Investigation of the stability system of the scapula in patients with cervical spine disorders

Assessment of scapular orientation and recruitment of the scapular stability muscles in patients with insidious onset neck pain and whiplash associated disorders

Harpa Helgadóttir

Thesis for the degree of Philosophiae Doctor

University of Iceland

Faculty of Medicine

School of Health Sciences

December 2010

Rannsókn á stöðugleikakerfi herðablaðs hjá sjúklingum með verki í hálshrygg

Mat á stöðu herðablaðs og kveikjumynstri stöðugleikavöðva herðablaðs hjá sjúklingum með hálsverki af óþekktum uppruna og eftir hálshnykk

Harpa Helgadóttir, PT, MHSc

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To my grandparents Sigurberg Benediktsson og Jóhanna Guðjónsdóttir

ÁGRIP

Talið er að röskun á stöðugleikakerfi herðablaðs geti framkallað og viðhaldið vanstarfsemi í háls- og brjósthrygg með því að valda þrýstings-, snúnings- og skriðálagi á liðum og liðumbúnaði. Þar sem þessar truflanir eru taldar tengjast hálsverkjum og endurteknum hálsverkjaköstum, felur meðferð vegna hálsverkja hjá sjúkraþjálfara í sér mat á stöðu herðablaðs og starfsemi stöðugleikavöðva herðablaðsins með leiðréttingum þegar við á. Stöðugleikakerfi herðablaðsins hefur ekki verið rannsakað hjá sjúklingum með hálsverki og þess vegna byggjast meðferðarúrræði fyrir þessa sjúklinga á niðurstöðum rannsókna á sjúklingum með axlarverki. Meginmarkmið doktorsverkefnisins var að rannsaka stöðugleikakerfi herðablaðsins hjá sjúklingum með hálsverki og meta hvort að sjúklingar með hálsverki af óþekktum uppruna og sjúklingar með hálsverki eftir hálshnykk hafi mismunandi truflanir. Stöðugleikakerfi herðablaðs var rannsakað með því að athuga hvort til staðar væri annars vegar truflað mynstur á stöðu herðablaðs þegar handleggur er niður með hlið og hinsvegar hreyfimynstri þegar handlegg er lyft. Kveikjumynstur stöðugleikavöðva herðablaðsins; sjalvöðva og síðusagtennings, var einnig athugað þegar handlegg var lyft. Aukamarkmið rannsóknarinnar var mat á stöðu háls- og brjósthryggs hjá þessum sama hóp sjúklinga. Tilgátan var sú að sjúklingar með hálsverki hafi truflaða stöðu á herðablaði, háls- og brjósthrygg ásamt truflun á kveikjumynstri stöðug-leikavöðva herðablaðs. Sjúklingar með hálsverki af óþekktum uppruna hafi öðruvísi truflanir en sjúklingar með hálsverki eftir hálshnykk.

Staða herðablaðs, háls- og brjósthryggjar og kveikjumynstur sjalvöðva og síðusagtennings var metið með þrívíddargreini (Fastrak) og yfirborðsvöðvarafrita hjá sjúklingum með hálsverki af óþekktum uppruna (n=22) og hálsverki eftir bílákeyrslu (n=27). Einkennalaus hópur var valin til samanburðar (n=23). Niðurstöður sýndu breytta stöðu herðablaðs, hálshryggs og truflað kveikjumynstur í stöðugleikavöðvum herðablaðs, hjá sjúklingum með hálsverki. Sjúklingar með hálsverki sýndu marktækt minnkaðan aftursnúning hægra viðbeins þegar handleggur var niður með hlið auk þess sem sjúklingar með hálsverki eftir bílákeyrslu sýndu minnkaðan uppsnúning vinstra herðablaðs þegar handleggur var niður með hlið miðað við samanburðarhópinn. Mismunur var á uppsnúningi viðbeins og framhalla herðablaðs á vinstri hlið milli sjúklinga með hálsverki af óþekktum uppruna og eftir bílákeyrslu. Niðurstöðurnar sýndu einnig marktæka seinkun á virkni síðusagtennings og minnkað horn milli höfuðkúpu og hálshryggs hjá sjúklingum með hálsverki. Engin munur var á stöðu brjósthryggs milli hópa.

Þessar niðurstöður benda til illa samhæfðrar vöðvavirkni sem minnkar gæði taugavöðvastjórnunar og raskar eðlilegum stöðugleika herðablaðs. Minnkað horn milli höfuðkúpu og hálshryggs hjá sjúklingum með hálsverki bendir til skertrar getu hálshryggs til þungaburðar sem getur meðal annars orsakast af truflaðri vöðvavirkni djúpra hálsbeygjuvöðva. Þessar breytingar á stöðugleikakerfi herðablaðs og stöðu hálshryggjar geta verið mikilvægur þáttur í viðvaranleika og auknum einkennum hjá sjúklingum með hálsverki.

Lykilorð: Hálsverkir, hálshnykkur, staða herðablaðs, stöðugleiki, kveikjumynstur.

ABSTRACT

Clinical reasoning suggests that alteration of the scapular stability system has the potential to create and sustain mechanical dysfunction in the cervical and thoracic spine by inducing compressive, rotational and shear forces to the articular tissues. These disturbances are considered to be an important feature in neck pain and the recurrence of neck pain. Current therapeutic guidelines for patients with cervical spine disorders therefore include analysis and correction of the function of the scapular stability muscles and scapular orientation. The scapular stability system has until now not been investigated in patients with neck pain and due to lack of research in this field, therapeutic guidelines intended to restore normal scapular stability in these patients are based on the results of research on the shoulder. The primary aim of this PhD project was to investigate the scapular stability system in patients with cervical spine disorders and to find out if there is a difference in impairments between individuals diagnosed with insidious onset neck pain (IONP) or whiplash associated disorders (WAD). The scapular stability system was investigated by assessing whether there is a pattern of altered scapular orientation when the arm is resting by the side and during arm elevation. The onset of muscle activation of the scapular stability muscles; trapezius and serratus anterior, when the arm is elevated was also evaluated. The secondary aim was to investigate the alignment of the cervical and thoracic spine in the same cohort. The hypothesis was that patients with cervical spine disorders demonstrate altered orientation of the scapula and altered alignment of the cervical and thoracic spine together with a disturbed onset of muscle activation in the scapular stability muscles. These impairments are based on the diagnosis of IONP and WAD.

