) is calculated using lines drawn perpendicular to the short sides of the triangle inscribed by the thoracic curve. Theta equals arc tan (B/X₁) + arc tan (B/X₂) (Greendale et al 2011).
Next the thoracic kyphosis was measured using two gravity dependent inclinometers (Isomed Inc. 975 SE Sandy Blvd, Portland, OR 97214, USA). As depicted in Figure 3.4, the feet of the inclinometers were placed over the spinous processes of T1/T2 and T12/L1. The readings were taken and recorded by a separate recorder to ensure blinding. The feet of both inclinometers were 2.5cm apart which remained constant for all subjects and testing sessions. Inclinometer measurements were performed three times in succession and an average was later used for analysis (Lewis and Valentine 2010, van Blommestein et al 2012).

After this initial testing session, the subject underwent separate tests with separate examiners, which consisted of scapular positioning measurements in standing and shoulder strength measurements in prone. Following these, the subject returned to rater one for re-testing of thoracic kyphosis. In order to assess inter-rater reliability, 12 subjects were chosen at random. Immediately after completion of measurements with rater one, rater two independently undertook the same protocol as rater one. Spinal landmarks were re-palpated for the second testing by rater one and again by rater two. Rater two was not present for the measurements taken by rater one, ensuring blinding between raters.

Figure 3.4 Application of manual inclinometers for thoracic kyphosis measurement.
3.2.3.4 Statistical analysis

Data was analysed using SPSS software, version 11.0 for Windows (SPSS Inc., Chicago, IL). The mean, standard deviation and range of thoracic kyphosis using the Flexicurve index, Flexicurve angle and the manual inclinometer were computed using descriptive statistics. Intra-rater and inter-rater reliability was determined by means of ICC, 95% confidence intervals and Standard Error of Measurement (SEM). ICC model 2 has been suggested to be best suited for generalising the findings to clinicians with similar clinical experience (Portney and Watkins 2000). Therefore, the ICC (2, 3) model for average measures was chosen. For the 12 participants in the inter-rater subset, the average of the three measures from the primary rater was compared with the single measure from the secondary rater, in order to calculate inter-rater reliability. The following previously established categories for expressing levels of reliability were used: <0.40, poor reliability; 0.40 to 0.6, moderate reliability; 0.6 to 0.75, good reliability; and >0.75, excellent reliability (Fleiss 1986). A linear regression was conducted to investigate the association between the Flexicurve angle and inclinometer angle. Using linear regression, a formula was computed to approximate the Flexicurve angle from the inclinometer angle. This takes the form: Flexicurve angle = (β coefficient x inclinometer angle) + intercept. Likewise, a formula was computed to approximate the manual inclinometer angle from the Flexicurve angle. This takes the form of inclinometer angle = (β coefficient x Flexicurve angle) + intercept.

3.2.4 Results

Subject demographic data is presented in Table 3.5. The weekly swimming distance of included participants ranged from 6km to 13km. Sixteen out of thirty subjects had a history of shoulder pain which had prevented them from swimming for at least one week. Eight out of thirty swimmers currently had shoulder pain in at least one shoulder. The information which has been collected on their shoulder pain history is presented in Table 3.6. The mean age of the portion with shoulder pain is 56 years and the mean current intensity of shoulder pain at the time of the study was 3.4 out of ten.
### Table 3.5 Characteristics of subjects.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (years)</th>
<th>Pain intensity</th>
<th>Duration of symptoms</th>
<th>Previous treatment</th>
<th>Duration since treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>3</td>
<td>6 weeks</td>
<td>Physiotherapy</td>
<td>2 years ago</td>
</tr>
<tr>
<td>2</td>
<td>68</td>
<td>4</td>
<td>10 years</td>
<td>Physiotherapy</td>
<td>14 months ago</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>1</td>
<td>12 years</td>
<td>Acromioplasty</td>
<td>10 years ago</td>
</tr>
<tr>
<td>4</td>
<td>77</td>
<td>4</td>
<td>20 years</td>
<td>Physiotherapy</td>
<td>18 months ago</td>
</tr>
<tr>
<td>5</td>
<td>68</td>
<td>4</td>
<td>5 years</td>
<td>No</td>
<td>n/a</td>
</tr>
<tr>
<td>6</td>
<td>65</td>
<td>4</td>
<td>4 years</td>
<td>Corticosteroid injection</td>
<td>3 years ago</td>
</tr>
<tr>
<td>7</td>
<td>39</td>
<td>1</td>
<td>6 years</td>
<td>No</td>
<td>n/a</td>
</tr>
<tr>
<td>8</td>
<td>51</td>
<td>6</td>
<td>8 months</td>
<td>Physiotherapy</td>
<td>Currently</td>
</tr>
</tbody>
</table>

Table 3.6 Description of the eight participants who have current shoulder pain, including their age, current shoulder pain intensity, their duration of symptoms and details of previous treatment.

Table 3.7 displays the mean, standard deviation and range of thoracic kyphosis values obtained from the Flexicurve index, Flexicurve angle and the manual inclinometer.

<table>
<thead>
<tr>
<th></th>
<th>Flexicurve index</th>
<th>Flexicurve angle in degrees</th>
<th>Manual inclinometer angle in degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.74 (F = 7.59, M = 7.8)</td>
<td>17.63 (F = 16.2, M = 18.6)</td>
<td>33.31 (F = 30.6, M = 35.1)</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.23 (F = 1.9, M = 2.4)</td>
<td>5.36 (F = 4.7, M = 5.7)</td>
<td>12.08 (F = 12.1, M = 13.2)</td>
</tr>
<tr>
<td>Minimum</td>
<td>3.12 (F = 5.43, M = 3.12)</td>
<td>7.26 (F = 7.8, M = 7.3)</td>
<td>12 (F = 17, M = 12)</td>
</tr>
<tr>
<td>Maximum</td>
<td>13 (F = 10.8, M = 13)</td>
<td>29.13 (F = 24.7, M = 29.1)</td>
<td>59 (F = 50, M = 59)</td>
</tr>
</tbody>
</table>

Table 3.7 Descriptive statistics. M=male, F=female.

Table 3.8 shows the intra-rater and inter-rater ICC and 95% confidence intervals. As a whole, inter-rater reliability of all methods was lower than intra-rater reliability. Intra-rater reliability was excellent and very similar for all methods, although the Flexicurve index and Flexicurve angle demonstrated slightly higher intra-rater reliability than the manual
inclinometer. In contrast, the inter-rater reliability of the manual inclinometer was higher than the Flexicurve index and Flexicurve angle. The manual inclinometer showed excellent inter-rater reliability while the Flexicurve index and angle showed good reliability. The SEM result based on the ICC (2, 3) data for intra-rater reliability was 1° for the Flexicurve angle, 2.2° for the manual inclinometer angle and 0.4 for the Flexicurve index. There was a poor association between the Flexicurve angle and inclinometer angle ($R^2=0.38$).

<table>
<thead>
<tr>
<th></th>
<th>Intra-rater reliability</th>
<th>Inter-rater reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>95% CI</td>
</tr>
<tr>
<td>Flexicurve Index</td>
<td>0.94</td>
<td>0.88-0.97</td>
</tr>
<tr>
<td>Flexicurve angle</td>
<td>0.94</td>
<td>0.88-0.97</td>
</tr>
<tr>
<td>Inclinometer angle</td>
<td>0.92</td>
<td>0.84-0.96</td>
</tr>
</tbody>
</table>

Table 3.8 Intra-rater and inter-rater reliability data

Figure 3.5 displays a bar chart showing the differences between the Flexicurve angle and manual inclinometer angle. These differences ranged from 2.4° to 36.2°. The mean difference between the two angles was 15.7°. The following equation was computed using linear regression to approximate the Flexicurve angle from the manual inclinometer angle: Flexicurve angle=($0.275 \times$ Inclinometer angle) + 8.478. To approximate the manual inclinometer angle from the Flexicurve angle, the following equation should be used: Inclinometer angle=($1.396 \times$ Flexicurve angle) + 8.694.

Figure 3.5 Bar chart displaying the manual inclinometer angle and Flexicurve angle obtained for each subject by rater one on occasion one.
3.2.5 Discussion

The primary focus of this study was to compare the intra-rater and inter-rater reliability of two clinical instruments for measuring thoracic kyphosis, the Flexicurve and the manual inclinometer. The key findings indicate that in a sample of swimmers with and without shoulder pain, the inclinometer demonstrated excellent intra-rater and inter-rater reliability. The Flexicurve index and Flexicurve angle both displayed identical reliability, with excellent intra-rater reliability and good inter-rater reliability.

The secondary purpose of this study was to compare the manual inclinometer angle and the Flexicurve angle. It is clear from Figure 3.5 that the thoracic kyphosis angles obtained by the Flexicurve and the manual inclinometer have large inherent differences, with the Flexicurve angle being much smaller than the inclinometer angle on every occasion. This trend was also revealed previously when Greendale et al. (2011) compared the formulated Flexicurve angle to the Debrunner’s kyphometer angle and the Cobb angle in an osteoporotic sample. As noted previously, the Flexicurve angle is an inscribed angle, which by definition will be smaller than the circumscribed angles estimated using the Cobb or Debrunner methods (Greendale et al 2011). Similar to these methods, the manual inclinometer provides a circumscribed angle which is evidently larger than the Flexicurve angle. Conversion equations have been provided by this study, which may facilitate within-user comparison of methods. Caution would be advised in the use of this conversion factor to non-swimming populations, until it is replicated in another population.

3.2.5.1 Intra-rater reliability

The excellent levels of intra-rater reliability (ICC=0.94) of the Flexicurve index reported in this study are in strong agreement with previous studies who used non-athletic populations. Teixeira and Carvalho (2007) report ICC’s of 0.87 for intra-rater reliability in a sample of 56 healthy participants of mean age 66 years. Similarly, Yanagawa et al. (2000) reported an ICC of 0.93 in 26 osteoporotic women of mean age 67 years. The high intra-rater reliability (ICC=0.92) of the manual inclinometer found in this study is also in agreement with previous studies. Lewis and Valentine (2010) investigated intra-rater reliability in 45 subjects with and without shoulder pain. In the asymptomatic and symptomatic group, Lewis and Valentine (2010) demonstrated ICC (2, 3)=0.97. These results are in strong agreement
with van Blommestein et al. (2012) who also demonstrated excellent intra-rater reliability of the manual inclinometer [ICC (2, 3) = 0.96].

3.2.5.2 Inter-rater reliability

This study allows direct comparison between the inter-rater reliability of the Flexicurve and the manual inclinometer as the participant sample is identical, the raters are identical, the landmarks palpated are the same for both instruments and the time between rater one and rater two measurements is the same.

The level of inter-rater reliability (ICC =0.86) of the Flexicurve index reported in this study is lower than that reported in the past. Previously, two separate studies reported an ICC of 0.94 in healthy samples (Teixeira and Carvalho 2007, D’Osualdo et al 1997). In addition, Greendale et al. (2011) reports an inter-rater ICC of 0.96 in 166 elderly participants with thoracic hyperkyphosis. There are three sources of random error that may have influenced the reliability results obtained by this study; the equipment, the patient and the clinician (Rothstein 1985). Due to the unstable nature of thoracic kyphosis (Portney and Watkins 2000), the thoracic kyphosis of the subjects may have changed between the measurements of rater one and rater two, during which the subjects undertook strength and ROM measures. Alternatively, there may have been a discrepancy in the palpated landmarks of both raters. These factors, however, are questionable as the inter-rater reliability of the manual inclinometer remained high. A possible contributing factor to the lower inter-rater reliability of the Flexicurve is the different levels of experience of each rater in using it. One rater had little prior clinical use with the Flexicurve while the other had years of clinical experience. Differences in the use of the Flexicurve may have involved variation in amount of pressure applied with the instrument and in translating the Flexicurve to paper. These challenges have previously been acknowledged (Hinman 2004, de Oliveira et al 2012). To the best of our knowledge, there is a noticeable absence of studies reporting inter-rater reliability of the manual inclinometer in the literature. The excellent levels of reliability observed in this study may facilitate the use of the manual inclinometer more widely in practice.

3.2.5.3 Clinical implications

The use of a simple, quick and reliable method for quantifying thoracic kyphosis is of value to clinicians, especially to physiotherapists working with large groups of swimmers.
This study indicates that thoracic kyphosis can be measured reliably with a Flexicurve or a set of manual inclinometers if the same clinician is to repeat the measurements. However, the inclinometer had higher inter-rater reliability than the Flexicurve which may favour its use in the swimming population. Furthermore, the manual inclinometer allows for instant interpretation of measurements compared to the Flexicurve index and angle which require subsequent calculations. The values obtained from the spinal measurements described in this study, in both degrees and kyphosis index could be used by clinicians to aid interpretation of values and to help to provide patient feedback. This is the first study to present the Flexicurve angle as described by Greendale et al. (2011) alongside the manual inclinometer angle. As reported previously, the Flexicurve angle obtained by this method is on average approximately 15° less than the inclinometer angle (Greendale et al 2011). The present study offers metrics that might allow researchers and clinicians to scale the Flexicurve angle to an approximate manual inclinometer angle in swimmers. The Flexicurve angle (1°) produced a lower SEM value than the manual inclinometer angle (2.2°), which is more favourable clinically.

3.2.5.4 Limitations of study

There are limitations to this study. The number of the subjects in the inter-rater subset was quite small. Future studies examining the inter-rater reliability of both instruments should incorporate a larger sample of participants. Although this study demonstrated high reliability for the inclinometer assessment tool, it does not demonstrate its validity as a measure of thoracic curvature. In order to establish validity, further research, comparing spinal angles obtained from these tools with those obtained from radiographic investigations, the gold standard, is required.

3.2.6 Conclusion

This study concludes that the manual inclinometer has excellent levels of intra-rater and inter-rater reliability and clinicians can be confident in its reliability in a group of swimmers. Both the Flexicurve index and angle have excellent intra-rater and good inter-rater reliability. Advantages associated with both the manual inclinometer and Flexicurve for use poolside are their ease of use and their portability. These positive characteristics combined
with their high levels of reliability should encourage clinicians to use these tools to help guide treatment progression or to monitor thoracic kyphosis levels. The Flexicurve angle may be the most attractive of all 3 methods due to its lower SEM. However, caution must be used when interpreting Flexicurve angles calculated by this method, in relation to the other methods. The comparison of the Flexicurve angle and other methods may not be valid, as it is repeatedly smaller than the Cobb angle (Greendale et al 2011) and the inclinometer angle.
3.3 Study IV: Validity of the manual inclinometer and Flexicurve for the measurement of thoracic kyphosis


3.3.1 Abstract

Introduction: The manual inclinometer and the Flexicurve are widely used instruments for the clinical measurement of thoracic spinal posture. While these instruments have demonstrated high levels of reliability, there have been no investigations of the validity of the manual inclinometer when compared to the gold standard radiographic measurement. The Flexicurve angle, obtained using a previously described formula, has demonstrated a moderate level of validity in older, hyperkyphotic populations. However, its validity in younger populations is unknown. The aim of this study is to examine the concurrent validity of the Flexicurve and manual inclinometer in relation to the radiographic Cobb angle for the measurement of thoracic kyphosis.

Methods: Eleven subjects (7 males, 4 females) underwent a sagittal plane spinal radiograph. Immediately following the radiograph, a physiotherapist measured thoracic kyphosis using the Flexicurve and manual inclinometer before the subjects moved from position. Cobb angles were subsequently measured from the radiographs by an independent examiner.

Results: A strong correlation was demonstrated between both the Cobb angle and the Flexicurve angle (r=0.96) and the Cobb angle and manual inclinometer angle (r=0.86). On observation of the Bland-Altman plots, the inclinometer showed good agreement to the Cobb angle (mean difference 4.8°±8.9°). However, the Flexicurve angle was systematically smaller than the Cobb angle (mean difference 20.3°±6.1°), which reduces its validity.

Conclusion: The manual inclinometer is a valid instrument for measuring thoracic kyphosis, with good levels of agreement with the gold standard. While the Flexicurve is highly correlated to the gold standard, they have a poor level of agreement. Therefore, caution must be taken when interpreting its results. The manual inclinometer provides a reliable, valid and clinically applicable method of measuring thoracic posture.
3.3.2 Introduction

Thoracic hyperkyphosis is an excessive curvature of the thoracic spine in the sagittal plane (Bansal et al 2014). It is observed among individuals of all age groups and has been implicated in a range of negative health consequences. Demographic research has identified that thoracic kyphosis generally appears to increase with age (Fon et al 1980) and thoracic hyperkyphosis is estimated to affect 20-40% of older adults (Takahashi et al 2005). An increase in thoracic kyphosis may be the visible manifestation of a pathological process such as Scheuermann’s disease during adolescence, it can result from postural habit (Gravina et al 2012) or it may be a normal physiological response to aging (Willner 1981).

An extensive array of impairments have been associated with thoracic hyperkyphosis, which include a slowing of gait, reduction in balance and increased risk of falls (Sinaki et al 2004). It may be for these reasons that thoracic hyperkyphosis is a predictor of mortality, independent of underlying spinal osteoporosis (Kado et al 2007b). Not only has thoracic hyperkyphosis been associated with disorders of the respiratory and neurological systems, it has also been associated with impairments in the musculoskeletal system including cervical pain (Griegel-Morris et al 1992), shoulder pain (Gumina et al 2008) and lower back pain (Ensrud et al 1997).

These negative health consequences place importance on the measurement of thoracic kyphosis by health care professionals. It drives the need for valid and reliable measurement tools for the purposes of screening, monitoring and assessing intervention in patient populations. The gold standard measurement for thoracic kyphosis is the Cobb angle, calculated from a sagittal plane spinal radiograph (Harrison et al 2001). The Cobb angle represents the angle subtended by the vertebral endplates above and below the thoracic curve (Briggs et al 2007). However, the limitations of radiographic measurement, including expense (de Oliveira et al 2012), limited portability, time-consumption and exposure to ionising radiation (Briggs et al 2007, Teixeira and Carvalho 2007), make it unsuitable for repeated clinical use.

A previous systematic review highlights the diverse range of non-invasive measurement devices which facilitate the measurement of thoracic kyphosis (Barrett et al 2014). This review identified the Flexicurve and manual inclinometer as cheap, simple tools which permit a quick clinical measurement of thoracic kyphosis. Both tools have previously

The primary output of the Flexicurve is a kyphosis index. Attempts have been made to translate the Flexicurve index into a corresponding Flexicurve angle, to aid comparison with the radiographic Cobb angle. Two studies (Teixeira and Carvalho 2007, Azadinia et al 2014) used an extensive third degree polynomial to calculate the Flexicurve angle and demonstrated conflicting levels of validity. One study demonstrated high levels of validity when calculating the Flexicurve angle using a Cartesian coordinate system (de Oliveira et al 2012). However, it required specialised computer software and was time-consuming. Greendale and colleagues proposed a simple translation formula which provides an approximate angle of thoracic kyphosis without the need for specialised software and have demonstrated its correlation with the Cobb angle in older adults with thoracic hyperkyphosis (Greendale et al 2011). Although the Flexicurve angle did not demonstrate agreement with the Cobb angle (Greendale et al 2011), the level of correlation and agreement in a younger, healthier population has yet to be established. To the knowledge of the authors, the validity of the manual inclinometer has not been investigated to date.

The aim of the present study was to determine the concurrent validity of the Flexicurve and manual inclinometer as a measure of thoracic kyphosis by comparison with the gold standard.

