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Abstract

Introduction: Excessive thoracic kyphosis is considered a predisposing factor for shoulder pain, though there is uncertainty about the nature of the relationship between shoulder pain and thoracic spine posture. The aim of this systematic review was to investigate the relationship between thoracic kyphosis and shoulder pain, shoulder range of motion (ROM) and function. **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. 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 whose long-term clinical relevance is unclear. Higher quality research is warranted to fully explore the role of thoracic posture in shoulder pain.

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 (Blanked, 2011). Due to the limited diagnostic accuracy of clinical tests (Blanked, 2009), SAPS has been adopted as an overarching term encompassing subacromial impingement, bursitis and rotator cuff (RC) tendinopathy (Blanked 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 mechanics has been investigated. Previous studies have demonstrated that approximately 15º 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 arm elevation requires approximately 9º of thoracic extension (Stewart et al., 1995). Thoracic hyperkyphosis, an angulation of the thoracic spine of greater than 40º (Greendale et al., 2011) or 50º (Willner, 1981; Teixeira and Carvalho, 2007), has been implicated as a contributing factor to shoulder pain (Grimsby and Gray, 1997). Crawford and Jull demonstrated that older adults with a large thoracic kyphosis had reduced arm elevation (Crawford and Jull, 1993). 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. Firstly, it has been postulated that a small 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 al., 2006). An additional hypothesis suggests that thoracic spine curvature may influence the shoulder girdle through muscular attachments (Michener et al., 2003) and by altering the length-tension relationship of the muscles attached to the scapula (Grimsby and Gray, 1997). The evidence to support these hypotheses is scant and investigations of the relationship of thoracic kyphosis with the shoulder girdle have been largely conducted in pain-free populations.

The impingement model of the shoulder 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 (Blanked, 2011; Blanked et al., 2015). In addition, a recent systematic review concluded that there is insufficient evidence for the role of scapula 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?

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).

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 1. Both observational and experimental studies were eligible for inclusion. The reference lists of the included studies were manually searched for other relevant studies.

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 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 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).

Data analysis

One reviewer (EB) extracted data relating to the study design, study population, postures used and outcome measures related to shoulder pain, range of motion and/or function. Variation in the study designs, study population and outcome measures used did not permit the pooling of data in a meta-analysis. Data were synthesized 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.

Results

Flow of trials through the review

Figure 1 details the flow of studies through the review process. A total of ten studies involving 2,794 participants were included in the review.

Characteristics of the included studies

Design

Six studies utilised a cross-sectional design which compared thoracic kyphosis between groups with and without shoulder pain (Blanked et al., 2005a; McClure et al., 2006; Otoshi et al., 2014; Blanked 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 et al., 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 (Blanked 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 (Blanked et al., 2005a; Blanked et al., 2005b). One of these studies compared thoracic kyphosis in people with and without shoulder pain (Blanked et al., 2005a) and one compared shoulder ROM in different thoracic postures (Blanked et al., 2005b). Study characteristics are displayed in more detail in Table 3.

Risk of bias

Four studies were deemed to be at low risk of bias (Kanlayanaphotporn et al., 2014; Bullock et al., 2005; Blanked et al., 2005b; Blanked and Valentine, 2010), three at moderate risk of bias (Kebaetse et al., 1999; McClure et al., 2006; Blanked et al., 2005a) and three at high risk of bias (Otoshi et al., 2014; Theisen et al., 2010; Greenfield et al., 1995). Every study demonstrated a low risk of bias when defining thoracic kyphosis and measuring thoracic kyphosis objectively, reported all of their intended outcomes and had no loss to follow-up. One study (Otoshi et al., 2014) did not report the reliability of their method for thoracic kyphosis measurement and used cut-off points for restriction of shoulder ROM, rather than absolute values. Six studies (Blanked et al., 2005a; Kebaetse et al., 1999; McClure et al., 2006; Theisen et al., 2010; Greenfield et al., 1995; Otoshi et al., 2014) did not carry out a power calculation or reach statistical power. Seven studies did not use blinded assessors (Kebaetse et al., 1999; Blanked et al., 2005a; Blanked et al., 2005b; Otoshi et al., 2014; McClure et al., 2006; Bullock et al., 2005; Greenfield et al., 1995). Seven studies did not report on potential conflicts of interest (Blanked et al., 2005a; Blanked et al., 2005b; McClure et al., 2006; Otoshi et al., 2014; Kanlayanaphotporn et al., 2014; Greenfield et al., 1995; Bullock et al., 2005) The involvement of the funding body with the investigations was unclear in five studies (Kebaetse et al., 1999; McClure et al., 2006; Kanlayanaphotporn et al., 2014; Greenfield et al., 1995; Bullock et al., 2005). Full details are shown in Table 4.