A three-dimensional tracking device (Fastrak) and a surface electromyography unit measured scapular orientation, the cervical-thoracic alignment and the onset of muscle activation of the trapezius and serratus anterior in patients with IONP (n=22) and WAD (n=27). A control group was selected for comparison (n=23). The results revealed altered scapular orientation, altered cervical alignment and altered onset of muscle activation in the scapular stability muscles in the symptomatic groups. The symptomatic groups demonstrated a significantly reduced retraction of the right clavicle and the WAD group a reduced left scapular upward rotation with arm by the side, compared to the control group. A different manifestation was revealed on the left side between the two symptomatic groups in clavicular elevation and scapular anterior tilt with arm by the side and during arm elevation. The results revealed a significantly delayed onset of muscle activation in the serratus anterior and a decreased cranial angle in the symptomatic groups. No difference was found in the thoracic alignment between the three groups.

These findings reflect inconsistent or poorly coordinated muscle activation which reduces the quality of neuromuscular performance, thus altering normal stability of the scapula in these patients. The decreased cranial angle may reflect a reduced weight bearing capacity of the cervical spine, which occurs, amongst other things, by altered muscle activity in the deep cervical flexors. These changes in the scapular stability system and the alignment of the cervical spine may be an important mechanism for maintenance, recurrence or exacerbation of symptoms in patients with cervical spine disorders.

Key words: Neck pain, whiplash, scapula orientation, stability, muscle recruitment.

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EMG	electromyography
GH	glenohumeral
IONP	insidious onset neck pain
MTC	mid-thoracic curve
NDI	neck disability index
SENIAM	surface electromyography for the non-invasive assessment of muscles
SH	scapulohumeral
SEU	system electronic unit
TukeyHSD	tukey honest significant difference' method
WAD	whiplash associated disorders

LIST OF ORIGINAL PAPERS

This thesis is based on the following papers:

I. Delayed onset of muscle activation of the serratus anterior in patients with cervical disorders. *Physiotherapy: In review*

II. Altered alignment of the shoulder girdle and cervical spine in patients with insidious onset neck pain and whiplash associated disorders. *Journal of Applied Biomechanics: In press*

III. Altered scapular orientation during arm elevation in patients with insidious onset neck pain and whiplash associated disorder. *J Orthop Sports Phys Ther,* 40(12), 784-791.

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DECLARATION OF CONTRIBUTION

Paper I

Harpa Helgadóttir (HH) and Einar Einarsson (EE) were responsible for designing the study under the guidance of Andrew Karduna (AK). HH recruited and screened participants in the study, and collected the data. EE and the staff at KINE (Hafnarfjördur, Iceland) provided technical assistance and developed the Excel macro onset filter that was used in the study. The data were processed through the filter under the supervision of HH. Sigrún Helga Lund (PhD student in statistics at the University of Iceland) assisted HH with the data analysis. The manuscript was written by HH and edited by EE, AK, Eyþór Kristjánsson, and Halldór Jónsson jr. The final version was approved by all authors.

Papers II and III

HH was responsible for designing the study under the guidance of AK. HH recruited and screened participants in the study and collected the data. Ásmundur Eiríksson (KINE, Hafnarfjörður, Iceland) developed the Fastrak software program that was used in the study. Atli Ágústsson assisted HH in constructing the excel software program that calculated the alignment of the cervical and thoracic spine. The data were processed under the supervision of HH. Sigrún Helga Lund and Kristin Briem assisted HH with the data analysis. The manuscript was written by HH and edited by AK, Sarah Mottram, Eyþór Kristjánsson, and Halldór Jónsson jr. The final version was approved by all authors.

1 INTRODUCTION

1.1 Clinical background and statement of the problem

Biomechanical reasoning indicates that altered activity or poor neuromuscular patterns in the musculature attaching the shoulder girdle to the axial skeleton induces compressive, rotational and shear forces on the cervical and thoracic spine (Behrsin & Maguire, 1986). It is argued that these disturbances, which affect scapular orientation with arms by the sides and during upper limb activities, have the potential to create or sustain symptomatic mechanical dysfunction in the cervical and thoracic spine, as well as in the shoulder girdle complex (Behrsin & Maguire, 1986; Janda, 1994; Jull et al., 2004b; Sahrmann, 2002).

Altered activity in the scapular stability muscles and impairments in scapular orientation are considered to be an important feature in neck pain and the recurrence of neck pain. Current therapeutic guidelines for patients with cervical spine disorders include the analysis and correction of the function of the scapular stability muscles, scapular orientation with arms by the sides and during upper limb activities (Jull, 1997; Jull et al., 2008; Jull et al., 2004b; Mottram, 1997; Mottram et al., 2009b).

The function of the scapular stability muscles and scapular orientation has only sparsely been investigated in patients with cervical spine disorders. Because of limited research in this field, therapeutic guidelines intended to restore normal scapular stability in these patients are based on the results of shoulder studies (Jull et al., 2008). It is thought that similar disturbances may be found in patients with cervical disorders, as in patients with shoulder disorders, but this has not been confirmed.