3.3.3 Methods

3.3.3.1 Subjects

A cross-sectional study design was carried out. The study sample was patients attending a spinal orthopaedic clinic for the purpose of a spinal radiograph and orthopaedic consultation. A sample of convenience was used in order to recruit participants at this clinic within the time frame of the study. The exclusion criteria were as follows: (i) under the age of 18 years, (ii) not referred for a lateral spine radiograph, (iii) unable to stand independently and (iv) a documented history of vertebral compression fracture. Ethical approval was granted by the University Hospital Limerick Research Ethics Committee. All subjects provided written informed consent.
3.3.3.2 Instrumentation

Two gravity-dependent inclinometers (Isomed, Inc., 975 SE Sandy Boulevard, Portland, OR, USA) were used. The feet of the inclinometers were 2.5 cm apart, which remained constant for all subjects. The Flexicurve (TridentR) is a flexible plastic-covered metal ruler, 60 cm in length, marked at 1 mm intervals.

3.3.3.3 Experimental procedure

3.3.3.3.1 Preparation

Initial preparation included the identification of the spinal landmarks required for skin-surface thoracic kyphosis measurement. For this, the subject was positioned in relaxed standing and the spinous processes of C7, T1, T2, T12 and L1 were identified by palpation and marked with an erasable pen. The interspinous space of L3/4 was identified at the level of the iliac crests (Chakraverty et al 2007) and the L1 and T12 spinous processes were marked by palpating superiorly from this reference point (Palastanga et al 2007). The 7th cervical vertebra was designated to have the most prominent spinous process (Palastanga et al 2007). Palpating inferiorly from this reference point, the T1 and T2 spinous processes were identified and marked (Lewis and Valentine 2010).

3.3.3.3.2 Radiographic measurement

The radiographic assessment was performed by a radiographer using a device made by Siemens, X-ray film from Fuji Films and a processor from Kodak. The same radiographer took all of the radiographic images. For the thoracic spine the focus was maintained on the seventh costal arch. In order to avoid the thoracic spine image being overlapped by the upper limbs, the shoulder and elbow were positioned at 90° flexion by the participant holding onto a bar in front of them. As the radiograph was being taken, the subject was instructed to stand in their normal relaxed posture and to hold their breath.
3.3.3.3 Flexicurve and manual inclinometer measurement

Non-invasive measurement of thoracic kyphosis was carried out by a physiotherapist with three years of experience using these tools for research purposes. The order between the Flexicurve and manual inclinometer measurement was determined for each subject individually by a coin toss. Both were measured directly after the X-ray, before the subject moved out of position. The tip of the Flexicurve was placed at C7 and was moulded to the contour of the thoracic spine in a caudal direction. The Flexicurve was then carefully transferred to paper and the curve was outlined. This process was repeated three times, being flattened between each measurement. Both the kyphosis index and Flexicurve angle were later calculated using the formulae, as described previously in Figure 3.3.

For the inclinometer measurement, the feet of the inclinometers were placed over the spinous processes of T1/T2 and T12/L1. The readings were read directly from the inclinometers and recorded. Inclinometer measurements were performed three times in succession and an average was used for analysis (Lewis and Valentine 2010, van Blommestein et al 2012). These protocols for both the Flexicurve and manual inclinometer measurement of thoracic kyphosis were previously shown to have excellent levels of inter-rater and intra-rater reliability (Barrett et al 2013).

3.3.3.4 Data analysis

An experienced orthopaedic consultant, who was not involved in taking the radiographic images, calculated the Cobb angle using the digital radiographic images. The two-line Cobb method was used to obtain the thoracic kyphosis angles. This method consists of tracing two straight lines, one extending from the T4 upper endplate and the other extending from the T12 lower endplate, respecting the inclination of the vertebrae. The Cobb angle is formed where these lines meet (Harrison et al 2001, Goh et al 1999).

Data were analysed using SPSS software, version 22.0 for Windows (SPSS, Inc., Chicago, IL, USA). Data were non-normally distributed (Shapiro-Wilks, p<0.05). Spearman’s rank correlation coefficient ($r_s$) was used to establish the linear relationship between the Cobb angle and both the Flexicurve angle and inclinometer angle. The values of $r_s$ were classified as: strong (>0.5), medium (from 0.3 to 0.5), small (from 0.1 to 0.3) and none (<0.1) (Cohen 1988). Bland-Altman analysis was carried out to graphically display the level of agreement between the measures. In the Bland-Altman plot, the mean of the two
paired angles are plotted on the x-axis and their differences are plotted on the y-axis (Bland and Altman 1986). These plots include approximate 95% confidence intervals.

### 3.3.4 Results

Eleven subjects (seven male, four female), with a mean±SD age of 40.9±20.1 years and body mass index of 24.4±5.4 kg/m$^2$ participated in the study. Six participants presented with a primary complaint of low back pain, four with thoracic pain and one with interscapular pain. Table 3.9 displays a description of thoracic kyphosis values obtained from the Cobb angle, inclinometer angle, Flexicurve angle and Flexicurve index. The mean±SD Cobb angle was 52±15.2°. The mean±SD inclinometer angle was comparable to the actual Cobb angle (47.2±17.7°). As demonstrated previously in older, hyperkyphotic patients (Greendale et al 2011), the Flexicurve angle averaged about 21° less than the Cobb angle (31.7±19.2°). Both the manual inclinometer and the Flexicurve demonstrated strong levels of correlation to the Cobb angle (Cobb and inclinometer angles $r_s=0.86$, $p=0.001$; Cobb and Flexicurve angles $r_s=0.96$, $p<0.001$).

<table>
<thead>
<tr>
<th></th>
<th>Cobb angle (degrees)</th>
<th>Manual inclinometer angle (degrees)</th>
<th>Flexicurve angle (degrees)</th>
<th>Flexicurve index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>52</td>
<td>47.18</td>
<td>31.7</td>
<td>12.75</td>
</tr>
<tr>
<td><strong>Standard deviation</strong></td>
<td>19.18</td>
<td>17.7</td>
<td>19.19</td>
<td>8.09</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>29</td>
<td>18</td>
<td>12</td>
<td>6.43</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>86</td>
<td>76</td>
<td>59</td>
<td>33.17</td>
</tr>
</tbody>
</table>

Table 3.9 Angles of thoracic kyphosis obtained using the radiograph, manual inclinometer and Flexicurve.

Figure 3.6 (a) and (b) displays Bland–Altman plots for the Cobb angle with both the manual inclinometer angle and the Flexicurve angle respectively. The differences were normally distributed (Shapiro-Wilks $p>0.05$) and so the assumptions of the Bland-Altman plot were satisfied. Both plots demonstrated wide 95% confidence intervals, which may be principally related to the small sample size used. Neither plot demonstrated proportional bias (Cobb and inclinometer angles $p=0.60$; Cobb and Flexicurve angles $p=0.67$) and the spread of the differences remained relatively consistent across the range of thoracic kyphosis magnitude. The Bland-Altman plots demonstrated that the manual inclinometer had good agreement with the Cobb angle (mean difference±SD = 4.8±8.9°), unlike the poor agreement between the Flexicurve angle and Cobb angle (mean difference±SD 20.2±6.1°). Figure 3.7
displays a graphical comparison of the Cobb angle and the paired manual inclinometer angle and Flexicurve angle obtained for each subject.

Figure 3.6 Bland-Altman plots for (a) the Cobb angle and manual inclinometer angle and (b) the Cobb angle and Flexicurve angle.
3.3.5 Discussion

3.3.5.1 Main findings

This study established the level of validity of two non-invasive tools, the Flexicurve and manual inclinometer, for measuring thoracic kyphosis in reference to the gold standard method, using both correlation and agreement. The manual inclinometer demonstrated a strong correlation and good level of agreement with the gold standard. Although there was a mean difference of 4.8° between the manual inclinometer and the Cobb angle, the clinical importance of this difference should be judged according to the purposes of the measurement. This mean difference is larger than the standard error of measurement for the inclinometer, which was previously demonstrated to be 2.2° (Barrett et al 2013). This indicates sources of error beyond measurement error. The mean difference between the manual inclinometer angle and Cobb angle observed in this study is similar to the differences reported for other clinical measurement devices. Previous studies have reported mean differences from the Cobb angle measurements of 1.4°-2.9° for the arcometer (D’Osualdo et al 1997, Chaise et al 2011), 5° for stereovideography (Leroux et al 2000) and 2.3° -2.8° for the Debrunner kyphometer (Greendale et al 2011, Korovessis et al 2001). The observed discrepancy
between the radiographic and skin-surface measurements could be attributed to the distortion of the contour of the thoracic spine by intervening soft tissue. Additionally, the Cobb angle itself is not without error, as intrinsic error associated with the Cobb measurement technique has been accepted to be approximately 5º (Morrissy et al 1990) and individual differences can be as large as 30º (Carman et al 1990). The primary source of error in calculating the Cobb angle appears to be the difficulty in identifying the bony landmarks accurately on the radiographic image (Carman et al 1990). However, the Cobb angle is still accepted as the gold standard due to its simplicity and clinical meaningfulness.

This is the first study to report an estimate of the validity of the manual inclinometer. However, one previous study demonstrated that the digital inclinometer had acceptable validity in individuals with thoracic hyperkyphosis who are less than 30 years (ICC= 0.89) and greater than 50 years old (ICC= 0.81) (Azadinia et al 2014). However, measures of agreement were not provided in that study (Azadinia et al 2014). Therefore, direct comparison between these results and the present study cannot be made as different statistical methods and study populations were used. However, it is reassuring that the manual inclinometer showed comparable levels of validity to the digital inclinometer even though judging the reading from the manual inclinometer may serve as an additional potential source of error.

The method of Flexicurve angle calculation used in this study was strongly correlated with the Cobb angle. Importantly, correlation quantifies the degree to which two variables are related but a high correlation does not imply that there is good agreement between the two methods (Geravarina 2015). When the measure of agreement was graphically displayed using a Bland-Altman plot, it was evident that large mean differences existed. The method of Flexicurve angle calculation used in this study produced angles which were systematically smaller than the radiographic Cobb angles. This finding is in agreement with a previous study which used an older, hyperkyphotic sample (Greendale et al 2011). In contrast, Greendale et al. (2011) demonstrated lower correlation of the Flexicurve angle with the Cobb angle, which varied from r=0.67 to r=0.76. One explanation of the higher correlation coefficient demonstrated in this study might be the fact that the measurement of thoracic kyphosis using the non-invasive tools directly followed the radiographic procedure, before the subject moved from position. This is in contrast to the previous study which took all measurements within a 4 hour window (Greendale et al 2011). This leaves the potential for variability in resting standing posture between measurement times.
Other methods of Flexicurve angle calculation have also been suggested. Two studies followed a method using a third degree polynomial formula (Teixeira and Carvalho 2007, Azadinia et al 2014). One of these studies reported strong validity (ICC=0.91) and mean differences of 0.8º, when the mean of two measurements was used for the analysis in a healthy population (Teixeira and Carvalho 2007). However, a subsequent study demonstrated a much lower ICC of 0.50-0.51 when comparing this third degree polynomial formula to the Cobb angle in older adults and children with hyperkyphosis (Azadinia et al 2014). Therefore, the validity of this technique in people with thoracic hyperkyphosis is questionable. One study which used a Cartesian coordinate system to calculate a Flexicurve angle reported high correlation (r=0.7) and an absolute mean difference of 6.5º ±4.7º (de Oliveira et al 2012). This mean difference between the Flexicurve and Cobb angle is smaller than demonstrated in the present study. However, as this method requires advanced calculations and specialised software, it may not be appropriate for everyday clinical use.

At present, there is no method which allows for the accurate translation of the Flexicurve index into a corresponding Cobb angle with close agreement. The reason for this is that the Flexicurve is designed to measure spinal curve using the contour of full thoracic spine, whereas the Cobb angle depends on the vertebrae at the limits of the curve. The Flexicurve may show higher agreement with the centroid angle, which computes thoracic kyphosis using the midpoints of all vertebral bodies from T1–T12. Further research is required to investigate this.

3.3.5.2 Implications for practice

The strong validity of the manual inclinometer demonstrates that it is an appropriate tool to aid clinicians in monitoring thoracic kyphosis over time and when determining the effectiveness of intervention strategies. Further, it is readily accessible to clinicians, relatively cheap and has high reliability. As the inclinometer angle relies totally on the two selected vertebral levels, deformities at these selected endplates may overestimate the degree of thoracic kyphosis. Therefore, the manual inclinometer may potentially be more suitable for use in healthy populations. Future research should consider establishing the validity of the manual inclinometer specifically in people with osteoporosis.

The Flexicurve allows for the provision of visual feedback to the patient which enables a qualitative evaluation of postural deviation. This attribute of the Flexicurve can aid postural retraining in patient populations. It can also permit the longitudinal study of change
in thoracic kyphosis induced by disease progression or therapeutic intervention. However, clinicians should be aware that the method used in this study to calculate a Flexicurve angle is not in agreement with the gold standard.

3.3.5.3 Limitations

This study has strengths including the skin-surface measurements directly after the radiographic procedure and the consideration of both correlation and agreement to provide an accurate reflection of validity. However, similar to other validation studies of thoracic kyphosis measurement devices (Perriman et al 2010, Ripani et al 2008), the number of participants in this study was small due to ethical considerations regarding radiation exposure. Although the method of Flexicurve and manual inclinometer measurement described here reflects how the tools are used clinically, the reliability of skin-surface palpation of bony landmarks has been debated in the literature (Lewis et al 2002).

3.3.6 Conclusion

In summary, the manual inclinometer has been demonstrated to have strong concurrent validity when compared to the gold standard Cobb angle technique. This is an important finding for health practitioners who require a simple, cost-effective, reliable and valid tool for use in clinical practice as either a screening tool or for longitudinal assessment of thoracic spine posture. The Flexicurve angle has a strong correlation with the Cobb angle but demonstrates poor agreement. Therefore, the Flexicurve angle, as calculated here, cannot be regarded as a valid measurement of thoracic kyphosis.
3.3.7 Chapter 3: Summary of key points

The aims of the three studies presented in Chapter 3 were to synthesise the evidence regarding the reliability and validity of methods of thoracic kyphosis measurement and to establish the reliability and validity of two clinical instruments for the measurement of thoracic kyphosis: the manual inclinometer and the Flexicurve. The findings of Study II highlighted the array of instruments used for the objective measurement of thoracic kyphosis from the skin-surface. However, the strength of evidence for the reliability and validity of many instruments was limited by the small number of studies which have examined their clinometric properties. Nevertheless, this review provided guidance towards the reliability and validity of instruments for measuring thoracic kyphosis in clinical practice, as well as for the clinical study of this thesis. Appendix 1 contains a published letter to the editor which highlights an additional study which was not identified through the database search of this review (Zaina and Negrini 2015). Appendix 2 contains a published letter to the editor in response to Zaina and Negrini (2015), which explains why this study was not included in the systematic review (the study was not published in any of the databases searched).

The results of Study III demonstrated the very high inter- and intra-rater reliability of both the manual inclinometer and the Flexicurve for thoracic kyphosis measurement. However, upon investigation of the validity of these instruments in Study IV, the method used to calculate the Flexicurve angle demonstrated poor agreement with the gold standard Cobb angle. In contrast, the manual inclinometer demonstrated both good agreement and high correlation with the Cobb angle. Compared to the other instruments identified in the systematic review, the manual inclinometer appears to be superior in terms of reliability and validity, as well as its ease of use and portability. Based on this, the manual inclinometer was considered appropriate for the measurement of thoracic kyphosis in the clinical study of this thesis.
Chapter 4: Clinical Studies

Chapter 4 presents the two clinical studies of the thesis. Study V is currently being prepared to be submitted for publication. Study VI is under review for publication. These studies quantitatively and qualitatively evaluated group exercise classes in separate samples of people with non-specific shoulder pain.

- **Study V** observes changes in pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following two different shoulder exercise interventions.
- **Study VI** is a separate qualitative study which examines the experiences of individuals who participated in the shoulder only exercise classes.
4.1 Study V: An evaluation of the effects of group exercise classes on shoulder pain, disability and thoracic kyphosis, in people with non-specific shoulder pain: a case series.


4.1.1 Abstract

Introduction: Thoracic spine posture is a common component of the assessment and treatment of shoulder pain. However, there is a lack of research which measures thoracic kyphosis before and after exercise based interventions in people with shoulder pain. It is therefore unknown if thoracic kyphosis changes following exercise programmes in this population. The aim of this study was to observe changes in pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following two different shoulder exercise interventions.

Methods: A case series was carried out in two physiotherapy sites which were carrying out shoulder exercise classes for people with shoulder pain. From September 2014 to January 2016, people with non-specific shoulder pain received one of two exercise classes; a six week block of classes containing only shoulder exercises (shoulder group) or a six week block of classes containing a mixture of shoulder and thoracic extension exercises (thoracic group). The Disabilities of the Arm, Shoulder and Hand (DASH) and the Numeric Rating Scale (NRS) were measured at baseline, six weeks and six months. Thoracic kyphosis was measured at baseline and six weeks using the manual inclinometer.

Results: The shoulder group contained 20 participants (11F, 9M, mean (SD) age of 60.44 (11.04) years) and the thoracic group contained 19 participants (11 F, 8 M, mean (SD) age of 57.68 (8.47) years). NRS and DASH improved significantly in both groups from baseline to six week and baseline to six month follow-up (p<0.001). Thoracic kyphosis did not change beyond measurement error in either group.

Conclusion: This study provides preliminary evidence that exercise classes improve pain and disability in people with non-specific shoulder pain. Thoracic kyphosis did not change in either group, indicating that a change in thoracic kyphosis was not necessary for the clinical improvements. A RCT is required to compare the effectiveness of shoulder exercise classes, with and without thoracic extension exercises, for the treatment of non-specific shoulder pain.
4.1.2 Introduction

An increase in thoracic kyphosis has long been postulated as a contributing factor in the development of shoulder pain (Griegel-Morris et al 1992, Ayub 1991, Calliet 1991, Grimsby and Gray 1997). As described in Chapter 1, this clinical hypothesis is supported by a small amount of cross-sectional research which demonstrates that a change in thoracic spine posture has an immediate and within-session effect on scapular position, scapular kinematics, acromiohumeral distance and shoulder muscle activity (Kebaetse et al 1999, Finley and Lee 2003, Gumina et al 2008, Kalra et al 2010, Greig et al 2008). However, these cross-sectional studies, which were carried out in people without shoulder pain, are low level evidence and have a limited capacity to explore the role of thoracic kyphosis in the development of shoulder pain. The systematic review in Chapter 2 provided some further support of a mechanical relationship between the thoracic spine and the shoulder joint (Barrett et al 2016), with a strong level of evidence that adopting a kyphotic spinal posture significantly reduces shoulder joint range of motion (ROM). However, this systematic review also provided moderate evidence of no association between thoracic kyphosis and shoulder pain.

Despite the paucity of evidence to support that thoracic kyphosis has a role in the development or maintenance of shoulder pain, the assessment and treatment of thoracic spine posture remains a common component of the physiotherapy management of shoulder pain. Multi-component exercise programmes, which aim to strengthen the rotator cuff and scapular muscles and improve shoulder ROM, are recommended in shoulder pain populations (Klintberg et al 2015, Diercks et al 2014). Exercises to reduce thoracic kyphosis are often included as an adjunct to shoulder strengthening and ROM exercises (Kachingwe et al 2008, Cohen and Ginn 1998, Kuhn 2009). However, despite the emergent evidence which describes the reliability and validity of many clinical instruments for the measurement of thoracic kyphosis, as described in Chapter 3, there is a lack of research which measures thoracic kyphosis before and after exercise based interventions. This is a significant gap in the literature as it is not known if providing an exercise programme containing either shoulder exercises only or a mixture of shoulder and thoracic extension exercises facilitates a change in thoracic kyphosis. There is a need for a study which measures if changes in thoracic kyphosis occur alongside changes in pain and disability following variations in exercise programmes in people with non-specific shoulder pain.