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 et al., 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 (Blanked et al., 2005a; Blanked et al., 2005b; Blanked 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 (Blanked et al., 2013). One study measured thoracic kyphosis using the Metrecom Skeletal Analysis System which digitised landmarks two inches above and below both T2 and Tll (Kebaetse et al., 1999). The reliability of this method for thoracic kyphosis measurement was previously reported to range from an intraclass correlation co-efficient 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.

The effect of thoracic kyphosis on shoulder pain

Six studies (Blanked et al., 2005a; McClure et al., 2006; Otoshi et al., 2014; Theisen et al., 2010; Greenfield et al., 1995; Blanked and Valentine, 2010) compared resting thoracic kyphosis in groups with and without shoulder pain. Values for these are shown in Table 5. In comparing a group with SIS to those without shoulder pain, Blanked and colleagues reported that there were no significant differences in resting standing thoracic kyphosis (Blanked 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 (Blanked 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% CI 1.02, 2.64).

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.

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 postures increased shoulder ROM when compared to a slouched 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 et al., 2014). Conversely, mean shoulder internal rotation ROM increased by approximately 20% from the erect to maximum slouched posture. Kebaetse and colleagues also reported significantly more maximum active shoulder abduction ROM in an erect posture compared to a slouched posture (Kebaetse et al., 1999). 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 ($p<0.001$) (Blanked 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 6. All four studies checked that the mean thoracic kyphosis angle significantly changed between postures (Kanlayanaphotporn et al., 2014; Kebaetse et al., 1999; Bullock et al., 2005; Blanked et al., 2005b).

Two of the studies which measured the relationship between thoracic kyphosis and shoulder pain (Blanked et al., 2005a; Otoshi et al., 2014) also investigated the association between shoulder ROM and thoracic kyphosis. Blanked 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) (Blanked 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).

Discussion

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.

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 (Blanked et al., 2005a; McClure et al., 2006; Theisen et al., 2010; Greenfield et al., 1995; Blanked 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. Blanked 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 (Blanked 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 nocioception, the potential role of the central nervous system (CNS) in maintaining shoulder pain has also been recognised (Littlewood et al., 2014). 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 3 months duration (Blanked et al., 2005; 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 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.

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, 2004). 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; Blanked et al., 2005b), as well as changes in the activation of a range of scapulothoracic muscles (Claus et al., 2005). 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 (Blanked 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.

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, prospective studies where thoracic kyphosis and shoulder outcomes (pain, function and ROM) are monitored longitudinally may develop understanding of the role of the thoracic spine in the etiology and management of shoulder pain. 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.

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) (Blanked, 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. 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.

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 prospective cohort 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.

References

Blanked, McCreesh K, Lewis J. Intrarater and interrater reliability of the Flexicurve index, Flexicurve angle, and manual inclinometer for the measurement of thoracic kyphosis. *Journal of Rehabilitation Research and Practice*. 2013; 1-7.

Blanked, Green A, Wright C. Subacromial impingement syndrome: the role of posture and muscle imbalance. *Journal of Shoulder and Elbow Surgery*. 2005a; 14(4): 385-392.

Blanked, Wright C, Green, A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *Journal of Orthopaedic & Sports Physical Therapy*. 2005b; 35(2): 72-87.

Bartolozzi D, Andreychik S. Determinants of outcome in the treatment of rotator cuff disease. *Clin. Orthop. Relat. Res.* 1994; 90–97.

Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Physical Therapy*. 2006; 86(4):549-557.

Bullock MP, Foster NE, Wright CC. Shoulder impingement: the effect of sitting posture on shoulder pain and range of motion. *Man. Ther.* 2005; 10:28-37.

Butler DS, Moseley GL. Explain Pain. Adelaide: Noigroup Publications. 2003.