This is the first research project that investigates the stability system of the scapula in patients with cervical spine disorders, by measuring scapular orientation with arm by the side and during arm elevation; and the onset of muscle activation and the recruitment pattern of the scapular stability muscles when the arm is elevated. The alignment of the cervical and thoracic spine was also measured as it is known to affect scapular stability (Falla et al., 2007b; Finley & Lee, 2003; Kebaetse et al., 1999; Kibler & McMullen, 2003).

1.2 Two groups of neck patients

Two groups of patients were assessed, one with insidious onset neck pain (IONP) and one with neck pain following a motor vehicle accident. Patients with IONP have a history of gradually increasing symptoms often connected to poor posture and degenerative changes due to work overload (Johansson et al., 2003). Patients with neck pain following a motor vehicle accident have a history of diverse symptoms directly connected to the collision. It has been hypothesized that a difference may exist in the impairments of these two groups of patients although opinion is polarized (Elliott et al., 2008; Falla et al., 2004a; Kristjansson & Jonsson, 2002; Nederhand et al., 2002).

The Québeck task force introduced and defined the term "Whiplash Associated Disorders" (WAD) which will be used for patients with neck pain following a motor vehicle accident: *"Whiplash is an acceleration-deceleration mechanism of energy transfer to the neck. It may result from rear end or side-impact motor vehicle collisions, but can also occur during diving or other mishaps. The impact may result in bony or soft-tissue injuries (whiplash injuries), which in turn may lead to a variety of clinical manifestations (Whiplash-Associated Disorders)"* (Spitzer et al., 1995).

The Québeck task force published a five grade classification of patients with WAD based on a combination of signs and symptoms (Spitzer et al., 1995). Patients diagnosed with WAD grade II participated in this study (Table 1). WAD grade II is described as neck complaint of pain, stiffness, or tenderness and musculoskeletal signs which include decreased range of motion and point tenderness (Spitzer et al., 1995).

Table 1. Québeck Clinical Classification of WAD

Grade	Clinical presentation
0	No complaint about the neck No physical sign(s)
I	Neck complaint of pain, stiffness, or tenderness only No physical sign(s)
II	Neck complaint and musculoskeletal sign(s)*
III	Neck complaint and neurological sign(s)+
IV	Neck complaint and fracture or dislocation

* Musculoskeletal signs include decreased range of motion and point tenderness.
+ Neurological signs include decreased or absent deep tendon reflexes, weakness, and sensory deficits.
Symptoms and disorders that can be manifest in all grades include deafness, dizziness, tinnitus, headache, memory loss, dysphagia and temporomandibular joint pain.

More severe musculoskeletal symptoms are more often reported in patients with WAD compared to patients with IONP (Falla et al., 2004a; Nederhand et al., 2002) as well as disturbances such as: balance disturbances; vertigo; dizziness; widespread hypersensitivity; concentration problems; memory loss; and psychological problems following the accident (Dumas et al., 2001; Field et al., 2008; Scott et al., 2005).

1.3 Scapular stability system

Optimal function of the scapular stability system includes the ability to maintain normal orientation of the scapula with the arms by the sides (scapular resting position) and during all activities of the upper limb. The muscular system is primarily responsible for scapular orientation as the sternoclavicular joint is the only bony-ligament attachment of the shoulder girdle to the trunk (Mottram, 1997). The proximal end of the clavicle attaches to the manubrium sternum, and the cartilage of the first rib through the sternoclavicular joint, a saddle-shaped synovial joint with three degrees of freedom. The distal end of the clavicle attaches to the acromion through the acromioclavicular joint, a plane synovial joint, also with three degrees of freedom. These joints depend on ligaments for strength and a disc that adds strength to the joint and prevents displacement (Magee, 1987; Williams & Warwick, 1980).

All muscles that are attached to the shoulder girdle contribute to its stability, but to different degrees. Comerford and Mottram (2001) classify the function of the muscles by using the concepts of local and global muscle systems and stability and mobility muscles. The characteristics of the local and global muscle systems are based on Bergmark's (1989) classification of the trunk muscles where the local muscle system increases the segmental stiffness, decreases excessive inter-segmental motion and maintains muscle control during low load task and activities. Movement and the control of high physiological loads are produced by the global muscle system (Bergmark, 1989). Comerford and Mottram (2010b) consider that the local and global muscle systems are both responsible for functional stability and must integrate together for efficient normal function. Their classification of the stability and mobility muscles is based on the work of Rood, in Goff (1972), Janda (1996) and Sahrmann (2002) where the stability muscles optimally assist postural holding, eccentrically decelerating or resisting momentum. These muscles which have a short moment arm and work over one joint, demonstrate a tendency for inhibition, to gain excessive flexibility, laxity and weakness in the presence of dysfunction. The mobility muscles optimally assist rapid, accelerated movement and produce high force or power. These muscles, which work over two or more joints demonstrate a tendency for over activity, loss of extensibility and excessive stiffness in the presence of dysfunction (Comerford & Mottram, 2010b; Goff, 1972; Janda, 1996; Sahrmann, 2002). Comerford and Mottram (2010a) emphasize that the global muscles may have a primary stability or mobility role and consider the trapezius to be a local and global stability muscle of the scapula but the serratus anterior a global stability muscle of the scapula. However, the levator scapulae, rhomboids and pectoralis minor are all considered to be global mobility muscles with a tertiary stability function at the scapula (Comerford & Mottram, 2010a; Mottram, 1997).

Potential mechanisms that can alter function of the scapular stability system, reflected by altered scapular orientation, include pain, tightness in the soft tissues, imbalances in muscle activity or strength, muscle fatigue and the cervical and thoracic curves (Kebaetse et al., 1999; Michener et al., 2003; Sahrmann, 2002).