As discussed in Chapter 1, group exercise classes have been shown to have at least equivocal effectiveness as individual physiotherapy treatment for musculoskeletal pain
(Bennell and Hinman 2011, Carr et al 2005, O’ Keeffe et al 2016), including shoulder pain (Russell et al 2014). In addition, they may have advantages in terms of social support and potentially cost-effectiveness. However, exercise classes for people with shoulder pain has received little research attention. Therefore, the aim of this study was to evaluate changes in shoulder pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following two different shoulder exercise classes. The hypotheses of this study are:

1. Null hypothesis: Shoulder pain and disability, as measured by the DASH and NRS, will not change in either group. Alternative hypothesis: Shoulder pain and disability will significantly reduce in both groups at six week and six month follow-up.
2. Null hypothesis: Thoracic kyphosis, as measured by the manual inclinometer, will not change in either group. Alternative hypothesis: Thoracic kyphosis will reduce significantly and beyond measurement error in the group receiving a mixture of shoulder and thoracic exercises and it will not reduce in the group receiving only shoulder exercises at six week follow-up.

4.1.3 Methods

4.1.3.1 Study design

A case series was conducted in two hospital sites which were running outpatient physiotherapy exercise classes for people with shoulder pain; St. Johns Hospital, Limerick and Midlands Regional Hospital, Portlaoise. The shoulder exercise classes conducted in these sites between September 2014 and January 2016 were included in the study. Participants received one of two variations in exercise classes; a six week block of classes containing only shoulder exercises (shoulder group) or a six week block of classes containing a mixture of shoulder and thoracic extension exercises (thoracic group). The physiotherapists maintained the number of blocks relatively even between both types of class as the study progressed, in order to balance the numbers in both groups. Ethical approval was obtained from the Health Service Executive Research Ethics Committee for the Midlands Area and St Johns Hospital Research Ethics Committee. All subjects signed an informed consent form prior to their participation in the study.
4.1.3.2 Case description

The primary sources of shoulder referrals to these physiotherapy departments came from local general practitioners and the pain and orthopaedic consultants associated with the hospitals. Due to the acknowledged challenges with structural shoulder diagnosis, the population of interest for this study were people with non-specific shoulder pain. Specific causes of shoulder pain, including referred cervical pain, frozen shoulder, recent trauma or surgery were excluded. Inclusion and exclusion criteria are listed in Table 4.1.

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over the age of eighteen</td>
<td>Cervical repeated movement testing affects shoulder pain and/or range of movement</td>
</tr>
<tr>
<td>Willing and able to participate</td>
<td>Equal restriction of active and passive shoulder flexion, abduction or external rotation</td>
</tr>
<tr>
<td>Minimum six week history of shoulder pain</td>
<td>Co-morbidities which would preclude participation in exercise</td>
</tr>
<tr>
<td>Shoulder pain is aggravated by resisted shoulder flexion, abduction or external rotation</td>
<td>Shoulder surgery or fracture within the previous twelve weeks</td>
</tr>
</tbody>
</table>

Table 4.1 Eligibility criteria for inclusion in the study.

The physiotherapist carried out a basic screening with the individuals taken from the referral list to ensure their suitability and willingness to participate in a group exercise class. Alternatively, participants who had previously received individual physiotherapy at the sites and who were thought to be suitable for an exercise class ceased individual physiotherapy and commenced the group. When a sufficient number of participants were registered (four to six), a six week course of exercise classes commenced. In the thoracic group, twelve out of nineteen participants received a mean (SD) of 3.8 (3.4) individual sessions prior to their entry into the exercise class and in the shoulder group, eleven out of twenty participants received a mean (SD) of 2.9 (3.0) individual sessions prior to their entry into the class. Individual physiotherapy contained exercise, manual therapy and/or electrotherapy modalities, depending on the needs of the patient. Importantly, however, the baseline measures for this study were taken immediately before the first exercise class, after which the participants did not receive any further individual physiotherapy.
4.1.3.3 Intervention

All participants received a 45 minute group exercise class, scheduled once a week for six weeks. Each class consisted of a five minute warm-up, followed by ten exercises (two minutes per exercise and one minute rest in between). Each participant carried out an individual number of repetitions and sets in the two minute interval, which was aimed to be progressed throughout the course of the exercise classes. Progress was verbally reported by the participant to the physiotherapist each week. The participants were allowed to experience pain during their exercises (Klintberg et al 2015), as long as the pain settled after the completion of the exercises and was not any worse the following day (Littlewood et al 2014a). As well as the class once per week, participants were encouraged to carry out the exercises at home every day on which the class was not taking place. Adherence to the home exercise programme was not monitored. Although the two types of classes had the same physiotherapist, structure and duration, they differed in the types of exercise provided (i.e. number of shoulder resisted, scapular resisted, shoulder ROM and thoracic exercises).

As there is no evidence for one specific type of resistance or ROM exercise over another for the treatment of shoulder pain (Littlewood et al 2012, Klintberg et al 2015, Abdulla et al 2015) and to account for the differences in space and equipment between the sites, the physiotherapists were provided with this small menu of specific exercises from which they could choose from in each section. This is detailed in Table 4.2.

4.1.3.3.1 Shoulder group

In this group, the ten exercises consisted of four shoulder resisted exercises, three scapular resisted exercises, two shoulder ROM exercises and one general body exercise. Shoulder and scapular resistance exercises were emphasised due to the accumulating evidence to support increasing the load capacity of the rotator cuff (Lewis 2010) and strengthening the scapular muscles (Holmgren et al 2012) in people with shoulder pain. The specific shoulder exercises used were based on those demonstrated to be previously effective in similar populations (McClure et al 2006, Cools et al 2007). This group did not receive any thoracic extension exercises.
4.1.3.3.2 Thoracic group

This group also completed ten exercises. However, in this group, four out of ten exercises instructed the participants to actively extend their thoracic spine to the end of their available range. These thoracic extension exercises were based on protocols used previously (Greendale et al 2009, Bautmans et al 2010, Bennell et al 2010) for reducing thoracic kyphosis. This group also received three shoulder resisted exercises, two scapular resisted exercises and one shoulder ROM exercise.

<table>
<thead>
<tr>
<th>Exercises per group</th>
<th>Examples of exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warm-up exercises (5 mins)</strong> Both groups</td>
<td>• Shoulder girdle range of motion (shoulder, scapular and neck movements)</td>
</tr>
<tr>
<td></td>
<td>• Pendulum exercises</td>
</tr>
<tr>
<td></td>
<td>• Gross body movements</td>
</tr>
<tr>
<td></td>
<td>• Posterior shoulder stretch 30 seconds x 3 repetitions</td>
</tr>
<tr>
<td><strong>Thoracic exercises</strong></td>
<td>• Sternal lifts in standing</td>
</tr>
<tr>
<td>Numbers performed per group:</td>
<td>• Thoracic extension with bilateral shoulder flexion</td>
</tr>
<tr>
<td>Thoracic=4</td>
<td>• Prone trunk extension with arms in W position</td>
</tr>
<tr>
<td>Shoulder=0</td>
<td>• Step forward with thoracic extension during unilateral shoulder flexion</td>
</tr>
<tr>
<td><strong>Shoulder range of motion exercises</strong></td>
<td>• Table slides</td>
</tr>
<tr>
<td>Numbers performed per group:</td>
<td>• Window wipers (internal/external rotation)</td>
</tr>
<tr>
<td>Thoracic group=1</td>
<td>• Active assisted shoulder movements</td>
</tr>
<tr>
<td>Shoulder group=2</td>
<td>• Pulleys</td>
</tr>
<tr>
<td><strong>Shoulder resisted exercises</strong></td>
<td>• Isometric/concentric/eccentric shoulder flexion, abduction and external rotation with weights/theraband</td>
</tr>
<tr>
<td>Numbers performed per group:</td>
<td>• Combined movements/diagonals</td>
</tr>
<tr>
<td>Thoracic group=3</td>
<td>• Seated/standing row</td>
</tr>
<tr>
<td>Shoulder group=4</td>
<td>• Forward press in supine</td>
</tr>
<tr>
<td><strong>Scapular resisted exercises</strong></td>
<td>• Wall-press / push-up</td>
</tr>
<tr>
<td>Numbers performed per group:</td>
<td>• Step-ups (with shoulder flexion if possible)</td>
</tr>
<tr>
<td>Thoracic group=2</td>
<td>• Walking lunge</td>
</tr>
<tr>
<td>Shoulder group=3</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.2 Components of the exercise class.
4.1.3.4 Outcome measures

The primary investigator, who was independent from the conduct of the exercise classes, carried out all baseline and follow-up measurements. Thoracic kyphosis was measured immediately before the first class at baseline and immediately after the last class at six week follow-up. Thoracic kyphosis was measured using a set of manual inclinometers, as described in Section 3.3.3.3.3. In Chapter 3, the manual inclinometer was demonstrated to have high levels of reliability and validity for the measurement of thoracic kyphosis. Although the minimal clinically important difference (MCID) of thoracic kyphosis is unknown, the standard error of measurement (SEM) of the manual inclinometer has been previously reported as 2.2° (Barrett et al 2013). The Numerical Rating Scale (NRS) was used to measure average pain intensity in the previous week and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was used to measure average disability in the previous week. These were measured immediately before the first class at baseline, directly after the last class at week six and via postal questionnaire at six months from baseline. The NRS is a reliable outcome measure, with a MCID of approximately 2 points in shoulder pain populations (Farrar et al 2001, Michener et al 2011). The DASH has been demonstrated to have excellent reliability, with a MCID of 10 points (Roy et al 2009).

Although special tests were not used to guide inclusion into this study due to their poor diagnostic accuracy (Hegedus et al 2008), four tests which are commonly used to diagnose subacromial impingement syndrome in clinical practice were used at baseline in order to provide detail of shoulder movements which aggravated the participants pain. These consisted of the Empty Can test, Hawkins-Kennedy test, Neers test and Painful Arc test (Cools et al 2008). This information may be useful for clinicians who use these tests in clinical practice.

In order to further describe the baseline characteristics of the participants, the number of painful body sites was assessed using the Standardised Noredic Questionnaire (SNQ) (Kuorinka et al 1987). The participants were asked to report whether they had experienced pain or discomfort in the following areas during the previous 12 months: neck, shoulder, elbow, hand/wrist, upper back, lower back, hip, knee and ankle/foot. This provided a score from zero to nine, where nine is pain at every site. Furthermore, the Subjective Health Complaints Inventory (SHCI) assessed the degree of the following 13 non-musculoskeletal symptoms: palpitations, chest pain, breathing difficulties, heartburn, stomach discomfort, diarrhoea, constipation, eczema, tiredness, dizziness, anxiety, depression and sleep problems.
Participants graded the intensity of each complaint experienced over the previous month on a four-point likert scale, where zero was not affected and three was severely affected, which gave a maximum overall score of 39.

4.1.3.5 Data analysis

Data were analysed using SPSS Statistics (22.0 for Windows, Chicago, IL, USA). Tests of normality were carried out to determine the normality of data at baseline (NRS, DASH, thoracic kyphosis), six weeks (NRS, DASH, thoracic kyphosis) and six months (NRS, DASH) in each treatment group. The two groups were described descriptively at baseline. The participants who completed and did not complete the six week and six month follow-up were tested for significant differences using the Mann-Whitney U test. Linear mixed models were used to carry out within-group repeated measures intention to treat analysis of DASH, NRS and thoracic kyphosis using all available data in each group and taking account of within-group correlation. The covariance model was unstructured. Marginal means for each group and time with associated 95% confidence intervals and within-group effect sizes were computed using linear mixed models. Effect size was classified as small=$\leq0.2$, medium=0.2-0.5 and large=$\geq0.8$ (Cohen 2013). The 5% level of significance was used throughout the analyses.

4.1.4 Results

4.1.4.1 Description of participants

In the thoracic group, nineteen participants were assessed at baseline, fifteen (79%) completed the six week follow-up and eleven (58%) completed the six month follow-up. In the shoulder group, twenty participants were assessed at baseline, seventeen (85%) completed the six week follow-up and eleven (55%) completed the six month follow-up. The participants who did not complete the six week (Table 4.3) and six month (Table 4.4) follow-up demonstrated no significant difference in any baseline characteristic than those who did. Table 4.5 provides a baseline description of the participants in each group and details the percentage of participants in each group who scored positively in each special test at baseline.
Table 4.3 Comparison of mean (SD) baseline characteristics between people who completed and did not complete six week follow-up.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Completed six week follow-up (n=32)</th>
<th>Did not complete six week follow-up (n=7)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>14M, 18F</td>
<td>3M, 4F</td>
<td>p=0.98</td>
</tr>
<tr>
<td>Age</td>
<td>60.09 (9.97)</td>
<td>54.86 (8.65)</td>
<td>p=0.21</td>
</tr>
<tr>
<td>Duration of symptoms (months)</td>
<td>9.09 (7.31)</td>
<td>4.86 (4.98)</td>
<td>p=0.16</td>
</tr>
<tr>
<td>Baseline NRS</td>
<td>5.14 (2.09)</td>
<td>5.00 (1.73)</td>
<td>p=0.87</td>
</tr>
<tr>
<td>Baseline DASH</td>
<td>52.29 (27.21)</td>
<td>54.64 (23.78)</td>
<td>p=0.83</td>
</tr>
</tbody>
</table>

Table 4.4 Comparison of mean (SD) baseline characteristics between people who completed and did not complete six month follow-up.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Completed six month follow-up (n=22)</th>
<th>Did not complete six month follow-up (n=17)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>11M, 11F</td>
<td>6M, 11F</td>
<td>p=0.37</td>
</tr>
<tr>
<td>Age</td>
<td>58.10 (8.94)</td>
<td>63.42 (11.07)</td>
<td>p=0.31</td>
</tr>
<tr>
<td>Duration of symptoms (months)</td>
<td>8.85 (7.14)</td>
<td>9.50 (7.89)</td>
<td>p=0.97</td>
</tr>
<tr>
<td>NRS 6 week improvement</td>
<td>2.60 (1.57)</td>
<td>2.13 (1.63)</td>
<td>p=0.41</td>
</tr>
<tr>
<td>DASH 6 week improvement</td>
<td>23.30 (19.33)</td>
<td>18.00 (19.34)</td>
<td>p=0.67</td>
</tr>
</tbody>
</table>

Table 4.5 Baseline characteristics of participants in each group.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Thoracic group (n=19)</th>
<th>Shoulder group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57.68 (8.47)</td>
<td>60.44 (11.04)</td>
</tr>
<tr>
<td>Gender</td>
<td>11 F, 8 M</td>
<td>11 F, 9 M</td>
</tr>
<tr>
<td>Duration of symptoms (months)</td>
<td>7.84 (5.82)</td>
<td>8.80 (8.24)</td>
</tr>
<tr>
<td>NRS</td>
<td>5.58 (2.08)</td>
<td>4.68 (1.12)</td>
</tr>
<tr>
<td>DASH</td>
<td>53.18 (27.57)</td>
<td>52.28 (25.85)</td>
</tr>
<tr>
<td>SHCI</td>
<td>8.35 (7.49)</td>
<td>8.84 (8.87)</td>
</tr>
<tr>
<td>SNQ</td>
<td>4.16 (2.99)</td>
<td>3.45 (2.63)</td>
</tr>
<tr>
<td>Positive Hawkins-Kennedy test</td>
<td>82%</td>
<td>74%</td>
</tr>
<tr>
<td>Positive Neer’s test</td>
<td>65%</td>
<td>59%</td>
</tr>
<tr>
<td>Positive Painful Arc test</td>
<td>66%</td>
<td>64%</td>
</tr>
<tr>
<td>Positive Empty Can test</td>
<td>42%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 4.6 demonstrates the mean (SD) values of NRS and DASH for both treatment groups at each time point, using only the participants who completed the follow-up. Table 4.7

4.1.4.2 Within-group analysis of shoulder pain and disability

There was a significant improvement in both NRS (p<0.001) and DASH (p<0.001) in both treatment groups from baseline to six week follow-up and baseline to six month follow-up.
demonstrates the mean (SD) value of NRS and DASH in both groups, as well as within-group effect sizes, using intention to treat analysis. The mean (SD) attendance at the six week exercise class was 4.63 (1.25) classes in the shoulder group and 4.46 (1.64) classes in the thoracic group.

<table>
<thead>
<tr>
<th></th>
<th>Thoracic group</th>
<th>Shoulder group</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRS Baseline</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>NRS 6 weeks</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>NRS 6 months</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>DASH Baseline</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>DASH 6 weeks</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>DASH 6 months</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 4.6 Mean (SD) NRS and DASH at baseline, 6 week and 6 month follow-up, without intention to treat analysis.

<table>
<thead>
<tr>
<th></th>
<th>Shoulder group</th>
<th>Thoracic group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.58</td>
<td>5.68</td>
</tr>
<tr>
<td>95% CI</td>
<td>(3.69, 5.46)</td>
<td>(4.78, 6.59)</td>
</tr>
<tr>
<td>ES</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mean</td>
<td>2.59</td>
<td>2.75</td>
</tr>
<tr>
<td>95% CI</td>
<td>(1.65, 3.53)</td>
<td>(1.76, 3.73)</td>
</tr>
<tr>
<td>ES</td>
<td>1.02</td>
<td>1.51</td>
</tr>
<tr>
<td>Mean</td>
<td>2.46</td>
<td>1.76</td>
</tr>
<tr>
<td>95% CI</td>
<td>(1.34, 3.58)</td>
<td>(0.82, 2.69)</td>
</tr>
<tr>
<td>ES</td>
<td>1.16</td>
<td>1.88</td>
</tr>
</tbody>
</table>

Table 4.7 Marginal Means for NRS and DASH at baseline, 6 weeks and 6 months with 95% Confidence Intervals (using linear mixed model as intention-to-treat analysis). ES=effect size.

4.1.4.3 Within-group analysis of thoracic kyphosis

There was a significant reduction in thoracic kyphosis in the shoulder group (p=0.02), in contrast to the thoracic group (p=0.19), where no such change occurred. However, the absolute change in thoracic kyphosis (0.84-1.4°) was very small and well within the standard error of measurement observed in study III (2.2°) (Table 4.8). Therefore, the change in thoracic kyphosis from baseline to six weeks cannot be distinguished from the measurement error which has been established previously (Barrett et al 2013).

<table>
<thead>
<tr>
<th></th>
<th>Thoracic group (n=19)</th>
<th>Shoulder group (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoracic kyphosis at baseline (degrees)</td>
<td>33.2 (7.1)</td>
<td>34.3 (9.5)</td>
</tr>
<tr>
<td>Thoracic kyphosis at 6 weeks (degrees)</td>
<td>32.3 (6.9)</td>
<td>32.9 (9.4)</td>
</tr>
<tr>
<td>Mean reduction in thoracic kyphosis (degrees)</td>
<td>0.84 (2.69)</td>
<td>1.40 (2.35)</td>
</tr>
<tr>
<td>Within-group significance</td>
<td>p=0.19</td>
<td>p=0.02</td>
</tr>
</tbody>
</table>

Table 4.8 Mean (SD) thoracic kyphosis measurements in both groups at each time point.
4.1.5 Discussion

The aim of this study was to evaluate changes in pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following shoulder exercise classes of different content. The groups observed in this study received either an exercise class containing a mixture of thoracic and shoulder exercises or containing only shoulder exercises. This case series showed that both groups improved significantly in pain and disability at six week and six month follow-up, which rejects the first null hypothesis of this study. However, thoracic kyphosis did not change beyond measurement error in either group following the six week treatment period, which fails to reject the second null hypothesis.

4.1.5.1 Improvements in shoulder pain and disability

A clear finding of this study was that group exercise classes can provide clinically meaningful improvements and large effect sizes in pain and disability at six week follow-up, which was further increased at six month follow-up. Due to the lack of a control group which received no treatment in this study, it is not clear if the observed improvements were a true treatment effect or merely a reflection of natural recovery. However, due to the chronic nature of the pain presented amongst participants of this study, with a mean duration of eight months, as well as the magnitude of change in both pain and disability, it is unlikely that the significant improvements observed over the course of this study were purely an effect of time.