Claus AP, Hides JA, Moseley GL, Hodges PW. Different Ways to Balance the Spine Subtle Changes in Sagittal Spinal Curves Affect Regional Muscle Activity. *Spine.* 2009; 34(6):208–214.

Crawford HJ, Jull GA. The influence of thoracic posture and movement on range of arm elevation. *Physiotherapy Theory Practice.* 1993; 9:143-8.

Culham E, Peat M. Functional anatomy of the shoulder complex. *J. Orthop. Sports Phys. Ther*. 1993; 18:342–350.

Diercks R, Bron C, Dorrestijn O, Meskers C, Naber R, de Ruiter T, Willems J, Winters J, van der Woude HJ. Guideline for diagnosis and treatment of subacromial pain syndrome A multidisciplinary review by the Dutch Orthopaedic Association. *Acta Orhopaedica.* 2014; 85(3):314-322.

Donatelli R. Physical Therapy of the Shoulder (Clinics in Physical Therapy). 4th ed. New York, NY: Churchill-Livingstone. 2004.

Duckworth DG, Smith KL, Campbell B, Matsen FA. Self-assessment questionnaires document substantial variability in the clinical expression of rotator cuff tears. *J Shoulder Elbow Surg.* 1999; 8:330–333.

Engebretsen K, Grotle M, Bautz-Holter E, Sandvik L, Juel NG, Ekeberg M, Brox JI. Radial extracorporeal shockwave treatment compared with supervised exercises in patients with subacromial pain syndrome: single blind randomised study. *BMJ* 2009; 339-360.

Fiebert IM, Spyropoulos T, Peterman D, Dotson L. Thoracic segmental flexion during cervical forward bending. *Journal of Back and Musculoskeletal Rehabilitation* 1993, 3(4):80-85.

Greendale G, Nili N, Huang MH, Seeger L, Karlamangla A. The reliability and validity of three non-radiological measures of thoracic kyphosis and their relations to the standing radiological Cobb angle. *Osteoporos Int* 2011; 22(6):1897-1905.

Greenfield B, Catlin PA, Coats PW, Green E, McDonald J. Posture in Patients with Shoulder Overuse Injuries and Healthy Individuals. *JOSPT.* 1995; 21(5): 287-295.

Greving K, Dorrestijn O, Winters J, Groenhof F, van der Meer K, Stevens M, Diercks RL. Incidence, prevalence, and consultation rates of shoulder complaints in general practice. *Scand J Rheumatol*. 2012; 41(2):150-155.

Grimsby O, Gray J. Interrelation of the spine to the shoulder girdle. In: Donatelli R, editor. Physical therapy of the shoulder. New York: Churchill Livingstone 1997; 95-129.

Gumina S, Di Giorgio G, Postacchini F, Postacchini R. Subacromial space in adult patients with thoracic hyperkyphosis and in healthy volunteers. *Chir Organi Mov.* 2008; 91:93-96.

Ijaz S, Verbee J, Seidler A, Lindbohm ML, Ojajärvi A, Orsini N, Costa G, Neuvonen K. Night-shift work and breast cancer– a systematic review and meta-analysis. *Scand J Work Environ Health.* 2013; 39(5):431-447.

Kalra N, Seitz AL, Boardman ND, Michener LA. Effect of Posture on Acromiohumeral Distance With Arm Elevation in Participants With and Without Rotator Cuff Disease Using Ultrasonography. *JOSPT.* 2010; 40(10): 633-640.

Kanlayanaphotporn R. Changes in sitting posture affect shoulder range of motion. *Journal of Bodywork & Movement Therapies.* 2014; 18:239-243.

Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three dimensional scapular kinematics. *Arch. Phys. Med. Rehabil.* 1999; 80:945-950.

Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J Clin Epidemiol.* 2009; 62(10):1–34.

Littlewood C, Malliaras P, Mawson S, May S, Walters SJ. Self-managed loaded exercise versus usual physiotherapy treatment for rotator cuff tendinopathy: a pilot randomised controlled trial. *Physiotherapy,* 2014; 100(1):54-60.

MacDermid JC, Ramos J, Drosdowech D, Faber K, Patterson, S. The impact of rotator cuff pathology on isometric and isokinetic strength, function, and quality of life. *J Shoulder Elbow Surg* 2004, 13:593–598.

McClure L, Michener A, Karduna, A.R. Shoulder Function and 3-Dimensional Scapular Kinematics in People With and Without Shoulder Impingement Syndrome. *Phys Ther*. 2006; 86:1075-1090.