1.3.1 Scapular orientation with arms by the sides

1.3.1.1 Normal orientation

Scapular orientation with arms by the sides varies considerably between individuals within the general population. In general, the clavicles are symmetrical, elevated approximately 6 degrees and retracted approximately 20 degrees at the sternoclavicular joint (Ludewig et al., 2009). The scapula sits between the second and the seventh rib on the posterior thorax (Williams & Warwick R, 1980), approximately 8 cm lateral to the thoracic spinous processes (Sobush et al., 1996). The optimum orientation of the scapula with the arms by the sides has been described as the mid position of the scapula between the individual available range of upward and downward rotation, external and internal rotation and posterior and anterior tilt. This has been described as the “scapular neutral position” (Mottram et al., 2009b). A difference in the scapular orientation between the dominant and non-dominant side has been demonstrated, where the distal end of the clavicle on the dominant side is typically less elevated and less retracted compared to the non-dominant side (Sobush et al., 1996).

Optimal orientation of the scapula is maintained by the scapular stability muscles; the trapezius and serratus anterior and requires minimal support from the passive bone-ligament system (Mottram et al., 2009b). Paralysis of these muscles due to injury to the accessory nerve and the long thoracic nerve, illustrates their contribution in maintaining scapular orientation. Trapezius paralysis results in a scapular orientation characterized by a depression of the acromion, protraction and upward rotation of the scapula (Kuhn et al., 1995).

The serratus anterior paralysis results in elevation, medial translation and downward rotation of the scapula (Kuhn et al., 1995).

1.3.1.2 Altered orientation

The presence of neck and shoulder pain is associated with altered activity in the scapular stability muscles (Falla et al., 2007a; Falla et al., 2004a; Ludewig & Cook, 2000; Sterling et al., 2001). Altered activity in the scapular stability muscles and short overactive muscles affect scapular orientation so it typically adopts a protracted and downwardly rotated position where the acromion drops forward and down (Mottram, 1997). In this orientation the scapular glenoid is in an inferior/ anterior direction, which has been termed inferior anterior glenoid (IAG) (Comerford & Mottram, 2010a). This dysfunctional pattern reflects altered activity (inefficiency) in the stability muscles and dominance of the mobility muscles (pectoralis minor, levator scapulae and rhomboids) (Mottram et al., 2009b; Sahrmann, 2002). Individuals with a history of shoulder pain have demonstrated a loss of scapular neutral position characterized by IAG and scapular orientation exercise has been described to address this dysfunction (Mottram et al., 2009a).

1.3.2 Scapular orientation during arm elevation

1.3.2.1 Normal orientation

Proper alignment of the shoulder girdle with the arms by the sides has for long been emphasized in physical therapy programs for patients with cervical spine disorders (Janda, 1994). However, the ability to orient the scapula during upper limb activities has only recently become a focus of therapeutic intervention in these patients (Jull, 1997; Jull et al., 2008; Jull et al., 2004b; Mottram, 1997; Mottram et al., 2009b). Assessment of scapular orientation includes analyzing scapular orientation during arm elevation. The sagittal and coronal planes are of limited use during functional activities and in comparison, abduction in the plane of the scapula is a more natural action. Scapular orientation is therefore most commonly assessed during arm elevation in the scapular plane (Ludewig et al., 2009).

Setting phase

The beginning of arm elevation where the scapula contributes minimally to the range of motion has been termed the “setting phase” of elevation. This phase, which is related to the setting action of the scapular stability muscles, is highly irregular as it has its own attributes in each individual and may depend on scapular orientation before the arm is elevated (Inman et al., 1996). The scapular stability muscles make small movements in this phase to position the glenoid adequately in relation to the humerus to promote stability and mobility of the glenohumeral joint (Mottram, 1997). The setting phase is considered to be the first 20 degrees of arm elevation in the scapular plane (Crosbie et al., 2008).

Full arm elevation

During full arm elevation the clavicle undergoes on average, around 31 degrees of posterior long-axis rotation, 16 degrees of retraction and 6 degrees of elevation, relative to the thorax. The scapula undergoes around 19 degrees of posterior tilt, 11 degrees of upward rotation and 8 degrees of internal rotation relative to the clavicle. However, relative to the thorax the scapula undergoes around 39 degrees of upward rotation, 21 degree of posterior tilt and 2 degrees of external rotation (Ludewig et al., 2009). The scapular centre of rotation is initially located at the medial root of the scapular spine but gradually migrates in the direction of the acromio-clavicular joint when the arm is fully elevated (Bagg & Forrest, 1988).

Differences between the dominant and non-dominant side, as well as between unilateral and bilateral elevation, have been reported. There is greater upward rotation of the scapula on the non-dominant side compared to the dominant side and greater external rotation of the scapula during unilateral elevation of the arm compared to bilateral elevation. The retraction of the scapula is also greater during unilateral elevation as the scapula approximate each other and the symmetry of trunk movements are maintained during bilateral elevation, thereby limiting scapular retraction (Crosbie et al., 2008).

The thoracic spine interacts synchronously with the humerus and the scapula when the arm is elevated. Side flexion and axial rotation of the thoracic spine are caused by unilateral arm elevation and extension by bilateral arm elevation. Upper thoracic motion slightly deviates towards the side of elevation. The lower thoracic spine flexes contra-laterally to the elevation. The axial rotation of the upper thoracic spine is greater than in the lower thoracic spine. Lumbar spine range of motion is insignificant for all arm movements. There does not appear to be any effect of age, height or weight on the ranges or patterns of motion during arm elevation (Crosbie et al., 2008).