Secondly, this study cannot elucidate if exercise delivered in a group is more effective than individually delivered exercise for this population, as a group receiving individual physiotherapy only was not included in this study. However, it is possible to cautiously compare the magnitude of change measured in this study to that of previous research which delivered physiotherapy treatment on an individual basis. Similar to the present study, Kachingwe et al. (2008) reported the effects of a physiotherapy exercise programme (shoulder strengthening, stretching, scapular exercise and postural exercise), delivered once per week for six weeks, with daily home exercises. This study, which was delivered individually to participants, reported a 20.8% reduction in the visual analogue scale for pain from baseline to six weeks, which is considerably less than the 54.1% (shoulder group) and 63.9% (thoracic group) improvement in NRS observed in this study, using intention to treat analysis. Another study demonstrated a similar mean improvement (17.1±12.4 points) in
DASH compared to the current study in people with subacromial pain of approximately six months duration (Savoie et al 2015). However, Savoie et al. (2015) delivered a combination of exercise and manual therapy in ten individual treatment sessions over a six week period. Although direct comparison to the current study is not possible, these broad comparisons support the potential for group exercise classes to provide similar, if not superior outcomes compared to individually delivered treatment for people with non-specific shoulder pain. This should be evaluated in future research, as described below.

4.1.5.2 Potential influence of individual physiotherapy before classes

It must also be considered here that approximately half of participants in each group received individually delivered physiotherapy prior to the classes which may have had a positive or negative effect on treatment outcomes. Prior experiences and expectations can effect on treatment outcome (Littlewood et al 2014b). Those who had successful outcomes of individual physiotherapy or those who had a preference for individual physiotherapy may have been less receptive to the exercise classes, which may have negatively affected treatment outcomes. In contrast, participants who had not been making progress in individual physiotherapy may have benefitted from a change in the mode of treatment delivery. Alternatively, the higher volume of treatment as a result of the combined individual and group sessions may have led to a greater clinical benefit and effect size, compared to if the participants had not received any prior treatment. To explore this further, Appendix 9, Table 1 contains a table describing the separated outcomes for the participants who received the exercise class only versus the exercise class with previous individual physiotherapy, for each group. This table does not demonstrate a clear pattern either in favour or against receiving previous individual physiotherapy, which is in ine with the statistical testing in Appendix 9, Table 2.

4.1.5.3 Thoracic kyphosis outcomes

In order to improve the understanding of the role of thoracic kyphosis in shoulder pain, this study examined potential changes in thoracic kyphosis following shoulder exercise programmes which included either a mixture of thoracic and shoulder exercises and shoulder exercises only. Despite the clear improvements in pain and disability, thoracic kyphosis did not change beyond measurement error in either group at the six week follow-up. The
significant reduction in thoracic kyphosis in the shoulder group was an interesting and unexpected finding. However, the actual change was well within the measurement error of the manual inclinometer provided by all previous studies which has reported it (Barrett et al 2013, Lewis and Valentine 2010, van Blommestein et al 2012). The potential reasons for the lack of change of thoracic kyphosis in either group will be discussed.

Firstly, it is important to consider the baseline measurements of thoracic kyphosis in this sample. The participants in this study had a mean (SD) thoracic kyphosis of 33.5° (8°) and a mean age of 59 (±10) years. As described in Chapter 1, a strong representation of normative data for thoracic kyphosis is lacking. However, previous research demonstrated the mean Cobb angle to be 33-40° in adults in the 50-59 year age bracket with normal thoracic spine curvature (Fon et al 1980). Even with the smaller angles of thoracic kyphosis demonstrated by the manual inclinometer compared to the Cobb angle in Study IV of this thesis (mean difference=4.8°), the degree of thoracic kyphosis observed in the current study was still within the normal limits defined previously (Fon et al 1980). Further, the values of thoracic kyphosis demonstrated in this study are slightly smaller (Lewis et al 2005a, Lewis and Valentine 2010, Greenfield et al 1995) and in some cases considerably smaller (McClure et al 2006, Theisen et al 2010) than those reported in the studies reviewed in Study I. Therefore, the results of this study support the conclusions of Study I, which suggest that people with shoulder pain on average demonstrate relatively normal angles of thoracic kyphosis. This normal mean degree of baseline thoracic kyphosis may have limited the capacity and necessity for thoracic kyphosis to decrease.

Previous RCTs which demonstrated significant reductions in thoracic kyphosis in people with thoracic hyperkyphosis were generally of a longer treatment duration (Bansal et al 2014). Although there appears to be no clear pattern of modifiability of thoracic kyphosis whether treatment is carried out for ten weeks (Kuo et al 2009), twelve weeks (Morey et al 1999, Katzman et al 2007, Benedetti et al 2008), six months (Greendale et al 2009) or two years (Itoi and Sinaki 1994, the treatment duration of six weeks used in this study was relatively short. Therefore, it is possible that a larger reduction in thoracic kyphosis may have been achieved if the treatment period was of a longer duration.

It is also important to consider the types of exercises provided in this study. Thoracic kyphosis did not change beyond measurement error following either six week exercise programme in this study, despite one programme containing four thoracic extension exercises. This is useful information which can be built upon by future research. Three out of four thoracic exercises provided in this study were carried out in standing and against no
resistance. It is not known if higher resistance exercises, which could be weighted and in prone position, would achieve a reduction in thoracic kyphosis. However, further studies are needed to explore this hypothesis.

As thoracic kyphosis did not change beyond measurement error in either group over the six week intervention period, the effect of changing thoracic kyphosis on shoulder symptoms cannot be analysed. Nevertheless, it is clear from this study that significant and clinically meaningful improvements in shoulder pain and disability were obtained without achieving a change in thoracic kyphosis. This suggests that a change in static thoracic kyphosis was not the mechanism by which improvements in shoulder pain and disability were achieved. Other potential mechanisms are described below.

4.1.5.4 Exploring potential mechanisms behind clinical improvement

There may be several mechanisms by which this intervention facilitated the observed clinical improvements. Although no changes were observed in static thoracic kyphosis, thoracic extension ROM was not measured in this study. Thoracic extension ROM may have improved following the thoracic extension exercises and/or the shoulder only exercise programme. There is cross-sectional research which demonstrates that thoracic spine ROM is significantly reduced in people with shoulder pain compared to a control group without shoulder pain (Theisen et al 2010, Meurer et al 2004). As thoracic extension forms part of the normal kinetic chain during shoulder elevation (Crawford and Jull 1993), an increase in thoracic extension ROM may improve the mechanics of the shoulder girdle during shoulder elevation.

Secondly, resisted shoulder exercises were included in both treatment groups. The intensity and duration of load placed on the rotator cuff tendons was increased gradually to facilitate structured tendon loading throughout the course of the classes and to improve the capacity of the rotator cuff tendons to withstand greater stress. Previous research reported that six weeks of daily home-based external/internal rotation resistance exercises provided significant improvements in isometric shoulder abduction and external rotation strength measured at 0º, 45º and 90º of scapular abduction using a hand-held dynamometer (Maenhout et al 2013). In fact, this study demonstrated that over a 12 week exercise programme, the greatest gains in strength were measured after the first six weeks. In contrast, Lombardi et al. (2008) reported clinical improvements in pain, function and general health, without a concurrent improvement in shoulder strength. It is clear from this study (Lombardi et al
that the clinical improvements observed after an exercise programme were driven by more than a strengthening effect.

The treatment outlined in this study involved 100% of the physiotherapist-patient contact time to be dedicated to the practice of exercise. In comparison to treatment approaches which involve passive therapies, the exercise-based treatment used here may have facilitated the participants to have a greater feeling of control and self-efficacy in the management of their shoulder pain. Previous research of exercise-based treatment in people with non-specific low back pain demonstrated improvements in self-efficacy and locus of control over an eight week intervention, which aligned with improvements in pain and function (Koumantakis et al 2005). Furthermore, changes in self-efficacy have been shown to be key to improvements in disability (Costa et al. 2011).

The treatment used in the current study is likely to have improved the participant’s skills in self-management and encouraged greater confidence in the participant’s use of their shoulder. Littlewood et al. (2013) acknowledged that, in people with rotator cuff tendinopathy, exercise may produce a beneficial adaptation in the central nervous system, especially if the exercises are similar to functional tasks. Further, the exercise-based treatment may have motivated patients to continue their exercises in a controlled and graduated manner on completion of the exercise classes. The sustained improvement at six month follow-up demonstrated in this study suggests that the participants were likely to have maintained positive exercise habits beyond the duration of the intervention. It is also possible that the group aspect of the intervention may have affected clinical outcomes. The potential benefits of exercise in terms of improving mood and symptoms of depression, anxiety and stress have been recognised (Salmon 2001). The group may have positively affected these symptoms by providing social support (Russell et al 2014).

4.1.5.5 Strengths and limitations

This study has strengths. It explored a relatively new treatment approach for people with non-specific shoulder pain. It did not use special tests of the shoulder to guide inclusion in the study due to the challenges acknowledged with structural diagnosis. Rather, the participants in this study may have consisted of a wide spectrum of clinical presentations which may better reflect clinical practice. The use of two sites in this study with two different physiotherapists improves the generalisability of the findings. The use of an exercise-based approach for the treatment of shoulder pain is firmly evidence-based. Furthermore, a series of
studies were undertaken in order to establish the most reliable and valid means of measuring thoracic kyphosis so that accurate conclusions could be drawn from the current study.

There are also limitations to the study. A sample of convenience was used, which introduces selection bias into the study. Secondly, as this study was not a RCT, true randomisation of participants to groups did not occur. The decision of the physiotherapist with regards to which class to run throughout the study may have been influenced by what type of exercise she considered appropriate for the participants after initial screening. The two classes took place at different stages throughout the study and participants were assigned to their class depending on when they presented for physiotherapy. This may have exposed different participants in each group to external influences, including the time of the year when the classes took place and the level of experience which the physiotherapist had in running the classes. Thirdly, some participants in both groups received individually delivered physiotherapy prior to their commencement of the six week block of exercise classes. Therefore, it is not possible to establish the isolated effects of the six week exercise class intervention as prior treatment, albeit before baseline measurements, may have affected the participant’s response to the intervention.

This study also had a poor response rate to six month follow-up in both groups. Potential reasons for this high drop-out rate can be speculated. The extensive length and time-consuming nature of the DASH may have dissuaded participants to fill it in. As the six month drop-outs tended to be slightly older, age may have been a factor. It is possible that some of the older participants may have had difficulty in filling out the questionnaires, with potential barriers including reading, writing, ability to post the questionnaires back or altered health status. However, response to treatment may also have influenced the six month follow-up rate. Participants who did not return the questionnaires at six month follow-up may have failed to maintain their six week treatment response and may have had poor six month clinical outcomes. Therefore, caution should be taken when interpreting the results of this study, as the treatment effects may be overestimated.

4.1.5.6 Future research

This study was not designed to compare the effectiveness of both of its treatment groups. Rather, two groups were used to evaluate the potential change in thoracic kyphosis in response to shoulder exercise programmes that did or did not include thoracic extension exercises. It would be useful for a RCT, which is adequately powered and assessor blinded, to
compare the effectiveness of shoulder exercise classes, with and without thoracic extension exercises, for the treatment of non-specific shoulder pain. In such a study, both groups would receive the same type and number of shoulder exercises, with one group randomly allocated to receive additional thoracic extension exercises. It would also be useful for such a study to increase the exercise parameters of the thoracic extension exercises, e.g. the resistance or duration of treatment, in order to build on the results of this study and to further explore the effects of the thoracic exercises on shoulder pain, disability and thoracic kyphosis. Additionally, an appropriate wash-out period should be used in which no treatment is provided prior to the study, which would reduce the influence of previous treatment as a confounding factor. It would also be valuable to record both adherence with the home exercises and any outside treatment that may have been obtained during the course of the intervention. To improve the long-term follow-up of such a study, the Quick DASH may be a more suitable alternative to the DASH, as it is shorter to complete and easier to interpret. A telephone call may also be a more effective means to obtain follow-up information from some people. The current study focused on measuring thoracic kyphosis as a potential mechanism of clinical improvements. However, future RCTs should incorporate moderation and mediation analysis of a wider range of physical (e.g. thoracic extension ROM, shoulder strength) and non-physical (e.g. fear, beliefs, self-efficacy) factors to better understand the mechanisms underlying improvements in pain and disability after an exercise intervention.

Although the exercise classes delivered in this study appeared to facilitate clinical improvements, a qualitative study which examines participant’s experiences of group exercise classes for shoulder pain would further enrich this quantitative data. There is little qualitative research available on group exercise classes for people with shoulder pain. Patient perspectives after the group exercise classes may generate knowledge that could be useful in future intervention planning and execution and may help to further elucidate the mechanisms of effect of shoulder exercise classes.
4.1.6 Conclusion

This case series suggests that group exercise classes may provide clinically meaningful improvements in pain and disability after six weeks in people with non-specific shoulder pain. These effects were sustained and further improved at six month follow-up. Thoracic kyphosis did not change beyond measurement error following an exercise programme containing either shoulder exercises or a mixture of shoulder and thoracic extension exercises. In this study, a change in static thoracic kyphosis was not necessary for clinical improvements in this sample of people with non-specific shoulder pain. In order to further develop the understanding of the role of thoracic kyphosis in shoulder pain, an RCT is required to compare the effectiveness of a shoulder exercise programme, with and without thoracic extension exercises, in people with non-specific shoulder pain.
4.2 Study VI: Exploring individual experiences of participation in a group shoulder pain exercise class: a qualitative study

Under Review.

4.2.1 Abstract

**Introduction:** Recent evidence has demonstrated that group-based physiotherapy interventions for musculoskeletal pain can have similar clinical outcomes compared to individual physiotherapy treatment. This study qualitatively examined the experiences of people who underwent physiotherapist-led group exercise classes for shoulder pain rehabilitation.

**Method:** Twenty-three people with shoulder pain, who had recently participated in a six week structured exercise class, were interviewed via telephone using a semi-structured approach. All recorded verbal data were transcribed verbatim and the transcripts were verified by the participants. A thematic analysis approach was used to analyse the data by drawing connections within and between the participants.

**Results:** The exercise classes were positively evaluated by all participants. Four themes emerged from the data analysis: the participant’s experiences of support, motivation and learning from peers; the preference for an exercise classes compared to individual shoulder physiotherapy; the physiotherapist as an educator and facilitator; beliefs about pain and exercise.

**Conclusion:** Among those interviewed, the exercise classes were described to provide an environment conducive to the development of relationships, friendships, humour and fun, gaining mastery of the exercises and encouraging the transition towards self-management of pain. For those who had previous experience of individual physiotherapy for their shoulder, the exercise classes were evaluated as the preferred mode of physiotherapy delivery.
4.2.2 Introduction

Shoulder pain is a significant problem in the general population that can have detrimental effects on quality of life, daily functioning and ability to work (Green et al 2003). Due to the difficulties associated with structural diagnosis in the shoulder (Lewis 2009), physiotherapists and researchers are beginning to use the term ‘non-specific shoulder pain’ (Gemmell et al 2014), to describe a range of diagnoses including rotator cuff tendinopathy, subacromial bursitis and subacromial impingement.

Over recent years, clinical guidelines have emerged supporting shoulder exercise as the benchmark treatment for shoulder pain (Diercks et al 2014, Klintberg et al 2015). The identified benefits of shoulder exercises have been described as improved physical functioning (Russell et al 2014), pain relief (Hanratty et al 2012), increased load capacity of the rotator cuff (Littlewood et al 2014a), restoration of neuromuscular control (Ginn and Cohen 2005) and improvement in scapular stabilisation (Cools et al 2014). Despite these benefits of exercise on physical outcomes, few studies have explored the patient’s experiences of exercise treatment for shoulder pain. The experiences of six patients with rotator cuff tendinopathy and two physiotherapists sampled from those allocated to the self-managed exercise group within a RCT were explored qualitatively to identify potential facilitators and barriers to this intervention (Littlewood et al 2014b). Participants who reported successful outcomes described a positive and supporting environment where they understood the reasons for undertaking the exercise and had means to return for pro-active follow-up.

In contrast to individual treatment, a group-based exercise class may offer additional benefits, for example, social support and cost-effectiveness. A previous quantitative study demonstrated that patients with frozen shoulder who underwent a physiotherapist-led group exercise class had superior clinical outcomes than those who received individual physiotherapy or a home exercise program (Russell et al 2014). Importantly, participants of this exercise class also demonstrated improvements in depression and anxiety scores.

No qualitative research has been conducted to specifically explore patient’s experiences of group-based exercise classes for the management of non-specific shoulder pain. In other musculoskeletal conditions, primarily low back pain, qualitative research has identified a range of positive and negative experiences of group-based exercise. For example, in a qualitative focus group study of people with chronic low back pain (CLBP), participants expressed a preference for exercise that matched their abilities and experienced a desire to
master the exercises, but were frustrated when they were not listened to and symptoms were aggravated (Slade et al 2009). A similar study of people with CLBP who attended a back rehabilitation group identified the critical role of the ‘exercise leader’ and again emphasised the need to consider the individual’s beliefs, attitudes and level of distress (Cook and Hessenkam 2000). Qualitative research is warranted to explore the patient’s experience of group exercise interventions for non-specific shoulder pain rehabilitation. The aim of this study is to explore the subjective experiences of participating in group exercise classes for people with non-specific shoulder pain.

4.2.3 Methods

4.2.3.1 Description of the shoulder exercise class

A six week group-based shoulder exercise class was carried out in two hospital outpatient physiotherapy departments in Ireland over the summer of 2014. The primary sources of shoulder-related referrals to these physiotherapy departments came from local GPs and the pain and orthopaedic consultants associated with the hospitals. The physiotherapists who delivered the classes had approximately 10 and 25 years of experience working in a clinical setting. The classes were 45 minutes in duration and typically consisted of four to six participants. Each exercise class consisted of a warm-up, followed by a series of ten exercises (two minutes for each exercise with one minute for rest). The exercises generally targeted shoulder strength (four exercises), scapular strength (three exercises), shoulder joint range of motion (two exercises) and whole body conditioning (one exercise), appropriate to the participant’s level of ability and goals. Participants did not receive any individual physiotherapy during the intervention period. The participants were allowed to experience a mild level of pain during their exercises, as long as the pain settled after the completion of the exercises and was not any worse the following day. Table 4.9 presents a guide of the content of the exercise classes.
| Warm up exercises (5 mins) | • Shoulder girdle range of motion (shoulder, scapular and neck movements)  
|                          | • Pendular exercises  
|                          | • Gross body movements  
|                          | • Posterior capsule stretch 30 seconds x 3 repetitions |
| Shoulder range of motion exercises (x2) | • Table slides  
|                          | • Shoulder pendular exercise  
|                          | • Window wipers (int/ext rot) |
| Shoulder resisted exercises (x4) | • Isometric/concentric shoulder flexion, abduction and external rotation  
|                          | • Combined movements/diagonals |
| Scapular resisted exercises (x3) | • Seated/standing row with theraband  
|                          | • Forward press with theraband  
|                          | • Wall-press |
| General strengthening (x1) | • Step-ups (with arm raise if possible)  
|                          | • Walking lunge |

Table 4.9 Example of content of the exercise classes.

4.2.3.2 Study design

As this study aimed to explore the participant’s experiences, a qualitative approach was most appropriate. The focus of the study was to develop themes to represent the participant’s lived experiences of the shoulder exercise classes. Ethical approval was obtained from the Health Service Executive Research Ethics Committee for the Midlands Area and St John’s Hospital Research Ethics Committee. All participants signed an informed consent form prior to their participation in the study.