Meurer A, Grober J, Betz U, Decking J, Rompe, JD. BWS-mobility in patients with an impingement syndrome compared to healthy participants, an inclinometric study. *Z Orthop Ihre Grenzgeb*. 2004; 142:415-420.

Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clinical Biomechanics.* 2003; 18(5):369-379.

Otoshi K, Takegami M, Sekiguchi M, Onishi Y, Yamazaki S, Otani K, Shishido H, Kikuchi S, Konno S. Association between kyphosis and subacromial impingement syndrome: LOHAS study. *J Shoulder Elbow Surg*. 2014; 23:300-307.

Ozaki J, Fujimoto S, Nakagawa Y, Masuhara K, Tamai S. Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion. *J Bone Joint Surg Am*. 1988; 70:1224-30.

Ratcliffe E, Pickering S, McLean S, et al. Is there a relationship between subacromial impingement syndrome and scapular orientation? A systematic review. *Br J Sports Med*. 2014; 48:1251–1256.

Rechardt M, Shiri R, Karppinen J, Jula A, Heliövaara M, Viikari-Juntura E. Lifestyle and metabolic factors in relation to shoulder pain and rotator cuff tendinitis: a population-based study. *BMC Musculoskelet Disord*. 2010; 11:165.

Reilingh ML, Kuijpers T, Tanja-Harfterkamp AM, van der Windt DA. Course and prognosis of shoulder symptoms in general practice. *Rheumatology*. 2008; 47(5): 724-30.

Seitz AL, McClure PW, Finucane S, et al. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? *Clin Biomech (Bristol, Avon).* 2011; 26:1–12.

Smith KL, Harryman DT, Antoniou J, Campbell B, Sidles JA, Matsen FA. A prospective, multipractice study of shoulder function and health status in patients with documented rotator cuff tears. *J Shoulder Elbow Surg.* 2000; 9:395–402.

Solem-Bertoft EVA, Thuomas KA, Westerberg CE. The influence of scapular retraction and protraction on the width of the subacromial space: an MRI study. *Clinical orthopaedics and related research.* 1993; 296:99-103.

Stewart SG, Jull GA Willems JM. An initial analysis of thoracic spine movement during unilateral arm elevation. *J Man Manip Ther*. 1995; 3:15-20.

Tashjian RZ, Farnham JN, Albright FS, Teerlink CC, Cannon-Albright LA. Evidence for an inherited predisposition contributing to the risk for rotator cuff disease. *J Bone Joint SurgAm*. 2009; 91:1136-42.

Teixeira F, Carvalho G. Reliability and validity of thoracic kyphosis measurements using flexicurve method. *Revista Brasileira de Fisioterapia*. 2007; 11(3):199-204.

Theisen C, van Wagensveld A, Timmesfeld N, Efe T, Heyse TJ, Fuchs-Winkelmann S, et al. Co-occurrence of outlet impingement syndrome of the shoulder and restricted range of motion in the thoracic spineda prospective study with ultrasound-based motion analysis. *BMC Musculoskelet Disord*. 2010;11:135.

Uhthoff HK, Sano H. Pathology of failure of the rotator cuff tendon. *Orthop Clin North Am*. 1997; 28:31-41.

van Tulder M, Furlan A, Bombardier C, Bouter L. Updated method guidelines for systematic reviews in the Cochrane Collaboration Back Review Group. In: The Cochrane library. Oxford: Update Software; 2003; 28:1290–9.

van der Windt DA, Koes BW, de Jong BA, Bouter LM. Shoulder disorders in general practice: incidence, patient characteristics, and management. Annals of Rheumatic Diseases. 1995; 54(12): 959-64.

Willner S. Spinal pantograph: a non-invasive technique for describing kyphosis and lordosis in the thoraco-lumbar spine. *Acta Orthop Scand.* 1981; 52:525-9.

Yamamoto A, Takagishi K, Kobayashi T, Shitara H, Ichinose T, Takasawa E, Shimoyama D. The impact of faulty posture on rotator cuff tears with and without symptoms. *J Shoulder Elbow Surg.* 2015; 24, 446-452.

Tables

Table 1. Eligibility criteria for inclusion.