Scapulohumeral rhythm

Scapular upward rotation contributes to roughly one third of arm elevation while two thirds occur in the glenohumeral joint (Crosbie et al., 2008; Ludewig et al., 2009). A large difference exists between individuals in the ratio between scapular upward rotation and glenohumeral motion during arm elevation in all planes (Bagg & Forrest, 1988; Michiels & Grevenstein, 1995). Although a great variability exists the 1:2 ratio is often proposed based on former studies (Bagg & Forrest, 1988; Inman et al., 1996). However, a recent study investigating the scapulohumeral rhythm (SH rhythm) taking into the account the movements of the spine demonstrates a larger ratio compared to former studies. The ratio is largest in the sagittal plane (1:4), smallest in the coronal plane (1:2.85) and transitional in the scapular plane (1:3.26). The dominant side demonstrates higher values than the non-dominant side (Crosbie et al., 2008) .

Although some data suggest that the greatest relative amount of scapular upward rotation occurs between 80 and 140 degrees of arm elevation (Bagg & Forrest, 1988) other data show a gradual regular curvilinear relationship throughout the entire range (Crosbie et al., 2008; Michiels & Grevenstein, 1995). The SH rhythm does not seem to be influenced by speed but decreased upward rotation of the scapula has been reported at 35 to 45 degrees of arm elevation using 3 kg handheld load in healthy individuals (Kon et al., 2008). Other studies have failed to show this difference (Fayad et al., 2006).

Scapular stability muscles

Optimal function of the scapular stability muscles: the trapezius and serratus anterior muscles are important for scapular control and may be influenced by the activity and extensibility of the mobility muscles (pectoralis minor, levator scapulae and rhomboids) which may compromise the muscle balance (Mottram, 1997; Mottram et al., 2009b; Sahrmann, 2002).

Normal function of the scapular stability muscles depends not only on the force production but also on neuromuscular control and recruitment of these muscles that requires a precise co-ordinated activity that occurs at the right moment, creating the right amount of force, maintained for the right length of time. This proper firing pattern and recruitment requires coupling of the upper-, middle- and lower trapezius with the serratus anterior muscle that results in “force couples” which are considered necessary for normal scapular orientation (Inman et al., 1996; Kibler & McMullen, 2003; Mottram, 1997). Appropriate activity of these muscles depends on proprioception which is linked to the sensation of position and movement of the joints, the sensation of force, effort and heaviness associated with the muscular activity; and the perceived timing of muscle contraction (Comerford & Mottram, 2010a; Gandeviaa et al., 1992). Muscle recruitment deficits are manifested by an altered pattern of recruitment or an altered timing (early/ delayed muscle onset). Dysfunction in the local stability system is revealed by failure of the local muscles to recruit prior loading of the joint, creating stiffness in order to stabilize the joint and control segmental motion (Comerford & Mottram, 2010b).

The serratus anterior muscle is the prime upward rotator of the scapula and needed for complete active arm elevation. The muscle also abducts, posteriorly tilts and externally rotates the scapula holding it flat against the thoracic cage during upper limb activities (Ludewig et al., 2009; Sahrmann, 2002). Paralysis of the serratus anterior prevents arm elevation above 120 degrees and the degree of scapular winging also increases when the arm is elevated (Kuhn et al., 1995).

Conflicting opinions exist in the literature about the role of the upper trapezius during arm elevation. It is thought that it elevates the scapula (Ludewig et al., 2009; Sahrmann, 2002; Williams & Warwick, 1980) which is supported by the fact that people with paralysis of the trapezius are unable to shrug the shoulder (Kuhn et al., 1995). However, an investigation of the anatomy and action of the upper trapezius indicates that the muscle has only a minimal role in scapular elevation as only the fibers from the superior nucha line which insert to the lateral third of the clavicle have a downward orientation (Johnson et al., 1994). When these fibers approach the clavicle their orientation is almost horizontal. These fibers are also small in size which limits their capacity to elevate the lateral portion of the shoulder girdle. This part acts on the clavicle and not the scapula and whatever upward action they might have would be wasted in the cervical fascia before the fibers reach the clavicle. The fibers that insert to the scapula are more transversely orientated which indicates that their action is to draw the clavicle, acromion and spine of the scapula backwards or medially, but not upward (Johnson et al., 1994). However, by rotating the clavicle backward about the sternoclavicular joint, the lateral end of the clavicle elevates causing upward rotation of the scapula. This action would be assisted by the lower trapezius fibers that have a transverse orientation in addition to an upward orientation (Johnson et al., 1994). It should be mentioned that the study conducted by Johnson et al. (1994) that primarily questions the role of the upper trapezius in elevating the scapula, only used small number of subjects which may be considered a limitation of the study.

The contribution of the upper trapezius in scapular upward rotation is also not clear. The large bulk of fibers that arises from C7 and T1 lie close to the scapular axis of rotation in the beginning of upward rotation thus having a short lever arm, but once the upward rotation has started, their lever arm becomes longer, generating upward rotation or resisting downward rotation (Comerford & Mottram, 2010a; Johnson et al., 1994). Other authors have recently rejected the idea that the upper trapezius plays a role in scapular upward rotation (Ludewig et al., 2004; Ludewig et al., 2009).

There are concurrent opinions about the role of the middle trapezius and the lower trapezius. The middle trapezius does not act around the scapular axis of rotation but acts directly on the axis, stabilizing the scapula against the upward action of levator scapulae and the lateral action of the serratus anterior, thus providing a stable base to allow the scapular-humeral muscles to generate force (Johnson et al., 1994; Wickham et al., 2010). The lower trapezius externally rotates the scapula, assists with upward rotation and minimally with posterior tilt (Ludewig et al., 1996; Ludewig et al., 2009). The lower trapezius also plays an important role in maintaining the normal path of the scapular axis of rotation through attachments at the spine of the scapula particularly during full arm elevation, preventing excessive elevation of the scapula (Bagg & Forrest, 1988; Kibler & McMullen, 2003) and resisting lateral displacement of the scapula through the action of serratus anterior (Johnson et al., 1994).