4.2.3.3 Participants

The eligibility criteria for the group exercise classes, which were already running prior to this study, are displayed in Table 4.10. All patients who had completed the six week exercise class during the eight weeks prior to this study were purposively sampled for this study. All patients accepted to take part in the interviews. Twenty-three participants, fifteen female and eight male, with a mean (SD) age of 64 (10.2) years were interviewed. The mean duration of symptoms prior to participation in the exercise class was 24.2 months (range: 3 weeks to 4.6 years). Twenty out of twenty-three participants received individual
physiotherapy prior to the exercise classes and the mean number of individual physiotherapy sessions completed before the exercise classes was 4.1 (± 2.9, range 0-12).

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<tr>
<th><strong>Inclusion Criteria</strong></th>
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<tr>
<td>Male and female.</td>
<td>Pain reproduced by neck movements.</td>
</tr>
<tr>
<td>Over the age of eighteen.</td>
<td>Less than twelve weeks after shoulder surgery or fracture.</td>
</tr>
<tr>
<td>Minimum six week history of shoulder pain.</td>
<td>Co-morbidities which would preclude participation in exercise.</td>
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Table 4.10 Eligibility criteria for participation in the exercise class.

4.2.3.4 Data collection

Semi-structured telephone interviews were carried out with each participant by a final year physiotherapy student (AH). With the participant’s permission, the interviews were audio recorded. Each participant was asked about their overall impression of the exercise classes, what they enjoyed about the classes, what they disliked about the classes, what affect the classes had on their shoulder symptoms and, if relevant, how they compare participating in the shoulder classes to receiving individual physiotherapy for their shoulder. In accordance with the aim of the study, these open-ended questions were designed to capture a range of positive and negative experiences of participating in the exercise classes. These questions were guided by previous research which explored participant’s experiences of group based exercise programmes in people with shoulder pain (Ohman et al 2011, Littlewood et al 2014), chronic low back pain (Slade et al 2009, Cook and Hassencamp 2000), fibromyalgia (Beltran-Carillo et al 2012), Multiple Sclerosis (Twomey and Robinson 2010) and in older people (Raymond et al 2016). These studies typically pose questions relating to the overall perceptions of the treatment, the negative and positive aspects of the treatment and the effects of the treatment. In the case of a new treatment approach, previous researchers have asked participants to compare the current approach to others (Ohman et al 2011, Littlewood et al 2014, Cook and Hassencamp et al 2000). The interviews lasted for approximately 20 minutes. All recorded verbal data were transcribed verbatim. The transcripts were verified by the participants through post or email.

It is recommended that participant sampling continues until a saturation point is reached and no new data is being generated (Green and Thorogood 2014). However, analysis of the data during data collection was not feasible for the short time frame during which data collection was completed in this study. Therefore, the number of interviews conducted was
determined by the number of available participants who completed the classes in the previous eight weeks. However, on analysis of the data, it was clear that data saturation was reached after the 18th interview as no new codes emerged from the remaining interviews.

4.2.3.5 Data analysis

Data analysis, interpretation and write-up were carried out by a second researcher (EB). The data were analysed thematically, by drawing connections within and between the participants, using the six stage process described previously (Braun and Clarke 2006). NVivo qualitative data analysis software (QSR International Pty Ltd. Version 10, 2012) was used to assist in data management and analysis. Initially, the researcher became highly familiar with the transcripts by reading them several times while actively searching for meanings. Next, a semantic approach was taken by generating initial codes while remaining firmly based in the participants words. This was done systematically throughout the data set by coding as many potential themes as possible. Next, these initial codes were sorted into broader preliminary themes. Visual representations of mind-maps were used to assist in this stage. The themes were then revised to ensure that data within the themes had good coherence (internal homogeneity), while also ensuring identifiable distinctions between themes (external heterogeneity) (Patton 1990). The final stages resulted in the defining and written description of the themes. During each of the six stages, a meeting was convened with another author (KR), who was an experienced qualitative researcher, to discuss and review the interview coding, the formation of preliminary themes and the decision of the final themes. The involvement of another researcher during the analysis was aimed to ensure that the correct analytical steps were carried out and that the themes were representative of the data. This improves the credibility of the final themes (Willig 2013).

4.2.3.6 Trustworthiness

Several strategies were incorporated to increase the trustworthiness of the study. The researchers were aware of the potential for the credibility of the data to be hampered by the participants responding with what they thought was the preferred social response (Krefting 1991). In order to encourage neutrality, the interviewer was independent to the exercise classes, which created an environment conducive to open and honest dialogue. A systematic approach to thematic analysis was adhered to (Braun and Clarke 2006), which attempted to
enhance the dependability of the data (Krefting 1991). A quality indicator for thematic analysis is that the identified themes are internally coherent, consistent and distinctive (Braun and Clarke 2006). This is the case for the results presented as themes are related but distinct from one another.

Reflexivity is a valuable tool to examine how the researcher shapes and influences the research process (Finlay 2002, Willig 2013). In this study, the author involved in the data collection was a female physiotherapist and the authors who undertook the analysis were two female physiotherapists and a female occupational therapist, all of whom were younger than the majority of participants in the study. Therefore, values that were identified as potentially influencing the research process were a desire to unravel positive experiences of the exercise classes and a desire to promote the exercise classes. To aid reflexivity, continuous discussion between researchers and reflective writing were used. The researchers aimed to be aware of their own positions and interests and how this may affect the research process. As recommended by Finlay (2002), in order to address the researcher’s potential influence on analysis we focused on interpreting the meaning of the words of the participants as they were intended.

4.2.4 Results

Based on this process of analysis, four themes emerged from the data: the participant’s experiences of support, motivation and learning from peers; the preference for an exercise classes compared to individual shoulder physiotherapy; the physiotherapist as an educator and facilitator; and beliefs about pain and exercise.

4.2.4.1 Theme 1: Support, motivation and learning from peers

The social experience of being part of a group was discussed by all participants. One participant described how the class reduced her feelings of isolation.

“The people that were there were the same as you... you didn’t feel you were the only one with sore shoulders” (Ann).

Almost all participants reported the development of friendships, the establishment of bonds and the pleasurable experience of being with other people within the exercise class.
“I got great satisfaction out of the shoulder class... as well as meeting friends. I wouldn’t have met them otherwise... and they were great company” (Mary).

Humorous descriptions were provided to describe the enjoyment experienced in the class “a bit of a laugh” (James). However, one participant communicated a deeper sense of attachment to her peers.

“I loved doing what we were doing, you miss the crowd, you miss the group” (Norma).

Several participants experienced increased levels of determination and adherence with their home exercise programme as a result of the group setting.

“You’re better off to do it in a group... you’d be more determined to do it... if you were on your own you wouldn’t do it... you don’t put the whole 100% effort in at home” (Ben).

The group setting was reported to influence the quality of the exercise participation because “when you do a thing collectively like that you do it more extensively and you do it properly” (Brian). Many of the participants described a sense of team work with features such as a sense of competition, collaboration and motivation as a result of a shared goal.

“It was almost like a team. I played team sports in my younger days so the value of the team and players and encouraging one another, a lot of that came out in those classes” (Tom).

A further benefit reported by participants of the group was the opportunity to learn from one another and to share common experiences and expertise.

“You can have conversations with people, ask them about their injury, they’ll ask you about yours, you’ll find out what they did that helped them that might help you and you tell those what you did that might help them, it was like a fountain of information at times” (Sarah).

In contrast, one participant felt under pressure as she “had to keep pace with the others... had to keep going” (Martina). Additionally, one participant felt uncomfortable when the other group members were of a different gender and age group.

“It was strange, I was the youngest of the group... there was four men in the class with us... they were in their maybe 50 plus so I kind of felt a little out of my comfort zone” (Rita).
4.2.4.2  Theme 2: Preference for exercise class compared to individual shoulder physiotherapy

The majority of participants reported a positive attitude towards the exercise class and regarded it as a more enjoyable experience compared to their previous experiences of individual shoulder treatment. As well as the supportive social environment, the preference of the exercise class was commonly related to the time dedicated to learning the exercises properly. The participants valued the regular schedule of the classes which reinforced the exercises each week.

“The repetitiousness of the class does stay in your mind rather than just going once a month to physio and you’re supposed to be doing all these exercises and so on you know” (Sandra).

As a result, participants reported carrying out the exercises more frequently at home.

“It suited me better because it kept the momentum going, it kept me included in having to do the exercises” (Martina).

Some participants felt that the attentive nature of the individual physiotherapy was still captured in the class environment as “that focus was never lost in a group” (Tom). It was clear that although it was a group exercise class, the participants still felt that they were receiving individual care and attention.

“Because there was only six, it was like you were getting one to one, you know what I mean, you were all around in a circle or up against the wall or whatever it was, it didn’t feel like a session” (Kate).

In contrast, two participants felt that they benefitted more from the individual physiotherapy. In these cases, previous physiotherapy treatment of their shoulder pain primarily consisted of manual therapy.

“I think the shoulder class was good but maybe, I think I got more out of the one to one. The one to one was good because she did a lot of physio on you, rubbing it and exercising it and that where’s with the group you done it all yourself” (Mary).

Similarly, another participant reported initial scepticism about the exercise class. Despite this, the participant experienced a favourable therapeutic response that persuaded her of the effectiveness of the exercise class.
“I wasn’t expecting to get anything out of it. In the beginning my first impression was oh I don’t think this is going to work... I needed more one to one intensive physio but it actually did help” (Paula).

One participant described how individual physiotherapy treatment may be more effective in the early stages, after which progression to a group exercise class may be appropriate.

“In the early stages I would think a one to one would be more meaningful than a class but as one progressed to a certain level, and nobody only the person treating them and the person being treated knows what that level is, then it’s time to move on to a group class” (Tom).

4.2.4.3 Theme 3: The physiotherapist as an educator and facilitator

Participants described the physiotherapist as having two key roles; an educator and facilitator. Although there was no formal education component to the exercise classes, several participants still reported gaining knowledge of how to manage their shoulder condition. This included knowledge about pacing and controlling pain and how to self-manage exercises.

“She used to tell me only to do what I could, only do what you are able” (Michael).

Although most participants reported experiencing pain during the classes they clearly developed an understanding of the importance of pacing and controlling their levels of pain during the exercises.

“It might have been a bit sore sometimes when we were doing some of the exercises” (Sarah).

“She would always say if you are in pain don’t push past the point of pain... always stop if you need to” (Ruth).

Many participants reported that the physiotherapist corrected and guided them to conduct the exercises with the right technique.

“It’s like going back to school and being taught properly how to do something” (Brian).

Many participants described the physiotherapist facilitating increased self-management and responsibility gradually as the classes progressed.

“In the earlier part they really babysat me and nursed me along and when I got to the point when I was doing the exercises myself... they just observed what was going on... they encouraged me to start swimming” (Mary).
The participants also described the physiotherapist as a pillar of support within the class and showed signs of a positive therapeutic alliance with the physiotherapist. “If anyone needed individual assistance she came over and spent time, spent some time with them as well, she did go round to everyone and say how are you getting on” (Ann).

4.2.4.4 Theme 4: Beliefs about pain and exercise

Many participants described their continued engagement with exercise after the completion of the exercise classes. One participant acknowledged a new belief about exercise as a tool to self-manage a flare up of symptoms, rather than relying on medication. “Still every day I do my exercises and I find that when I feel the pain coming on in my arm I have a walking stick and I just do exercises with that, I haven’t taken pain killers in I don’t know how long, I am good with pain now” (Margaret).

One participant illustrated the transition from protecting her painful shoulder at the beginning to embracing an active approach. “I was going around in a sling for weeks but when I came to (clinical site), the first thing they said was we’ll get rid of that thing for you... it was almost a harness that was holding my right arm in place” (Mary).

In line with this, several participants demonstrated a new understanding of shoulder pain and exercise and acknowledged themselves as key mediators of their own recovery. “You have to get the shoulder moving, you have to build up the muscle for it to improve... it won’t improve by itself” (James).

Several participants described returning to normal functional activities on completion of the exercise classes. The participants described the uptake of leisure activities as a key modality to managing their shoulder pain and regaining their quality of life. “I’m swimming, golfing a little and I’m driving my car and lugging two grandsons around occasionally” (Mary).

Some participants demonstrated new beliefs about pain “I have come to tolerate more pain now... I’m living with it” (Sarah). One participant acknowledged that recovery from his
shoulder pain was “a very slow process” (Brian) and demonstrated a sense of awareness that his shoulder pain may never completely resolve.

4.2.5 Discussion

There is a growing body of evidence supporting the role of exercise in the management of shoulder pain (Hanratty et al 2012, Littlewood et al 2012, Abdulla et al 2015). However, much of this evidence is based on quantitative research methods with a focus on symptomatic response. This is the first study to explore the subjective experiences of people with non-specific shoulder pain who participated in structured, group-based exercise classes. The analysis identified four themes describing participant’s experiences. Participants described receiving support, motivation and learning from peers and expressed a preference for exercise classes rather than individual shoulder physiotherapy. Participants described the physiotherapist’s role as an educator and facilitator and highlighted beliefs about pain and exercise.

4.2.5.1 Theme 1: Support, motivation and learning from peers

A central feature of the participant’s experience of the exercise classes was the social network that they developed with the other participants. The social environment positively enhanced the participant’s experience of the exercise classes, with benefits described in terms of peer support, motivation and learning.

The social experiences within the exercise class motivated the participants to sustain their exercises at home. A previous study showed that the social networks within an exercise class enhanced adherence to and persistence with the exercise program (McAuley et al 2003). This is important as the commitment of the individual to their exercise programme contributes to the effectiveness of physiotherapy treatment in people with shoulder pain (Geraets et al 2006). Participants emphasised the pleasurable aspects of being with others, the development of relationships, friendships, humour and fun. Importantly, previous research has shown affective attitudes is one of the most reliable predictors of exercise behaviour (Rhodes and Fiala 2009). Therefore, the findings of this study illustrate the potential advantages of exercising in a social environment in terms of the participant’s engagement and investment in their exercises.
Research has highlighted that the basic motivational factors associated with exercise are generally robust across different pain populations (Rhodes and Courneya 2003). In particular, the motivational benefits of peer support have been reported in other populations. A qualitative metasynthesis identified that social support, professional support and outcome expectations influence intention to exercise and the execution of exercise among people with Multiple Sclerosis (Christensen et al 2015). A study of older inpatients’ perceptions and experiences of group physiotherapy identified similar findings about the motivational benefits of a group intervention, where participants reported that they enjoyed exercising with their peers and valued the physical and social benefits of group physiotherapy (Raymond et al 2016). A study of the views of people with chronic obstructive pulmonary disease regarding maintaining an active lifestyle following a course of pulmonary rehabilitation found that participants expressed a desire to exercise within a peer group combined with an opportunity for social interaction (Hogg et al 2012).

Findings also revealed that participation in the exercise classes reduced feelings of isolation among the participants and opportunities to share their experiences with their peers was very positively evaluated by most. The participants shared advice and information with each other, for example solutions to practical and functional problems. As noted in previous literature, the sharing of information in this way can assist in problem-solving (Wills and Shinar 2000). The transfer of knowledge amongst participants in a group setting has been previously recognised to facilitate the sharing of expertise, which acknowledges the participants as the experts of their own condition (Twomey and Robinson 2010).

4.2.5.2 Theme 2: Preference for an exercise class compared to individual shoulder physiotherapy

There is an emerging body of evidence to support group-based exercise classes as providing similar, if not superior, clinical outcomes compared to individual physiotherapy both within shoulder pain (Russell et al 2014) and other painful conditions (Unsgaard-Tøndel et al 2010, Hudson and Ryan 2010). As both can yield similar clinical benefit, the participant’s preference and expectations gain significance. The exercise class presented in this study was fully exercise-based and did not include passive treatment. In a profession which has traditionally been predominantly ‘hands-on’, this had potential to conflict with the participant’s expectations. However, the majority of participants embraced the exercise-based approach and were open to this form of treatment. Specifically, they valued the time...
dedicated to weekly practice of their exercises and the incentive that the class gave them to continue with their exercises. These findings are consistent with a qualitative study of 20 individuals who sought physiotherapy for back, neck or shoulder pain, which found that most informants preferred active treatment strategies such as exercise and advice for self-management of pain, allowing them to actively engage in their therapy (Bernhardsson et al 2015). Some preferred passive treatments, primarily acupuncture or massage therapy, largely due to prior beliefs and experiences of these treatments. However, trust in the physiotherapist’s ability to choose the appropriate treatment for them, as well as a desire to participate in clinical decision-making, fostered active engagement in physiotherapy.

Not all participants in this study embraced the exercise class in the beginning. A previous RCT in people with shoulder pain demonstrated reduced effectiveness of treatment when patient needs were not met (Thomas et al 2004). However, even though two participants demonstrated initial scepticism in this approach, they subsequently reported achieving positive outcomes. Similarly, Littlewood et al. (2014b) reported that most patients with rotator cuff tendinopathy expressed expectations of a ‘hands-on’ physiotherapy treatment approach. However, this did not serve as a barrier when a self-managed exercise approach was offered within a positive and supporting environment where patients understood the reasons for undertaking the exercise.

In this study most participants felt that the attentive nature of the individual physiotherapy was still captured in the class environment and although it was a group exercise class, the participants still felt that they were receiving individual care and attention. This is similar to reports of older adults receiving a group physiotherapy program in a hospital setting, who expressed that the perceived attentiveness of group instructors contributed to participants feeling that treatment was similar to individual shoulder physiotherapy (Raymond et al 2016).

4.2.5.3 Theme 3: The physiotherapist as an educator and facilitator

Participants described the physiotherapist as having two key roles; educator and facilitator. Although there was no formal education component to the exercise classes, several participants still reported gaining knowledge of how to manage their shoulder condition, how to monitor their pain levels and an understanding of how to load their shoulder appropriately. The participants also valued the role of the physiotherapist as an exercise expert, as this enabled them to gain a sense of mastery over their exercises. A prospective study of 274
patients presenting for physiotherapy treatment of a musculoskeletal disorder in Australian clinics found that respondents specifically valued interpersonal aspects of care, including advice and information about their condition and an explanation about self-management (Hush et al 2012). In turn, this improved patient satisfaction. Additionally, a qualitative systematic review and meta-synthesis investigating patient and physiotherapist perceptions of factors that influence patient-therapist interaction identified good education, communication skills and patient-centred care as being important to patients (O’Keeffe et al 2015).

Although participants valued the role of the physiotherapist as an educator, there is a delicate balance between providing education to participants and facilitating responsibility and independence in managing pain. A qualitative review and metasynthesis which investigated clinician perceptions of delivery of self-management approaches identified key challenges involved in moving away from the traditional biomechanical model (Mudge et al 2014). In particular, clinicians experienced difficulty in sharing control and forming equal partnerships with their patients. In the current study, it would seem that this balance was achieved, as the participants described experiencing a supportive environment in the beginning with a transition towards self-directed exercise as the classes progressed. Therefore, the physiotherapist was adaptable and flexible when supporting the participants at different stages of their journey.

4.2.5.4 Theme 4: Beliefs about pain and exercise

Participants reported developing a new understanding of the importance of exercise in the management of their shoulder pain and a shift towards self-management of pain through exercise. It is evident that participants not only understood the role of exercise in building a strong shoulder, but they also adapted to coping with a flare-up of shoulder pain by doing their exercises. Research has shown that the patient’s understanding of their pain and how they behave in response to pain has a strong effect on the resulting level of disability and the risk of chronicity (Gheldof et al 2010). A RCT investigating a combined rehabilitation programme in people with osteoarthritis of the knee demonstrated that positive exercise beliefs and confidence in the ability to exercise was associated with better functioning at six months (Hurley et al 2007).