Inclusion Criteria	**Exclusion Criteria**
(1) Thoracic posture is examined in relation to shoulder pain, range of motion or function	(1) The study does not specifically examine shoulder pain in isolation, but includes other pain regions, e.g. cervical spine
(2) Studies must have (i) a control group without pain or (ii) involve 2 different positions/postures involving more/less thoracic kyphosis	(2) Spinal posture as a whole is considered without commenting specifically on thoracic posture.
(3) The study is published in English	(3) Studies not available in the English language.
(4) Experimental studies must compare the effect of an intervention directly aimed at changing posture, e.g. postural advice	

Table 2. Levels of evidence approach (van Tulder et al., 2003).

Level of Evidence	**Criteria**
Strong	Consistent findings among multiple high quality studies
Moderate	Consistent findings among multiple low quality studies and/or one high quality study
Limited	Consistent findings in one low quality study or only one study available
Conflicting	Inconsistent evidence in multiple studies irrespective of study quality

Table 3: Descriptive characteristics of studies and their populations.

Author(s), year	Recruitment, setting	Design	SS	Population
Kanlayanaphotporn, 2014	Participants were recruited by convenience sampling, Thailand.	Same-participant repeated-measures design.	30	Pain-free males aged 18-35 years, mean age 20 years. Exclusion criteria: 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.
Kebaetse et al., 1999	Participants were recruited by convenience sampling, USA.	Same-participant repeated-measures design.	34	Pain-free (18F, 16M, mean age 30.2 (8.7)) Exclusion criteria: a history of shoulder pain or shoulder injury, pain with active or resisted isometric shoulder abduction.
Bullock et al., 2005	Participants were recruited from a hospital physiotherapy department, UK.	Same-participant repeated-measures design.	28	28 participants with SIS (14M, 14F, mean age 48.2 (13.9)) DOS: mean 3.6 (4.7) years Diagnostic criteria: 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.
McClure et al., 2006	Shoulder patients were recruited from University based orthopaedic practice, controls were recruited from the university, surrounding community and contacts of investigators, USA.	Observational, cross-sectional comparison group study.	90	45 participants with SIS (21F, 24M, mean age 45.2 (12.8)) 45 control participants (21 F, 24 M, mean age 43.6 (12.4)) DOS: 2< 1 month, 14= 1-3 months, 12= 3-6 months, 17 > 6 months Diagnostic criteria: At least 3 of following: positive Neer impingement 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.
Blanked et al., 2005a Blanked et al., 2005b	Participants were recruited by a specialised shoulder therapist, UK.	This investigation was carried out as part of a placebo-controlled crossover design	120	60 participants with SIS (25F, 35M, mean age 48.9 (15.2)) 60 pain-free participants (31F, 29M, mean age 34.1 (9.9) DOS: mean 1.1 years (SD 2.5 years), range 2 weeks to 22 years Diagnostic criteria: 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.

Blanked and Valentine, 2010	Participants with symptoms were recruited through orthopaedic and physical therapy outpatient departments, participants without symptoms were recruited through 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. Most common 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 40years who attended a local health check-up, Japan.	This investigation was carried out as part of a prospective cohort study for identifying people at cardiovascular risk.	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
Thiesen et al., 2010	Participants were recruited from an outpatient clinic of the Department of Orthopaedics and Rheumatology of the University Hospital Marburg, 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 4: Risk of bias in and across included studies.

Reference	Exposure definition	Exposure assessment	Reliability of exposure assessment	Analysis bias	Confounding factors	Attrition	Blinded assessors	Selective reporting	Funding	Conflict of interest
Kanlayanaphotporn 2014	LR	LR	LR	LR	LR	LR	LR	LR	UR	UR
Kebaetse 1999	LR	LR	LR	HR	LR	LR	HR	LR	UR	LR
Bullock 2005	LR	LR	LR	LR	LR	LR	HR	LR	UR	UR
McClure 2006	LR	LR	LR	HR	LR	LR	HR	LR	UR	UR
Blanked 2005a	LR	LR	LR	HR	LR	LR	HR	LR	LR	UR
Blanked 2005b	LR	LR	LR	LR	LR	LR	HR	LR	LR	UR
Otoshi 2014	LR	LR	HR	HR	HR	LR	HR	LR	LR	UR
Blanked and Valentine 2010	LR	LR	LR	LR	LR	LR	UR	LR	LR	LR
Thiesen 2010	HR	LR	LR	HR	LR	LR	LR	LR	LR	LR
Greenfield 1995	LR	LR	LR	HR	HR	LR	HR	LR	HR	HR

HR=high risk of bias; LR=low risk of bias; UR=unclear risk of bias

Table 5: Comparison of thoracic kyphosis and shoulder ROM in groups with and without impingement.