Scapular mobility muscles

The levator scapulae and rhomboid muscles adduct, downwardly rotate and elevate the most medial part of the scapula. The levator scapulae also has a tertiary stability function at the scapula by resisting a downward force through the arm e.g. when carrying (Comerford & Mottram, 2010a). Pectoralis minor, the biceps brachii (caput brevis) and the coracobrachialis which attach to the coracoid process, can create a forward pull on the scapula causing anterior tilt and protraction of the scapula along with the pectoralis major (Kibler & McMullen, 2003; Williams & Warwick, 1980). The pectoralis minor also causes downward rotation of the scapula which may affect upward rotation of the scapula during arm elevation (Kibler & McMullen, 2003). The pectoralis minor has a tertiary stability function at the scapula during action such as pushing and punching and on weight bearing activities where the muscle assists in the transfer of weight of the trunk to the upper limbs (Comerford & Mottram, 2010a). Tightness in the posterior capsule of the glenohumeral joint, a short or overactive latissimus dorsi , infraspinatus or teres minor may pull the scapula into excessive abduction during arm elevation (Comerford & Mottram, 2010a; Sahrmann, 2002).

1.3.2.2 Altered orientation

It is suggested that the presence of pain leads to inhibition or delayed activation in the muscles that control joint stability (Hodges & Richardson, 1996). This alters patterns of neuromuscular control and recruitment during functional movement (Sterling et al., 2001). This is supported by reports that an experimental and chronic pain in the neck and shoulder affects the magnitude of variability of task timing, kinematics and muscle activation during repetitive arm movement. The variability in task timing increased in the presence of both experimental and chronic pain compared with non-painful conditions. Experimental pain increased the variability of the starting position of the arm, the arm range of motion, the arm and trunk movement area, and the acceleration of the arm. In the chronic pain condition, the variability of arm and trunk acceleration and electromyography (EMG) activity was decreased compared with healthy controls. These results indicate that pain may alter the magnitude of motor variability, and when acute pain develops into a chronic pain, changes in motor patterns take place (Madeleine et al., 2008).

The presence of pain in the neck area is known to affect the function of the trapezius as a EMG study has demonstrated that injection of hypertonic saline in the upper trapezius causing experimental pain in "healthy subjects" results in reorganization in the coordination of trapezius during shoulder flexion (Falla et al., 2007a). On the painful side decreased activity was demonstrated in the upper trapezius but increased activity in the lower trapezius. However, the upper trapezius on the contralateral side to the pain demonstrated increased activity. These findings demonstrate that pain in the upper trapezius changes the motor control in the upper and lower trapezius not only on the painful side but also on the contralateral side.

Decreased ability to relax on completion of an upper limb task has been reported in the upper trapezius in patients with neck pain (Johnston et al., 2008). However, muscle activity levels of the upper trapezius over the work day have not been shown to increase in service workers with low observed biomechanical exposure, despite high prevalence of shoulder and neck pain (Westgaard et al., 2001). Interestingly, a difference has been reported between patients with IONP and WAD where WAD patients have a tendency of higher and longer muscle activation patterns in upper trapezius during upper limb tasks (Nederhand et al., 2002), and a decreased ability to relax after tasks compared to patients with IONP, reflected by significantly higher muscle activity levels in the upper trapezius (Falla et al., 2004a).

Altered scapular orientation most frequently occurs because of altered activity or poor neuromuscular patterns in the scapular stability muscles as well as altered activity and extensibility of the mobility muscles which compromises the muscle balance (Mottram et al., 2009b; Mottram, 1997; Sahrmann, 2002). It is also known to be associated with increased cervical- and thoracic curves (Kibler & McMullen, 2003) as a slouched position may increase scapular elevation, reduce upward rotation and posterior tilt of the scapula when the arm is elevated (Finley & Lee, 2003; Kebaetse et al., 1999).

Altered scapular orientation during arm elevation is considered to play an important role in patients with shoulder disorders (Kibler et al., 2009; Ludewig & Cook, 2000; Ludewig et al., 2009). Reduced clavicular retraction, scapular upward rotation, scapular posterior tilt and increased clavicular elevation has been reported and linked to decreased activity in the serratus anterior muscle, to imbalances of forces between the upper- and lower parts of the trapezius muscle (Kibler & McMullen, 2003; Ludewig & Cook, 2000; Ludewig et al., 2009; Lukasiewicz et al., 1999; McClure et al., 2006) and to short and overactive scapular mobility muscles (levator scapulae, rhomboids and pectoral muscles) (Mottram, 1997; Sahrmann, 2002). Altered muscle activity has been demonstrated in these patients by EMG in the serratus anterior and the trapezius (Cools et al., 2007a; Cools et al., 2003; Glousman et al., 1988; Kibler, 1998; Kibler & McMullen J, 2003; Ludewig & Cook, 2000; Pink et al., 1993; Scovazzo et al., 1991; Wadsworth & Bullock-Saxton, 1997). These studies highlight serratus anterior as the primary stabiliser of the scapular-thoracic region, functioning in a manner similar to other important stabilisers in the body. The altered activity in the scapular stability muscles is presented as a disorganization of their normal firing pattern which decreases their ability to produce torque and stabilise the scapula (Kibler, 1998; Kibler & McMullen J, 2003). It is considered that the serratus anterior, middle and lower trapezius may be susceptible to inhibition (Cools et al., 2007a; Cools et al., 2003; Kibler, 1998) but upper trapezius tends to be overactive (Kibler, 1998; Kibler & McMullen, 2003; Ludewig & Cook, 2000). Interestingly an increase in muscle activity levels has been demonstrated in the upper- and lower trapezius during arm elevation in the scapular plane in subjects with symptoms of shoulder impingement relative to a group of subjects without symptoms of shoulder impingement (Ludewig & Cook, 2000). However, decreased activity has been demonstrated in the upper trapezius during swimming in competitive swimmers with shoulder pathology compared to swimmers who had normal shoulders (Ruwe et al., 1994). The discrepancy may be explained by different groups of people as well as different upper limb activity but the results still suggest that the upper trapezius may react with either increased or decreased activity in painful situations.