Many patients reaped the benefits of this positive coping strategy as they described an experience of functional gain and improved quality of life. Some participants described the ability to return to functional activities and hobbies with confidence and enjoyment. This
shows evidence of functional self-efficacy, which refers to a person’s confidence in his or her ability to perform specific activities (Somers et al 2012). Importantly, self-efficacy has been identified as an important factor in pain-related disability, depression and pain coping strategies used among older adults with diverse chronic pain conditions (Turner et al 2005).

One participant described how the physiotherapist facilitated him in removing his sling and encouraged him to start moving his arm. This is important as poor coping strategies and fear-avoidance behaviours have been recognised as a poor prognostic indicator for shoulder pain (van der Heijden 1999). However, not all participants experienced such symptomatic improvements and for some, the focus was on experiencing an improvement in their tolerance of pain. A recent qualitative analysis using semi-structured interviews in people hospitalised for acute low back pain demonstrated a theme of ‘living in spite of pain’ (Stisen et al 2016), where the informants attempted to maintain an active social and family life without focussing on their pain.

4.2.5.5 Limitations of the study

It is acknowledged that this study represents only a narrow range of subjective experiences which has limited generalisability to other shoulder pain conditions, such as frozen shoulder or post-surgical rehabilitation. Further, the data is only representative of a small number of physiotherapy settings and the delivery of an exercise class may vary greatly between different clinical sites and physiotherapists. This study is also limited by the nature of interviews carried out and the single medium by which data was collected. The interviews were brief and could have explored participant’s experiences in greater depth. In-depth interviews are required to reveal deeper layers of the participant’s experiences (Milena et al 2008), which could be further strengthened by the researcher noting observations within the exercise classes. Nevertheless, this study provides an overview of a range of participant’s experiences of shoulder exercise classes, which has received no research attention to date.

4.2.5.6 Implications for practice

The demographics of the participants of this study are reflective of patients commonly presenting the physiotherapy practice, in terms of age group and gender. The majority of participants had chronic shoulder pain and had previous experiences of individual physiotherapy for their shoulder at some point in their past. This qualitative research supports
the delivery of group-based exercise classes for the management of non-specific shoulder pain. The study highlights key areas of relevance to the participants which should be acknowledged when designing an exercise class for this population. Firstly, the advantages of a social support network should not be underestimated and attempts should be made to foster relationships within the group. If feasible, it may be advantageous to group participants based on similar baseline characteristics including age, gender and functional capabilities, in order to facilitate appropriate information sharing and motivation. Participants of an exercise class strive to gain mastery of their exercises, which is facilitated by regular practice and advice on technique. The physiotherapist should be aware of the beliefs, preferences and expectations of the participants. If needed, appropriate educational strategies should be used to instil confidence in the exercise classes and to foster realistic expectations. Finally, the physiotherapist should educate the participants in load management and facilitate the participants to becoming independent and active copers of their shoulder pain.

4.2.6 Conclusion

Previous research has focused on the measurement of objective clinical outcomes to determine the effectiveness of exercise programmes for the rehabilitation of people with non-specific shoulder pain. This study elucidated the broader benefits of group exercise classes for the shoulder. The central themes to this research consisted of experiences of support, motivation and learning from peers, preference for an exercise class compared to individual shoulder physiotherapy, the role of the physiotherapist as an educator and facilitator and beliefs about pain and exercise. The findings will assist physiotherapists in designing an exercise class for this population which is reflective of aspects of importance to the class participants. Future qualitative studies should use in-depth interviews to provide a more detailed account of the experiences of a group exercise classes for the rehabilitation of shoulder pain.
4.2.7 Chapter 4: Summary of key points

The main aims of the studies in Chapter 4 were to observe changes in pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following two different shoulder exercise class interventions and to qualitatively examine the experiences of people with non-specific shoulder pain who participated in the shoulder only exercise classes. The results of Study V demonstrated that group exercise classes significantly improved pain and disability in this population at six week and six month follow-up. Furthermore, thoracic extension exercises did not significantly reduce thoracic kyphosis in this intervention. This indicates that thoracic kyphosis may be difficult to change and may not be the dominant driver of clinical improvements. The results of this study must be interpreted within the context of the study design and its limitations, as discussed in Study V.

Study VI provided qualitative evidence of the largely positive experiences of the shoulder exercise classes in a different sample of people with non-specific shoulder pain. Interestingly, patients with non-specific shoulder pain regarded physiotherapy treatment through group exercise classes as a positive alternative to individual physiotherapy for their shoulder. The themes identified in this study have several implications for clinical practice. The study suggests that physiotherapists should provide enough time and feedback to allow the participants to gain skills and mastery of the exercises. Furthermore, physiotherapists should foster social support and team-building in the exercise classes and should guide patients towards gradually becoming independent with their exercises, in managing their pain and towards functional re-integration.

While this chapter contributes to the overall aim of the thesis, which is to examine the role of thoracic kyphosis in shoulder pain, the chapter also adds a new dimension to the thesis, i.e. the group aspect. The thesis develops here to investigate the effectiveness of group exercise classes using quantitative and qualitative methods. Both studies in this chapter are connected through the use of the same clinical sites and physiotherapists which delivered the intervention. However, the studies were separated by a year and therefore used a different set of participants. As shoulder exercise classes are a relatively unexplored mode of physiotherapy treatment delivery for people with shoulder pain, this adds further novelty to the thesis.
5  Chapter 5: Discussion

The purpose of this chapter is to review and discuss the studies presented in the body of the thesis, drawing together the findings in context of the role of thoracic kyphosis in shoulder pain. The chapter will discuss the clinical implications of the thesis, the strengths and limitations of the thesis and provide directions for future research.
5.1 Scope of thesis

The biomechanical influence of spinal and scapular posture on the shoulder joint has long been of interest to researchers and clinicians (Kendall et al 1952, Neer 1972, Donatelli 1997, Sahrmann 2002). There has been a large clinical investment in postural rehabilitation, amongst attempts to modify other physical factors such as muscle strength, muscle activity and muscle length, in the treatment of shoulder pain. However, the evidence regarding postural alterations as a cause of shoulder pain has been largely anecdotal, with disproportionate clinical implications. In recognition of a lack of well-grounded scientific evidence to support the role of posture in shoulder pain, researchers have objectively measured spinal and scapular position in shoulder pain populations (Ludewig and Cook 2000, McClure et al 2006). Several components of posture have been hypothesised to have implications on the shoulder, with increased thoracic kyphosis, forward head posture and scapular protraction, scapular internal rotation and scapular anterior tilt theorised as precipitating shoulder pathology (Gray and Grimsby 2004). Undoubtedly, there are close biomechanical relationships between these structures and surrounding musculature, with potential for each to have isolated or combined effects on the shoulder. The role of thoracic kyphosis in shoulder pain was of specific interest to this thesis. This thesis aimed to investigate the anecdotal hypothesis that thoracic kyphosis contributes to shoulder pain through a series of research investigations.

5.2 Key findings

- A systematic review of the literature demonstrated moderate evidence that thoracic kyphosis is very similar in people with and without shoulder pain, suggesting that increased thoracic kyphosis may not be a consistent postural deviation in people with shoulder pain. However, maximum shoulder ROM was significantly greater, both among people with and without shoulder pain, after assuming an extended thoracic posture compared to a flexed thoracic posture.

- A systematic review of the literature synthesised the level of evidence regarding the reliability and validity of a range of thoracic kyphosis measurement methods. The strongest level of evidence for reliability existed in support of the Debrunner
kyphometer, Spinal Mouse and Flexicurve index and the strongest level of evidence for validity supported the arcometer and Flexicurve index.

- A reliability study demonstrated that the Flexicurve and manual inclinometer had excellent levels of intra- and inter-rater reliability for thoracic kyphosis measurement in a population of swimmers.
- When measuring thoracic kyphosis in people undergoing spinal radiographs, the manual inclinometer had good concurrent validity with the gold standard Cobb angle, whereas the Flexicurve angle had poor validity.
- A six week intervention of group exercise classes was effective in improving pain and disability at six week and six month follow-up in two separate groups of people with non-specific shoulder pain. The groups observed in this case series received either exercise classes containing a mixture of thoracic and shoulder exercises or exercise classes containing only shoulder exercises. Thoracic kyphosis did not change in either group beyond measurement error after the six week intervention period.
- A qualitative analysis of the experiences of participants of the shoulder exercise classes identified four key themes. These consisted of experiences of support, motivation and learning from peers, preference for an exercise class compared to individual shoulder physiotherapy, the role of the physiotherapist as an educator and facilitator and beliefs about pain and exercise.

5.3 Chapter 2: Introductory systematic review

Study I of this thesis, described in Chapter 2, reported moderate evidence that people with shoulder pain do not demonstrate a larger thoracic kyphosis when compared to people without shoulder pain. This finding challenges the clinical belief that an increased thoracic kyphosis is a common postural abnormality in people with shoulder pain. This is in line with a recent systematic review which reported a distinct lack of consistency in scapular position and scapular kinematics when comparing people with and without shoulder pain (Ratcliffe et al 2014). The combined evidence from these two reviews demonstrates that thoracic and scapular posture is not consistently different between people with and without shoulder pain. This strengthens the argument that an ‘ideal’ posture and consistent postural deviations in people with shoulder pain, as described in the literature (Kendall and McCreary 1993, Grimsby and Gray 1997, Sahrmann 2002), might not exist.
There are two key issues which limit the ability of the studies under review in Study I to elucidate the role of thoracic kyphosis in shoulder pain. Firstly, the cross-sectional design of these studies, which consist of subjects who already have pain, makes it difficult to explore the role of thoracic kyphosis as a precipitating cause of shoulder pain. It could, for example, be speculated that an increased thoracic kyphosis may contribute to the onset of shoulder pain. However, it is has also been shown that postural adaptations occur in response to pain (Hodges and Moseley 2003). Diederichsen et al. (2009) demonstrated significant changes in scapulothoracic and scapulohumeral muscle activity after experimentally induced pain in the supraspinatus tendon. Alterations in acromiohumeral distance, scapular position and scapular kinematics have also been observed in response to experimentally induced fatigue of the rotator cuff muscles (Maenhout et al 2015, Ebaugh et al 2006), suggesting that posture may continually adapt according to the local condition of the shoulder joint. Therefore, measuring thoracic kyphosis in people who already have pain may not provide an accurate reflection of their thoracic posture before they had pain.

Secondly, thoracic kyphosis varies widely between individuals and may be associated with individual factors including genetics and body mass index (Smith et al 2011). This is reflected in the large standard deviations of approximately 10º demonstrated in the studies under review. Although the studies under review attempted to clinically categorise their populations as having SIS or SAPS, this was likely to incorporate people with variations in clinical presentation, degree of thoracic kyphosis and potentially different factors driving their pain. Examining thoracic kyphosis in such diverse samples may not be specific enough to elucidate the role of thoracic kyphosis in shoulder pain. Undoubtedly, there is potential that an increased thoracic kyphosis may be an important factor in shoulder pain in a small cohort of patients. However, for others, other physical factors (e.g. shoulder strength) or indeed psychological, cognitive or lifestyle factors may play a larger role in causing and maintaining shoulder pain.

This review also demonstrated that, in both people with and without shoulder pain, short-term improvements in shoulder ROM were achieved in an erect posture in comparison to a slouched posture. It is clear that the experimental constraints of these studies provided an unrealistic reflection of the relationship between the thoracic spine and the shoulder, in terms of the extremes of thoracic postures tested and the static, seated positions of the participants during testing. The authors of these studies explained their findings by hypothesising potential alterations in scapular kinematics and subacromial space between thoracic postures (Kebaetse et al 1999, Bullock et al 2005, Kanlayanaphotporn 2014). However, the broader
literature has demonstrated that the response in the scapula and acromiohumeral distance to alteration in thoracic kyphosis is not consistent (Kebaetse et al 1999, Finley and Lee 2003, Gumina et al 2008, Kalra et al 2010).

Although the reasons for increased shoulder ROM in the upright thoracic posture are not clear, it has been demonstrated that the thoracic spine undergoes natural movement in conjunction with shoulder flexion (Crawford and Jull 1993, Theodoridis and Ruston 2002). Therefore, when thoracic movement is purposely and unnaturally restricted, it is likely that this would restrict shoulder movement (Theisen et al 2010). Importantly, there is no evidence that this had an effect on shoulder pain. In fact, the studies which used a symptomatic population demonstrated that the pain intensity experienced during shoulder movement was largely unchanged between postures (Lewis et al 2005b, Bullock et al 2005).

In summary, the evidence provided by this review suggests that increased thoracic kyphosis may not be a consistent postural deviation in people with shoulder pain. However, the research design of the included studies limits their capacity to capture if a change in thoracic kyphosis affects an individual’s shoulder pain.

5.4 Chapter 3: Methods

Chapter 3 consisted of three studies. Study II was a systematic review which served to identify thoracic kyphosis measurement techniques, to synthesise the evidence of their reliability and validity and to gain an understanding of their feasibility for use in a clinical research study. In addition to strong measurement properties, a method which was quick and easy to use in a clinical setting for research purposes was also necessary. The results of this review demonstrated the extensive array of approaches proposed to measure thoracic kyphosis, ranging from simple hand-held tools to more advanced video imaging systems. The review highlighted that the Flexicurve was the instrument which was most supported by current evidence in terms of both reliability and validity. However, this research had been primarily conducted in osteoporotic women, thereby capturing only large degrees of thoracic kyphosis. There was a need to test the reliability of this measurement device in people with relatively normal degrees of thoracic kyphosis, which may better reflect the shoulder pain population.

The manual inclinometer was a suitable measurement device due to its portable nature and its ability to provide an instant angle of thoracic kyphosis. The review highlighted two
studies which demonstrated very high levels of intra-rater reliability of the manual inclinometer. Of relevance, one of these investigations had been carried out in people with shoulder pain, which highlighted its potential applicability to this population. However, the inter-rater reliability and validity of the manual inclinometer for thoracic kyphosis measurement had not been previously investigated and was required before it could be used in Study V of this thesis.

Study III was intended to address the deficits in research knowledge regarding the reliability of the manual inclinometer and Flexicurve for thoracic kyphosis measurement. The population chosen for this study was competitive swimmers, as shoulder pain is a common musculoskeletal complaint in this population (Bedi 2011). Although the sample used in this study did not directly correspond with the population used in Study V, as only 27% had current shoulder pain, there was only a 1° mean difference in thoracic kyphosis measured using the manual inclinometer between both studies. On comparison of the characteristics of the portion of participants with shoulder pain in Study III with the participants of Study V, both similarities and differences are present. Both were of similar age (56 years versus 58 years), which may indicate a common degenerative component to their pain. However, the mean shoulder pain intensity in Study III was slightly lower than that of Study V (3.4 versus 4.8 out of 10). The duration of symptoms of the participants in study III was also considerably longer than those in Study V. Therefore, the participants of Study V represented a more acute and more intense episode of shoulder pain compared to a milder and more recurrent pattern of shoulder pain of the participants in Study III.

This study demonstrated that both measurement devices had excellent levels of intra- and inter-rater reliability. The intraclass correlation coefficient was considered suitable to report reliability, as this takes variations between individuals into account (van de Ven-Stevens et al 2009). The results demonstrated reliability for converting the Flexicurve index, the primary output of the Flexicurve, to the Flexicurve angle in this population, using an equation presented previously (Greendale et al 2011). In recognising that the Flexicurve angle is not as easily acquired as the inclinometer angle, a further output of this study was an equation from which the Flexicurve angle could be approximated from the manual inclinometer angle. However, this may only be specific to the sample used in this study, as large inherent differences existed between the Flexicurve and manual inclinometer. This reliability study also provided the SEM for measuring thoracic kyphosis using these instruments. This was an important value to establish for Study V of the thesis, where the
error in measurement must be distinguishable in order to estimate the true value of any change in thoracic kyphosis.

After confirming the reliability of these measurement tools, Study IV of this thesis aimed to establish the concurrent validity of the Flexicurve and manual inclinometer for measuring thoracic kyphosis. Although it was not possible to target a specific shoulder pain population due to ethical restrictions, a clinical population who were already undergoing spinal radiographs was used. In this study, the Flexicurve angle correlated well with the Cobb angle. However, there were consistently large differences between them. Therefore, the specific method used for translation of the Flexicurve index to an angle in Study IV was not as accurate as the other methods described previously (Teixeira and Carvalho 2007, de Oliveira et al 2012) and is thus this formula is not recommended for use. The Flexicurve may have advantages for providing a visual representation of thoracic kyphosis for monitoring longitudinally. However, for the purposes of this thesis, it would not have been possible to extrapolate degrees of thoracic kyphosis with the confidence required to allow interpretation. In contrast, the manual inclinometer had both good agreement and high correlation with the Cobb angle, supporting the concurrent validity of this method. Although the sample size for this study was small, a standardised measurement procedure was carried out in both Study III and Study IV, which was replicated when measuring thoracic kyphosis in Study V of this thesis.

5.5 Chapter 4: Clinical studies

Evidence-based clinical practice guidelines for shoulder pain consistently recommend shoulder exercise as an integral part of physiotherapy treatment (Albright et al 2001, Hopman et al 2013, Hanchard et al 2004, Diercks et al 2014). While exercise-based interventions appear to be beneficial for people with shoulder pain, in terms of pain, disability, quality of life and general health, the mechanisms which underlie the improvements are poorly understood. To date, only one study (McClure et al 2004) has attempted to both modify and measure posture, including thoracic kyphosis, through exercise in people with shoulder pain and examine this in relation to clinical outcome. The uncertainty regarding the relationship between thoracic kyphosis and shoulder pain challenges the evidence-base for physiotherapists attempting to change thoracic kyphosis in this population.
Study V was a case series which sought to observe changes in pain, disability and thoracic kyphosis in two groups of people with non-specific shoulder pain, following shoulder exercise classes of different content. It is clear from Study V that although both groups improved significantly in pain and disability at six week and six month follow-up, thoracic kyphosis did not change beyond measurement error in either group. The results of Chapter 3 provide some assurance that the manual inclinometer provided reliable pre- and post-intervention measurements. As the number of thoracic extension exercises used in the thoracic group of this study was arguably more than that normally used in clinical practice for people with shoulder pain (Kuhn 2009), these findings challenge the clinical assumptions that the inclusion of thoracic extension exercises in a shoulder exercise programme provides a measurable and meaningful reduction in thoracic kyphosis. Previous studies in women with thoracic hyperkyphosis demonstrated small changes in thoracic kyphosis following a targeted intervention (Bennell et al 2010, Bautmans et al 2010). The findings of this thesis suggest that thoracic kyphosis may be more difficult to reduce in people with a relatively normal degree of thoracic kyphosis and in many cases, alteration might be unnecessary. However, it is not known if the use of different thoracic exercises, the use of a longer intervention period or the use of a more targeted sample would have produced larger reductions in thoracic kyphosis in Study V. The effect of thoracic extension exercises on improving dynamic thoracic extension during shoulder elevation was not assessed in this study and it is possible that this improved despite the relatively unchanged static thoracic kyphosis.

Similar to Study V of this thesis, McClure et al. (2004) reported improvements in pain and function after a six week exercise-based intervention in people with shoulder pain, without accompanied changes in scapular kinematics or thoracic kyphosis. A common limitation to Study V of this thesis and McClure et al. (2004) is that only static thoracic kyphosis was assessed. Cross-sectional research has demonstrated that people with shoulder pain had significantly less thoracic spine extension mobility during shoulder flexion when compared to people without shoulder pain (Theisen et al 2010, Meurer et al 2004). However, to our knowledge, there has been no research which investigates a potential change in thoracic extension ROM during shoulder elevation following thoracic extension exercises in this population. It is possible that the exercises used in this study altered the motor control of the thoracic spine during shoulder movement, in order to achieve a greater range of thoracic spine extension during functional shoulder movement. Future research should establish if thoracic extension exercises, as described in this study, increases thoracic spine extension ROM during shoulder elevation and the potential effect of this on clinical improvements.
The factors generating and maintaining shoulder pain may differ between individuals. Thoracic kyphosis may be relevant to a subgroup of people with non-specific shoulder pain. It is not clear at present how best to identify people whose shoulder pain may be influenced by thoracic posture. Smart et al. (2012a) provided a mechanism based classification of nociceptive pain aimed to guide clinicians in identifying the dominance of this pain mechanism in individuals with chronic low back pain. As peripheral nociceptive pain is usually associated with a consistent, mechanical pattern, physical factors, including static and dynamic thoracic kyphosis, may have the potential to be most relevant for people whose pain is driven by peripheral nociception. It may be important to establish if shoulder symptoms are aggravated by thoracic flexion and eased by thoracic extension. However, further research is needed to identify specific clinical characteristics (signs and symptoms) which could best identify a group of patients who might benefit from thoracic extension exercises.