Study	Mean (SD) thoracic kyphosis (Pain group)	Mean (SD) thoracic kyphosis (Control group)	p value	Shoulder ROM (impingement group)	Shoulder ROM (control group)	p value
McClure et al., 2006	69.4 (6.4)	70.5 (6.0)	P=0.415	Active flexion: 144.6 (17.4) Active IR: 50.1 (19.5) Active ER: 90.9 (17.0) Passive IR: 28.4 (12.5)	Active flexion: 163.5 (6.0) Active IR: 70.0 (12.6) Active ER: 111.9 (10.0) Passive IR: 163.5 (6.0)	P<.001
Blanked et al., 2005a	37.1 (7.1)	35.7 (8.2)	p>0.05	Shoulder flexion: 120.5 (30.9) Shoulder abduction: 111.3 (31.8)	Shoulder flexion: 157.3 11.9 Shoulder abduction: 156.1 (12.1)	p<0.05
Blanked and Valentine 2010	37.6°(9.5°)	35.5°(6.0°)	p>0.05	Not stated	Not stated	Not stated
Otoshi et al., 2014	31.6% positive WOT (indicator for hyperkyphosis)	20% positive WOT (indicator for hyperkyphosis)	p<0.05	Positive RSE: 34.3% (shoulder flexion below 150º)	Positive RSE: 7.7% (shoulder flexion below 150º)	p<0.05
Greenfield et al., 1995	38º (10.7º)	34º (11.5º)	p>0.05	Not stated	Not stated	Not stated
Thiesen et al., 2010	45.9° (10.8°)	44.8° (10.6°)	p=0.66	Not stated	Not stated	Not stated

ROM=range of motion, SD=standard deviation, SIS=subacromial impingement syndrome, WOT=wall-occiput test, RSE=restricted shoulder elevation, IR=internal rotation, ER=external rotation.

Table 6: Comparison of thoracic kyphosis and shoulder ROM in erect and slouched sitting postures.

Study	Population	Mean (SD) thoracic kyphosis in degrees (erect)	Mean (SD) thoracic kyphosis in degrees (slouched)	p value	Shoulder ROM (erect)	Shoulder ROM (slouched)	p value
Kanlayanaphotporn, 2014	30 pain-free males, mean age 20.5 years	21.5 (9.7)	C.S: 28.5 (9.5) M.S: 38.0 (9.8)	p < 0.001	Shoulder flexion: 168.0 (8.0) Shoulder abduction: 175.7 (6.8) Shoulder ER: 90.7 (11.5) Shoulder IR: 55.3 (11.0)	Shoulder flexion: CS: 152.4 (13.9) MS: 132.5 (16.6) Shoulder abduction: CS: 159.8 (16.0) MS: 135.1 (20.7) Shoulder ER: CS: 78.9 (10.9) MS: 64.7 (9.8) Shoulder IR: CS: 60.3 (12.8) MS: 65.6 (14.0)	p < 0.001
Kebaetse et al., 1999	34 pain-free participants, mean age 30.2 years	26.4 (11.5)	38.5 (10.8)	p < 0.001	Shoulder abduction: 157.5 (10.8)	Shoulder abduction: 133.9 (13.7)	p < 0.001
Bullock et al., 2005	28 patients with SIS, mean age 48.2 years	35.61 (13.70)	53.46 (12.02)	p <0.0001	Shoulder flexion: 127.32 (25.81)	Shoulder flexion: 109.65 (25.53)	p =0.0001
Blanked et al., 2005b	60 people with SIS, 60 healthy controls	Mean change (SE) from normal to erect posture (using postural taping): Symptomatic: –5.8 (0.66) Asymptomatic:–6.4 (0.72)		p < 0.001	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)		p < 0.001

ROM=range of motion, SD=standard deviation, CS=comfortable slouched, MS=maximum slouched, SIS=subacromial impingement syndrome.

Figures

Figure 1: PRISMA flow diagram