1.4 Scapular stability in patients with cervical spine disorders

Previous studies investigating the shoulder girdle in patients with cervical spine disorders have primarily been directed at the alignment of the shoulder girdle with arms by the sides, measuring the upward and forward displacement of the acromion with reference to the 7th cervical spinous process or by angular measurements using these landmarks. These studies evaluating the protraction/ retraction and elevation/ depression of the shoulder girdle do not take into consideration the alignment of the thoracic cage nor do they measure scapular orientation (Braun, 1991; Paris, 1990; Szeto et al., 2002; Yip et al., 2008). A more protracted position of the shoulder girdle, in association with increased cervical curves, has been reported and correlated to greater levels of disability (Braun, 1991; Paris, 1990; Szeto et al., 2002). An increased forward excursion of the shoulder girdle during prolonged viewing of computer display-devices has also been reported in office workers with neck pain compared to asymptomatic office workers (Szeto et al., 2005b).

A more depressed position of the shoulder girdle has been reported in patients with tension-type headache (Nagasawa et al., 1993). An intermediate lateral projection of an X-ray spinogram was used to determine the position of the shoulder girdle as the lower cervical and upper thoracic spine is generally obscured by the shoulder girdle. The term “low-set shoulder” was used in cases where the first thoracic vertebra (mild cases) and upper third or more of the second thoracic vertebra (severe cases) were clearly visualized. In the controls (n=225) a mild low-set shoulder was observed in 38% (n=86) of the subjects but severe in only 3.8% (n=8). In patients with tension-type headache (n=372) 48% (n=180) had mild low set shoulders and 9.1% (n=34) severe. There was no significant difference in the number of mild or severe low-set shoulders between sexes or age groups (Nagasawa et al., 1993). A relationship has also been observed between depressed shoulder girdles and thoracic outlet symptoms, where the reported symptoms, which were considered consequences of the depressed alignment of the shoulder girdle, were aggravated by scapular downward traction and relieved by scapular elevation (Swift & Nichols, 1984).

Scapular orientation during arm elevation has not been investigated in patients with neck pain and neither has the coordination of the scapular stability muscles. Altered muscle activity has been reported in the cervical flexors and the upper trapezius in patients with neck pain (Falla et al., 2004b; Falla & Farina, 2005; Jull et al., 2004a; Jull et al., 2004b; Szeto et al., 2005a), but disturbances in the middle trapezius, lower trapezius and the serratus anterior have not been investigated in these patients.

Interestingly, a significant decrease in shoulder proprioception has been reported in patients with WAD compared to healthy controls. Both groups underwent a shoulder proprioception test involving active ipsilateral arm position-matching (Sandlund et al., 2006). Altered shoulder proprioception might affect coordination of the scapular stability muscles and scapular orientation in these patients.

This current research study is the first to investigate scapular orientation in patients with cervical spine disorders, which applies the definition of body segments and joint coordinate systems proposed by the Standardization and Terminology Committee of the International Society of Biomechanics. This includes measuring three dimensional orientation of the scapula described by two clavicular rotations: elevation/ depression and protraction/ retraction, and three scapular rotations: upward/ downward rotation, internal/ external rotation and anterior/ posterior tilt (Figure 1) (Karduna et al., 2001; Wu et al., 2005). Scapular orientation was measured with arm by the side and during arm elevation. This is also the first research study that investigates the onset of muscle activation and the recruitment pattern of the scapular stability muscles; the trapezius and the serratus anterior, in patients with cervical spine disorders.

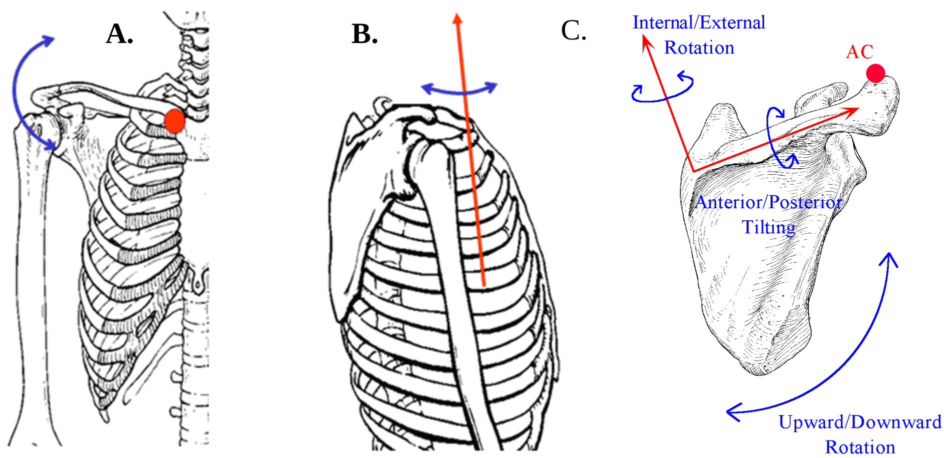


Figure 1. (A) Clavicular elevation/depression, (B) Clavicular protraction/retraction, (C) Scapular rotations.

1.5 Cervical and thoracic alignment

It has been suggested that the optimal alignment for sagittal balance of the cervical spine requires the second cervical vertebra (axis) to be in vertical alignment with the seventh cervical vertebrae (vertebra prominence) and the first cervical vertebra (atlas) with the first thoracic vertebra (Panjabi et al., 2001). Normal values for the cervical lordosis have also been presented by a circular model based on a height/length ratio (Harrison et al., 1996).