Physical factors including thoracic kyphosis may not always dominate the pain experience as pain can be perceived in the absence of peripheral sensory input, especially in the presence of altered pain processing and central sensitisation (Struyf et al 2015). There is accumulating evidence within musculoskeletal pain that physical factors, including tendon structure (Drew et al 2012), spinal ROM and trunk extensor strength (Steiger et al 2012), do not exhibit change in response to an exercise programme. The focus of the exercise classes in Study V was purely on exercise, as opposed to passive treatments such as manual therapy, which may have provided a strong message to the participants that loading and moving their shoulder is key to managing their pain, thus enabling them to have substantial control over their pain, with the potential for improvements in self-efficacy, fear and coping. It is plausible that these factors may have a role in reducing the hyperexcitability of the central nervous system through activation of descending nociceptive inhibition (Nijs et al 2012). It is important that future research attempts to measure potential changes in factors across the biopsychosocial spectrum after exercise-based interventions in people with non-specific shoulder pain and to determine if they are related to observed clinical improvements.

Study VI of this thesis examined the experiences of participants who took part in the shoulder exercise classes, in order to further explore the mechanisms of effect of the exercise classes and to provide practical guidance for physiotherapists when designing and executing exercise classes for this population. Although different samples of participants were used in Study V and Study VI of this thesis, Study VI can to some extent elucidate potential mechanisms which may have contributed to the observed clinical improvements observed in Study V. In Study VI, it became clear that the social environment of the group exercise
classes had the potential to provide a strong treatment effect. The participants described the advantages of being in a group in terms of forming friendships, sharing experiences and learning, conjuring a sense of competition and motivating continued adherence with exercise. The group element created an environment which developed the participant’s interest in exercise and a desire to master and progress with their exercises. These advantages of the group setting may not be achieved in individual treatment.

The value which the participants placed on repetition and practice of the exercises is a strong message to physiotherapists and this should be fostered in clinical practice. Study VI of this thesis supports that exercise should be the dominant component of physiotherapy treatment for non-specific shoulder pain or at least sufficient time dedicated to exercise in a treatment session to allow the patient to value its importance. The superiority of the exercise classes compared to individual treatment described by Russell et al. (2014) may have been due to the higher dosage of exercise in the exercise class group. Although adherence was not measured in Study V of this thesis, the responses from Study VI suggest that many people tended to undertake the prescribed home exercise programme as a result of the continued evaluation of the exercises each week and the motivating effects of the group setting.

The participants in this study gained skills in self-management, as they experienced an ability to be independent in their exercise programme, to self-regulate their exercises, to self-manage their pain and to better tolerate their shoulder problem. These self-management behaviours may have been important in explaining the continued improvement in clinical outcomes at six month follow-up demonstrated in Study V. The literature generally acknowledges that in order to impart optimal skills in self-management in chronic musculoskeletal pain populations, a multidimensional intervention that includes both education and training should be used (Lorig and Holman 2003, Carnes et al 2012, Toomey et al 2014). Although informal learning from peers and the physiotherapist was experienced, it is quite possible that an added component of formal education incorporated into the exercise classes may have provided superior clinical outcomes and further sustained long-term improvements.

### 5.6 Clinical implications

- Chapter 3 of this thesis provided a description of the reliability and validity of a range of thoracic kyphosis measurement techniques. It recommended the use of the manual
inclinometer as a reliable, valid and clinically feasible means to measure static thoracic kyphosis. The Flexicurve angle, as calculated in this thesis, should not be regarded as an accurate description of the degree of thoracic kyphosis and may be more suitable for providing visual feedback to patients whose thoracic kyphosis is measured longitudinally, as it does show high reliability for repeated measures.

- Clinicians should be aware of the lack of evidence supporting consistent postural deviations of the thoracic spine in people with shoulder pain. In addition to the systematic review in Chapter 2 of this thesis, previous research has suggested equivocal findings in terms of scapular kinematics (Ratcliffe et al 2014) and EMG muscle activity (Chester et al 2010) in people with and without shoulder pain. Thus, the evidence to support lack of consistent postural deviations in people with shoulder pain is building, as well as evidence to support a broader range of physical, social, cognitive and psychological factors in shoulder pain.

- A case series (Study V) demonstrated that static thoracic kyphosis did not change over a six week intervention period in people with non-specific shoulder pain receiving either shoulder exercises only or a mixture of shoulder and thoracic exercises. Of clinical relevance, static thoracic kyphosis may be difficult to change in this population, even after a targeted clinical intervention. This may be due to the relatively normal degree of thoracic kyphosis which was demonstrated in the sample in Study V. As Study I demonstrated comparable degrees of thoracic kyphosis in people with and without shoulder pain, thoracic kyphosis may not consistently require alteration in people with shoulder pain.

- As clinical outcomes improved in the absence of a reduction in thoracic kyphosis, static thoracic kyphosis may not be the dominant factor necessitating clinical improvements in people with non-specific shoulder pain. Therefore, the physiotherapy treatment of people with non-specific shoulder pain should not routinely focus on the reduction of static thoracic kyphosis. The relevance of dynamic thoracic extension during shoulder movement in people with non-specific shoulder pain is less clear at present and cannot be elucidated by this thesis. The contribution of thoracic posture to an individual’s pain experience may require individual assessment, with consideration of the dominant factors relevant to each individual’s pain. It is not clear at present if the SSMP is an effective means of assessing and guiding treatment in people with non-specific shoulder pain.
The results of the clinical studies presented in Chapter 4 suggest that it is important that physiotherapists emphasise exercise when treating people with non-specific shoulder pain. Group exercise classes may be an effective and feasible mode of physiotherapy delivery in quite a broad clinical population of shoulder pain. Scapulohumeral and scapulothoracic resistance and ROM exercises of a six week duration, in which patients had contact with a physiotherapist once per week and carried out exercises at home every other day, was sufficient to produce clinically meaningful improvements in pain and disability, with large treatment effects.

In Study VI, several characteristics of group exercise classes were valued by the participants and should be fostered by clinicians. These include peer support and learning, weekly repetition of exercises, facilitation by the physiotherapist towards independence with exercise, encouragement towards functional re-integration and education from the physiotherapist regarding the correct execution of and pacing with exercises.

5.7 Strengths and limitations of thesis

This doctoral thesis has several strengths. Firstly, it used a step-wise process of research investigations and a variety of research designs to contribute evidence towards the role of thoracic kyphosis in shoulder pain. The method of measuring thoracic kyphosis in Study V was well supported in terms of its reliability and validity in the earlier studies. Further, in light of the constraints of quantitative research, qualitative research was used to explore the experiences of participants who took part in the exercise classes, in order to explore potential mechanisms of clinical improvement among people with non-specific shoulder pain. As well as contributing to the evidence regarding the role of thoracic kyphosis in shoulder pain, the thesis explored approaches to the physiotherapy management of shoulder pain. This includes confirming the findings that exercise classes are an effective mode of physiotherapy delivery for people with non-specific shoulder pain.

In addition to the limitations discussed specifically in the individual studies, there are also broader limitations to this thesis. Firstly, Study I and Study V assessed static thoracic kyphosis and it is not known if thoracic extension ROM during functional shoulder movements is altered in people with non-specific shoulder pain or improved after the intervention. Secondly, although this thesis aimed to develop the understanding of the role of
thoracic kyphosis in shoulder pain, the studies in the thesis can only examine the importance of thoracic kyphosis as a factor in the maintenance of shoulder pain. Thus, while thoracic kyphosis does not appear to be the dominant factor causing clinical improvements in people with non-specific shoulder pain, the influence of thoracic kyphosis as a precipitating cause of shoulder pain was not evaluated in this thesis. The contribution of increased thoracic kyphosis to the development of shoulder pain would be difficult to establish and would require prospective longitudinal research which assesses people over time before they develop shoulder pain. Such a research design would make it very challenging to identify the relative contribution of thoracic kyphosis to shoulder pain, amongst the multitude of factors which are likely to interact to cause shoulder pain. Structural diagnosis of shoulder pain is challenging, as described in Chapter 1. The clinical studies in this thesis therefore included people with non-specific shoulder pain, which had the potential to incorporate people with mixed shoulder presentations. Therefore, it is possible that the relationship between thoracic kyphosis and shoulder pain may have been stronger if a more homogenous population of people with shoulder pain, however that might be defined, was used. Lastly, the population used across the reliability study, validity study, quantitative study and qualitative study differed. While this must be acknowledged, it is not likely to affect the overall findings of the thesis.

5.8 Future research

Outcome measures in shoulder pain research tend to assess the effectiveness of an intervention in terms of symptomatic response. More research is required to determine the specific mechanisms by which people with shoulder pain respond or do not respond to exercise and other interventions. As static thoracic kyphosis was not demonstrated to be an indicator of clinical improvement in this study, it would be of value to examine the effect of thoracic extension exercises delivered over a longer treatment duration or at a higher resistance. It would also be useful to examine the effect of thoracic extension exercises on dynamic thoracic extension and whether this influences treatment outcome in people with shoulder pain. This should be assessed in relation to shoulder movement, i.e. range of thoracic extension achieved during maximum shoulder flexion. Equally, psychological and general health factors, which are now considered important drivers of change in chronic pain
by altering central sensitivity, should be assessed in shoulder pain interventions, i.e. self-efficacy, pain catastrophizing, fear-avoidance, depression and anxiety.

It would be of value to compare the effectiveness of shoulder exercise programmes, which include and do not include thoracic extension exercises, for reducing shoulder pain, disability and thoracic kyphosis, in people with non-specific shoulder pain. As discussed in Study V, in order to draw valid conclusions from such a study, a fully blinded RCT, which is adequately powered to detect between-group differences in outcomes and contains a period of no treatment prior to the study, is needed. In order to isolate the added effect of thoracic extension exercises, both groups should receive the same exercises with the addition of the thoracic exercises of interest to one group. Such a study would provide more direction for clinical practitioners regarding the value of addressing thoracic spine posture within a shoulder exercise programme.

Finally, an adequately powered RCT is needed to compare the clinical and cost-effectiveness of group exercise classes to individual physiotherapy treatment for people with non-specific shoulder pain. The long-term assessment of this treatment should also be considered. To our knowledge, Russell et al. (2014) was the only RCT which has compared the outcomes of physiotherapy delivered in an exercise class or through individual physiotherapy treatment for shoulder pain. However, as well as being carried out in people with frozen shoulder, the individual treatment used in this study (Russell et al 2014) mainly involved passive modalities with little emphasis on exercise. Therefore, two very different treatment approaches were used via different modes of delivery, making it difficult to determine the group effect on clinical outcome. In order to provide more insight into the group effect, an RCT in which the individual treatment is also exercise based, without the use of manual therapy, is warranted.

5.8.1.1 Providing opportunities for future research

I have recently received an Irish Research Council New Foundations Grant to enable me to disseminate the results of this doctoral thesis in clinical practice and to provide guidance to clinicians who wish to implement shoulder exercise classes in their clinical settings. This will include a structured workshop for clinicians to network and learn more about the classes, the development of a suitable education component for the classes and the formation of an ‘exercise class package’, including assessment and evaluation forms for
clinicians to use. A greater uptake of these classes in clinical settings would facilitate larger, multicentre trials to investigate their effectiveness in the future.

5.9 Conclusion

This doctoral thesis concludes that thoracic kyphosis can be measured with validity and good reliability in a clinical setting using the manual inclinometer. However, static thoracic kyphosis, measured in relaxed standing, may not be strongly related to shoulder pain. This is evident through (i) a systematic review which observed comparable degrees of thoracic kyphosis in people with and without shoulder pain and (ii) a case series in people with non-specific shoulder pain which observed significant improvements in pain and disability, without a change in thoracic kyphosis, in two groups receiving exercise classes containing either shoulder exercises or a mixture of shoulder and thoracic extension exercises. Through qualitative investigation, people with non-specific shoulder pain expressed experiences of support, motivation and learning from peers and a preference for an exercise class compared to individual physiotherapy for managing their shoulder pain. The qualitative research also highlighted the role of the physiotherapist as an educator and facilitator and beliefs about pain and exercise. It is proposed that future research should examine the clinical and cost-effectiveness of group exercise classes compared to individual physiotherapy treatment in people with non-specific shoulder pain and better explore the mechanisms which underlie the improvements experienced after exercise-based rehabilitation. It would be of value to compare the effectiveness of shoulder exercise programmes, which include and do not include thoracic extension exercises, for reducing shoulder pain, disability and thoracic kyphosis, in people with non-specific shoulder pain. The role of thoracic extension ROM during shoulder elevation in people with non-specific shoulder pain was not the focus of this thesis and should be an area of future research.
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5.11 Appendices

Appendix 1


Dear Editor,

We would like to congratulate Barrett and colleagues for their systematic review about the clinical evaluation of thoracic kyphosis (Barrett et al 2014). In everyday clinical life reliable, easy-to-use and safe tools are necessary, the sagittal profile of the spine being relevant both in the case of scoliosis (Glassman et al 2005, Negrini et al 2012) and for patients with hyperkyphosis (Zaina et al 2009); but even if many different methods exist, they are not always well known. The authors reported details about many of the most used tools around the world, and even if it hasn't been possible to perform a meta-analysis due to the heterogeneity of papers and data, many clinical details are correctly reported, providing a useful summary of the state of the art.

Nevertheless, we would like to attract the authors’ and readers’ attention to a paper entitled ‘How to measure kyphosis in everyday clinical practice: a reliability study on different methods’ (Zaina et al 2012) that has not been included in this review despite fulfilling the inclusion criteria. The topic was the reliability of the IncliMed, also reported in a paper by Gravina and colleagues (Gravina et al 2012) which was instead included in the present review. We think it would be of great relevance to also add our data since our group is independent from the one that invented the IncliMed (Gravina et al 2012), and usually data collected from an independent rater are more generalizable. According to our data, the k value for IncliMed varied from fair to good. The mean difference for kyphosis was 0.40 (CI 1.68 - 0.86), whereas for the lordosis it was 0.54 (CI 1.84 - 0.75). The repeatability coefficient was 7.36 for kyphosis, 7.94 for lordosis.

Moreover, in the same paper, we report data about the rasterstereography performed with arms in different positions, showing a clear influence of arm positioning in the measurement of the thoracic kyphosis and lumbar lordosis and the normative data of the plumbline distance at C7, T12 and L3. The sagittal plumbline evaluation, as described by Stagnara, is well known and diffuse in clinical practice, and even if it doesn't measure an angle, it describes the sagittal profile (Kotwicki 2008, Zaina et al 2008). We think that this latter part of our paper would probably not fit the inclusion criteria, but it is relevant to also know about these kinds of evaluation. One of the limitations of clinical practice is secondary to the lack of reliable tools, as demonstrated by the review by Barrett and colleagues. The authors reported that, in fact, validity data are available for only a few of them. Moreover, comparisons between different tools are also missing; even though the authors commented on the different results of each single study, highlighting those with better measurement errors, a comparison should be made on the same patients to be really reliable.
Appendix 2


Dear Editor,

We would like to thank Dr Fabio Zaina and colleagues for bringing their study ‘How to measure kyphosis in everyday clinical practice: a reliability study on different methods’ to our attention (Zaina et al 2012). We appreciate their interest in our systematic review. We acknowledge that the above study has not been included in the systematic review, despite the eligibility criteria being fulfilled. However, since the article was published as part of an electronic book, it was not included in the databases searched by the reviewers. The article was not identified as part of the manual reference search conducted by the authors, presumably as it had not, as yet, been cited.

The information and article reference provided by Zaina and colleagues will be of great additional value to those interested in measuring thoracic kyphosis non-radiographically.
Appendix 3

Author contributions to studies presented in this thesis


Study design: EB, KM, KOS, JL
Literature searching and study selection: EB, MOK
Quality appraisal: EB, MOK
Data extraction: EB
Analysis and interpretation: EB, KM, KOS, JL
Drafting final manuscript: EB, KM, JL, KOS
Submission to journal: EB


Study design: EB, KM
Literature searching and selecting: EB
Quality appraisal: EB, KM
Data extraction: EB
Analysis and interpretation: EB, KM, JL
Drafting final manuscript: EB, KM, JL
Submission to journal: EB


Study design: EB, KM, JL
Ethics application: EB, KM
Participant recruitment: EB, KM
Data collection: EB, KM
Analysis and interpretation: EB, KM
Drafting final manuscript: EB, KM, JL
Submission to journal: EB

Study design: EB, KM, JL, KOS
Writing and reviewing ethics application: EB, KM
Subject recruitment: EB, BL
Data collection: EB, BL
Data analysis and interpretation: EB, KM
Drafting final manuscript: EB, KM, KOS, JL
Submission to journal: EB


Study design: EB, KM, JL, KOS
Ethics application: EB, KM
Participant recruitment: EB, CC, MC
Data collection: EB, CC, MC
Analysis and interpretation: EB, HP, KM
Drafting study: EB, KM, KOS, JL


Study design: EB, AH, KM
Data collection: AH, KM, MK, CC
Data analysis and interpretation: EB, KM, KR
Drafting final manuscript: EB, KM, KR, KOS
Submission to journal: EB
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Volunteer Information Sheet

“A profile of scapular, thoracic and shoulder joint variables in an Irish Masters Swimmers and their relationship with shoulder pain”

Dear Volunteer,

As part of my Masters project in the University of Limerick and two 4th year undergraduate projects, we are conducting research on shoulder and spinal posture in Masters swimmers. This information sheet will inform you about the study.

What is the study about?

The project aims to measure shoulder blade (scapula) position, shoulder (glenohumeral) position and back curvature (thoracic kyphosis) in Masters swimmers and examine the reliability of measuring back posture between different people and the same person.

What will I have to do?

Your involvement in this project will be at a time of convenience for you. You will be assessed in a private room in the Health Sciences building in the University of Limerick, where you will be asked to stand with a normal, relaxed posture and move and hold your arms in various positions. An assessor will measure your scapular alignment and shoulder positions using different instruments in these positions. A second tester will measure the curve in your back using an inclinometer at two different times. This measurement will also be recorded by a third tester. You will be dressed in your usual swimming attire and privacy/dignity will be assured.
What are the benefits?

The findings of the study may inform the components of a treatment programme if you suffer from a shoulder injury or a prevention programme if you do not suffer from a shoulder injury.

What are the risks?

Potential redness of skin from palpation and contact with measurement tools or potential adverse reaction to marking equipment may occur. A marker which is easily erased, tissue, baby oil and alcohol swabs will be used to minimise redness. Short term pain may be provoked during some of the tests.

What if I do not want to take part?

Participation in this study is voluntary and you can choose not to consent or to withdraw consent and stop participating in this study at any time.

What happens to the information?

The information that is collected will be kept confidential and stored on the researchers’ computer with a protection password. The information will be made anonymous and kept for a period of seven years, after which it will be deleted and/or disposed of sensitively.

Who else is taking part?

Other members of the Limerick Masters swim team will be invited to participate in the research.

What if something goes wrong?

In the unlikely event that something goes wrong during the measurement session, the testing will immediately stop until the investigator and participant(s) are ready to resume the session or the session will be stopped completely.

What happens at the end of the study? At the end of the study the information will be used to present results but the information will be completely anonymised. All data gathered from the research will be held by the principal investigator for up to 7 years in a password-protected computer at UL after which it will be deleted and/or disposed of sensitively.

What if I have more questions or do not understand something?

If you have any questions related to any aspect of the study you may contact any of the researchers. It is important that you feel that all your questions have been answered.
What happens if I change my mind during the study?
At any stage should you feel that you want to discontinue being a participant, you are free to stop and take no further part. There are no consequences for changing your mind about participating in the study.

Contact details

Principal Investigator
Karen McCruesh, Physiotherapy Dept., University of Limerick, Tel (061) 234233 Email: Karen.McCreesh@ul.ie

Other investigators
Eva Barrett    David Niblock and Aoife Hale
Masters Student Undergraduate Students (Final Year Project)
Dept.Physiotherapy Dept.Physiotherapy
085-7328739    University of Limerick
Eva.Barrett@.ul.ie

Thank you for taking the time to read this. We would be grateful if you would consider participating in this study.
Information Sheet

"An investigation of the validity of the Flexicurve and manual inclinometer for thoracic kyphosis measurement; a comparison with the gold standard"

Dear Volunteer,

Thoracic kyphosis is the outward curve in the middle section of your back. As part of my PhD degree in the University of Limerick, I am conducting research on specific tools for measuring the curve in your back. This information sheet will inform you about the study.

What is the study about?

The ‘Flexicurve’ and ‘manual inclinometer’ are two small, hand-held tools used by physiotherapists to measure the curve in your back. The tools are put on the surface of your back at specific points and angles are then read from the tools. This project aims to establish whether these tools are measuring the true curve of your spine. This will be done by comparing the angles from the tools with the angles obtained on your X-ray.

What will I have to do?

Your involvement in this project will be during your scheduled X-ray appointment at Croom Hospital. You will be assessed in a private X-ray room. Your X-ray will be carried out as per usual procedures by your radiographer. You will be asked to stand in a relaxed standing posture while the X-ray is being taken. After the X-ray, a physiotherapist will then measure your spinal posture with the two hand-held tools. This requires you to stand in a relaxed posture for a maximum of 10 minutes. You will be dressed in the usual X-ray attire and privacy/dignity will be assured.
What are the benefits?

The findings of the study will give physiotherapists and other health professional’s confidence that these tools are giving them the true spinal angles. This will enable the tools to be used more in health practice and for research.

What are the risks?

X-rays use small amounts of radiation. You will not be required to have an X-ray solely for the purpose of this study. You will be undergoing radiological assessment for your own health reasons. Potential redness of skin from contact with the measurement tools and skin markings may occur. Contact time will be kept to a minimum and a pen which is easily erased, tissue, baby oil and alcohol swabs will be used to skin irritation. Slight fatigue may occur due to continued standing after the X-ray. Subjects will be allowed to have a rest (in sitting) if required. Measurement time after the X-ray will be kept to a maximum of 10 minutes.

What if I do not want to take part?

Participation in this study is voluntary and you can choose not to consent or to withdraw consent and stop participating in this study at any time.

What happens to the information?

The information that is collected will be kept confidential and stored on the researchers’ computer with a protection password. The information will be made anonymous and kept for a period of seven years, after which it will be deleted and/or disposed of sensitively.

Who else is taking part?

Other individuals who are undergoing spinal X-rays are taking part in this study.

What if something goes wrong?

In the unlikely event that something goes wrong during the measurement session, the testing will immediately stop until the investigator and participant(s) are ready to resume the session or the session will be stopped completely.

What happens at the end of the study? At the end of the study the information will be used to present results but the information will be completely anonymised. Anonymised collection of results may be published in a physiotherapy journal and presented at a physiotherapy conference. All data gathered from the research will be held by the principal investigator for up to 7
years in a password-protected computer at UL after which it will be deleted and/or disposed of sensitively.

**What if I have more questions or do not understand something?**
If you have any questions related to any aspect of the study you may contact any of the researchers. It is important that you feel that all your questions have been answered.

**What happens if I change my mind during the study?**
At any stage should you feel that you want to discontinue being a participant, you are free to stop and take no further part. There are no consequences for changing your mind about participating in the study.

**What are the time requirements for involvement with the study?**
You will be needed for a maximum of 10 minutes after your X-ray is finished. Measurements will be taken on a single occasion after your scheduled X-ray only.

**Contact information**

**Principle investigator**
Eva Barrett, Postgraduate Student, Department of Clinical Therapies, University of Limerick
Contact: Eva.Barrett@ul.ie

**Other investigator**
Karen McCreesh, Lecturer and researcher, Clinical Therapies Department, University of Limerick.
Contact: Tel (061) 234233 Email: Karen.McCreesh@ul.ie

Thank you for taking the time to read this. We would be grateful if you would consider participating in this study.

*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
Email: ehsresearchethics@ul.ie
Volunteer Information Sheet

TITLE: Exercise classes for the management of shoulder pain: effectiveness and patient perceptions

What is the study about?

The aim of the study is to examine the effectiveness of exercise classes for shoulder pain and to determine patient perceptions of involvement in the class.

What will I have to do?

You have already been assessed by your physiotherapist who has determined you are suitable for inclusion in a group exercise class for shoulder pain. You will carry out all the procedures associated with the class as per usual, however if you provide your consent, your data from the class will be included in an evaluation of the effectiveness of the class. Six months after the exercise class finishes, you will be posted two questionnaires and will be asked to complete these and send them back to the University of Limerick. This will allow us to understand if the effects of the class were maintained. In order to post the questionnaires to you, the investigators will obtain your address and phone number from your physiotherapist. However, if you do not wish for this to happen you may opt out. This evaluation will be carried out by researchers from the University of Limerick, who will receive your data in anonymised form. A second part of this study involves asking patients what they think of being involved in a group exercise class. For this investigation, a researcher (a final year physiotherapy student at UL) will carry out short (15 min) telephone interviews with people who have completed the class. If you consent to this, your name and telephone number will be provided to the research team. The researcher will arrange a time to phone you and will audio-record a short interview with you over the phone. The audio recording will be deleted as soon as the interview has been transcribed in writing in anonymised form.

What are the benefits?

The findings of the study may help us to decide if exercise classes are an effective way to treat shoulder pain and whether patients have a good experience when taking part.

What are the risks?

There are no risks to taking part in this study. If you provide your telephone number it will only be used to invite you to be involved in the interview part of this study.
What if I do not want to take part or change my mind during the study?

Participation in this study is voluntary and you can choose not to consent, or to withdraw consent at any time. There are no consequences for withdrawing or not taking part. Your data will remain confidential at all times.

What if something goes wrong?

Your involvement in the study will immediately stop until the investigator and participant is ready to resume, or will be stopped completely.

Please do not hesitate to contact me if you have any questions.

Investigator: Karen McCreesh, Dept of Clinical Therapies, University of Limerick, Tel (061) 234233 Email: karen.mccreesh@ul.ie
I have agreed to participate in this research study. I understand that my participation is purely voluntary and that I may withdraw at any point.

I have read and understand the attached participant information leaflet and have been given the opportunity to seek clarification where necessary.

The procedures involved in this study have been fully explained by the undersigned author(s).

I am fully aware of all the procedures involving myself and of any risks/benefits associated with the study.

I understand what the project is about and that personal information and results are strictly confidential and will be used for statistical purposes only.

Signature (Participant): ____________________________ Date: __________

Signature (Investigator): ____________________________ Date: __________

Signature (Witness): ____________________________ Date: __________
Informed Consent Form

Title of Project: "An investigation of the validity of the Flexicurve and manual inclinometer for thoracic kyphosis measurement; a comparison with the gold standard"

I __________________________ have agreed to participate in this research study. I understand that my participation is purely voluntary and that I may withdraw at any point.

I have read and understand the attached participant information leaflet and have been given the opportunity to seek clarification where necessary.

The procedures involved in this study have been fully explained by the undersigned author(s).

I am fully aware of all the procedures involving myself and of any risks/benefits associated with the study.

I understand what the project is about and that personal information and results are strictly confidential and will be used for statistical purposes only.

Signature (Participant): __________________________ Date: ____________

Signature (Investigator): __________________________ Date: ____________

Signature (Witness): __________________________ Date: ____________
Exercise classes for the management of shoulder pain: effectiveness and patient perceptions

Consent form

I have read and understood the information sheet provided  Yes ☐  No ☐

I understand that participation is voluntary and that I may withdraw at any time  Yes ☐  No ☐

I consent to allow my data from the class to be included in this study  Yes ☐  No ☐

I consent to being contacted by telephone to take part in an interview. I consent to audio recording of this interview  Yes ☐  No ☐

Name of Participant (PRINT)_______________________ Date __________

Signature: _____________________________________

Physio/Investigator (PRINT) _______________________ Date __________

Signature: _____________________________________
Appendix 7: Raw data and normality plots

Study III: Raw data for 30 participants tested and retested by Rater 1 for intra-rater reliability and the subset of 12 tested by Rater 2 for inter-rater reliability. Also presented are the normality histograms for the six columns of data.

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Study IV: Raw data collected for 11 subjects tested using the radiographic Cobb method, manual inclinometer and Flexicurve. Formulas for the calculation of the Flexicurve index and Flexicurve angle based on the raw Flexicurve data are described in Figure 3.3.

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Study V: Raw data for 39 participants tested at baseline (NRS, DASH, TK), 6 weeks (NRS, DASH, TK) and six months (NRS, DASH). Also presented are the normality histograms for each column of data.

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Shoulder Group (NRS)
Shoulder group (DASH)

Mean = 52.38
Std. Dev. = 25.546
N = 20

Mean = 31.26
Std. Dev. = 17.454
N = 17

Mean = 33.09
Std. Dev. = 16.492
N = 11
Thoracic Group (NRS)

Mean = 5.68
Std. Dev. = 2.083
N = 19

Mean = 2.73
Std. Dev. = 2.463
N = 15

Mean = 1.55
Std. Dev. = 1.835
N = 11
Thoracic group (DASH)
Thoracic kyphosis normality plots

Shoulder group

Thoracic group
Appendix 8: Study III Demographical questionnaire

Personal information

ID:

Male or female:

Date of birth:

Weight (kg):

Height (cm):

Hand you write with:

Sport history

Main sport of interest:

Number of years swimming with Limerick Masters Swimmers:

Number of years involved in swimming competition:

Average number of weekly training sessions in the pool:

Average weekly swimming distance:

What swimming stroke do you specialize in/ practice most:

Shoulder pain history

Have you ever missed time in the pool due to shoulder pain? If so, for how long?

How long ago was this?

Have you ever received treatment for shoulder pain? If so, please explain.

Have you shoulder pain at the moment? If so, which shoulder? If both shoulders, which is worse?

How long have you had this pain?

On a scale of 1 to 10, how severe your pain is after a swimming session. 0 is no pain and 10 is the worst pain imaginable (e.g. getting your arm cut off!):
Appendix 9: Study V Extra tables

**Table 1.** Separated outcomes for group versus group with previous physiotherapy using mean, standard deviation (SD) and 95% confidence intervals (CIs).

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<td>18.50 (20.47)</td>
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Table 2. Between-group statistical comparison based on the values in Table 1 (using the Mann-Whitney U test).

<table>
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<th>Thoracic (group only and group with previous physiotherapy)</th>
<th>Shoulder (group only and group with previous physiotherapy)</th>
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<tr>
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<tr>
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<td>0.24</td>
</tr>
<tr>
<td>NRS 6 months</td>
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</tr>
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<td>DASH Baseline</td>
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<td>DASH 6 weeks</td>
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<td>DASH 6 months</td>
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</table>
Appendix 10: Study VI Question Route

Tell me about your shoulder pain problem.
What treatment have you had for your shoulder pain problem to date?
Tell me about your overall impression of taking part in the shoulder class.
What did you enjoy about the shoulder class?
What did you dislike about the shoulder class?
What effect do you think participating the shoulder class had on your shoulder pain?
How would you compare participating in the shoulder class to receiving one-to-one physiotherapy for your shoulder pain?
Would you participate in a group physiotherapy exercise class again in the future if required?
Do you have any further comments or suggestions regarding the shoulder class?
Appendix 11: Study VI sample transcript

Amy: Tell me about your shoulder pain problem

Tom: Well it started because I had a multiple fracture and dislocation so it entailed a replacement from, from just above my elbow up to the ball joint—I had to have it replaced—so it is a prosthesis that I have had ever since 2008, October 2008.

Amy: Ok.

Tom: And I have been dealing with it through, through swimming to a lesser degree—now I might add as I have an asthmatic situation and that was affected by swimming—by chlorine in the water or whatever it was. But I After I had the surgery for the replacement I, I attended St. John’s for, I can’t remember for how many months, for physio—which was vital to me—absolutely vital to me—and I’m still doing little bits of that, but not as disciplined as I was at the start but I’m, I’ve regained a little bit of movement but not much and I’m playing some golf, doing the normal chores, with with obviously with certain restrictions.

Amy: Ok, brilliant. How did the shoulder pain affect your daily life?

Tom: O, it affected it in many many ways—am simple things like tying my shoelaces obviously anything over chest height—I can’t—shelves or something that I’m trying to get something from—in clothing or like taking a towel out of the hot press—it is obviously very difficult—and most times impossible.

Amy: Ok

Tom: Am, how else, In the earlier stages I couldn’t drive the car for something like five months because I couldn’t stretch my right hand which is the side which was injured. Or ah, I couldn’t get as far as putting the key into the ignition. But obviously through exercises, through the physio it helped me greatly. And it’s a question now Amy really of dealing with it—and not allowing it to dominate you.
Amy: Exactly

Tom: That is the best way I can put it to you. But it certainly is, is, is a permanent disability. Definitely. But am, as I said again, to reiterate without the early intervention by the physio in St. John’s em I wouldn’t have advanced as well as I did.

Amy: Yes

Tom: In fact for the first (I can’t remember the timing) I was going around in a sling for weeks but when I went to St. John’s and had the surgery in the Limerick Regional Hospital—ah when I came to St. John’s the first thing they said was we’ll get rid of that thing for you—which was, twas almost a harness that was holding my right arm in place.

Amy: Yes

Tom: But After that it was onwards and upwards.

Amy: Yes, exactly. What actual treatment have you had to date?

Tom: Ah I’ve had the continual exercises in various forms---in in the ah, in St. John’s---and a lot of it is self motivation. In the earlier part they, they really babysat me, really, and and, and nursed me along and when I got to the point when I was doing the exercises myself, ah they just observed what was going on but am, they encouraged me to start swimming---and the swimming was another giant step. So effectively Amy what I would say, at the beginning it was coming to terms with it, which was rather difficult and as it progressed the little things like---what do you call them---the elastic bands that I was stretching---the various exercises that I was doing and that with the swimming---and as I said they kept an eye on that and kept encouraging me to do that---it really was I suppose a small little bit or maybe a big bit of teamwork. That that that Particularly at the time, the senior physio in St. John’s was am, was out
injured---had a serious injury herself around the same time so Carmela took over the reins then and she was absolutely brilliant to me---
absolutely brilliant to me and this has no connection at all to a previous injury
I had 24 years before I had this thing. I had a fractured pelvis and Martina who was the physio who was helping me originally in St. John’s---she was brilliant through that. So what

I learnt that time probably carried on to the current injury. I’m ignoring it as much as one can. I’m am, as I said ya, I’m swimming---swimming, golfing a little and I’m driving my car and lugging two grandsons around occasionally---so certainly the motivation of, of the people who treat me and I suppose my family---that is what has kept me going. But I’m still back, I’m attending St. John’s and I did a series of classes and they were superb.

Amy: Tell me your overall impression of the shoulder group classes

Tom: They’re great I would say Amy ---they’re great---because it was almost like a team---sort of, having said that now---there were 3 women, 4 women with me at those particular ones that I attended but it was a sort of teamwork. I played team sports in my younger days so the value of the team and players and---ah encouraging one another---a lot of that, ah, came out in those classes. I think much much more so I would say than a one-to-one situation then go, if for instance if physiotherapy has treatement then go, I think that these were superb in that regard.

Amy: What did you enjoy about the class?

Tom: Am What did I enjoy about it? O jeepers! That’s a difficult one now Amy. I enjoyed I suppose the fact that there were other people there and we were all encouraging each other on and that made it, if you like enjoyable, and certainly almost looking forward to going there. You know, Now, you know there was a few people there we shared experiences and everyone got on with it and ah even some of the people ---we were all
certainly sixty on age group—everybody was encouraging everybody else.

And I think that’s a big factor for motivation—to get the physio buying into it and all the patients—be it four, six, ten, whatever, all buying into it—I think that is superb.

Amy: Yes

Tom: You Know If you are in and having treatment and you are on the bed or whatever and they treat you and that’s good, that’s fine, it’s very focused, very central but that focus was never lost in a group—and you know if anyone slacked they got a little bit of gentle verbal—you know, and that’s what I found anyway

Amy: What did you dislike about the class?

Tom: There was nothing I disliked about it—it was, it was a means to improving my situation—it was never going to replace my shoulder but there was nothing I disliked about it. And I couldn’t say enough positive things about the medical staff in St. John’s, it would sound probably patronising but no—they were brilliant. And I didn’t have any problems with that

Amy: What effect did participating in the shoulder class have on your shoulder?

Tom: I would say any, any improvements because it was a prosthesis would be marginal. I, I got the upper end of those marginals—I really did—and sometimes, you know, there is sort of a level you reach and then there is somebody behind you and they’re just much the same as yourself and they’re saying go on, a little bit further—a little bit further. So that is the little motivation that was very good.

Amy: How would you compare the shoulder class to one to one physio?

Tom: I suppose Amy, it depends on the extent of the injury. I would say in the early stages I would think a one to one would be more meaningful than a class but as
one progressed to a certain level and no body only the person treating
them and the person being treated knows what that level is---then it’s time to move
on to a group class.

But definitely in the early stages I would have to say the one to one is vital. It is just
like getting
you up and teaching you to walk and now that you have learnt to walk
now you move with the class.

Amy: Would you participate in a group physiotherapy class in the future if
required?

Tom: I have every intention of doing it, yes.

Amy: Brilliant. Tom, any further comments or suggestions regarding the
shoulder class.

Tom: I don’t really Amy---I mean, that might sound like I’m saying the people there are
Perfect, I’m sure they’re not and I’m sure they wouldn’t like to be seen like that but
it is
all about teamwork and trying to do their best. And I couldn’t understate or
overstate the value
of teamwork and as I said to you I played in sport and on teams at a
reasonably high level and what went on between the fellows before a game,
or during training helped the team to move forward---the same, ah, mantra
applies with group classes in physio. To come in there in the morning everything
was laid out----the plan was there---the people came in , took their places
and continued on---that is brilliant. But You would have the earlier ones that can
kind of, deal
with the initial impact of the injury, you know as I said again which is vital but the,
the, the roll on into

classes is brilliant.

Amy: That is all Tom, thank you.
### Appendix 12: Study VI Development of themes

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<tr>
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<th>References</th>
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<td>When the patient compares themselves to others in the class in a positive light</td>
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**Preliminary themes:**

Support, motivation and enjoyment gained from other members of the group.
Altered behaviour and beliefs around exercise.
Preference for group treatment compared to individual.
Outcomes after the class on shoulder symptoms.
Comparison and learning between group members.
Beliefs of physiotherapy treatment and potential for recovery prior to classes.
Positive experiences of class format.
Education received during the class and the role of physiotherapy.

**Final themes:**

The participant’s experiences of support, motivation and learning from peers
The preference for an exercise classes compared to individual shoulder physiotherapy
The physiotherapist as an educator and facilitator
Beliefs about pain and exercise