Several studies have investigated and linked altered cervical lordosis to symptoms in the neck area and a high incidence of degenerative changes in the cervical spine (Harrison et al., 2000). Altered cervical and thoracic alignment (Kibler & McMullen, 2003) is also known to contribute to altered orientation of the scapula (Falla et al., 2007b; Finley & Lee, 2003; Kebaetse et al., 1999) and is considered to be an important mechanism influencing cervical (Edmondston et al., 2005; Szeto et al., 2005b) and scapular (Kibler & McMullen, 2003; Thigpen et al., 2010) kinematics. Evidence is emerging demonstrating that normal cervical alignment is associated with efficient function of the deep cervical flexors (cervical stability muscles) (Falla et al., 2007b) and the scapular stability muscles (Weon et al., 2009). However, there is conflicting evidence as to whether there is a difference in cervical alignment between patients with neck pain and asymptomatic subjects (Edmondston et al., 2007; Hanten et al., 2000; Harrison et al., 2004; Nagasawa et al., 1993; Yip et al., 2008). An association between prolonged neck pain and a more flexed cervicothoracic posture has been reported in adolescents (Straker et al., 2009) but associations have not been found between changes in the thoracic curve and cervical spine disorders in adults (Szeto et al., 2005a).

2 AIMS

According to the following aims, patients with IONP and WAD were compared to asymptomatic subjects.

- The primary aim was to investigate the scapular stability system in patients with cervical spine disorders.
    - First, by assessing whether there is a pattern of altered scapular orientation when the arm is resting by the side and during arm elevation.
    - Secondly, by assessing the onset of muscle activation of the scapular stability muscles when the arm is elevated.
    - Thirdly, to determine whether a different manifestation is found between patients with IONP and WAD.
- The secondary aim was to investigate the alignment of the cervical and thoracic spine in the same cohort.

The hypotheses tested in this thesis were:

- Patients with cervical spine disorders demonstrate:
    - Alterations in the scapular stability system revealed by altered orientation of the scapula and altered onset of muscle activation in the scapular stability muscles.
    - Altered cervical and thoracic alignment compared to asymptomatic subjects.
- A different manifestation is found between patients with IONP and WAD.

3 MATERIAL AND METHODS

3.1 Study design

This was a clinical measurement, cross-sectional, three group comparison. The scapular orientation, the onset of muscle activation of the scapular stability muscles as well as the alignment of the cervical and the thoracic spine was investigated in two groups of patients with cervical spine disorders and compared with baseline measurements of healthy controls. Both sides were measured to observe whether a different pattern existed between the dominant and the non-dominant side. The research was approved by the Bioethics Committee of Landspitali University Hospital and was conducted at the Research Centre of Movement Science at the Department of Physiotherapy, University of Iceland.

3.2 Subjects

Twenty-two subjects with IONP (20 women and 2 men) and twenty-seven subjects with WAD (24 women and 3 men) were recruited at physical therapy clinics on a voluntary basis in Reykjavik municipal area after giving their informed consent. A sample of convenience consisting of twenty-three asymptomatic subjects (18 women and 5 men) served as controls (Table 2). All subjects were right-handed. The subjects in the control group were selected to match the subjects in the symptomatic groups, according to their height, weight, age, gender and physical activity level. Physical activity level was assessed by asking whether the subject engaged in some kind of physical activity on a regular basis (sports, exercises etc.). If the answer was yes the subject was asked what kind of physical activity and how many times per week.

Demographic information (height, weight, age, gender and physical activity level) was collected. Intensity of pain was evaluated with a 10-cm Visual Analogue Scale (VAS) anchored by no pain and pain as bad as it can be. The VAS was used to indicate the minimal, maximal and average intensity of neck pain experienced over the past seven days. Disability was measured by the Neck Disability Index (NDI) (Vernon & Mior, 1991) which is a self report instrument for the assessment of activities of daily living of sufferers of disabling neck pain. The index is considered to be a condition-specific disability rating instrument, sensitive to the levels of severity of the complaint. It consists of ten items addressing functional activities such as personal care, lifting, reading, work, driving, sleeping and recreational activities as well as pain intensity, concentration, and headache. There are six potential responses for each item ranging from no disability (0) to total disability (5). The overall score (out of 50) is calculated by adding up the responses of each individual item and multiplying the total by two. The total percentage is therefore 100. A higher score indicates greater pain and disability. The interpretation intervals for scoring are as follows: 0 to 8 is no disability, 10 to 28 is mild, 30 to 48 is moderate, 50 to 68 is severe, above 68 is complete (Vernon & Mior, 1991). The posed questionnaire is included in Appendix 1.

Inclusion criteria for the pain groups were: age 18 to 55, a score of at least 10 on the NDI, and neck symptoms of more than six months duration. Symptoms that have lasted more than six months are considered chronic (Hartling et al., 2001). Subjects were allocated to one of two groups: Group 1 consisted of subjects with IONP that had no history of an accident related to the shoulder girdle or neck, such as whiplash injury. Group 2 consisted of subjects diagnosed with a WAD grade II that had no prior history of symptoms in the neck area before the motor vehicle accident. A third group included the controls (Group 3) which were between age 18 to 55 with neither cervical- or shoulder dysfunction. The cervical spine was examined by a physical therapist trained in Manual Therapy, to confirm the presence or absence of cervical segmental joint dysfunction in patients with neck pain and controls, respectively. The glenohumeral joints were examined for pain, restriction, and impingement signs (Magee, 1987). Subjects were excluded if they had any known pathology or impairment in the shoulder joint, history of head injury or spinal fractures, systemic pathology and serious psychological condition.

Table 2. Demographic details of participants.

	control group Women (n=18) Men (n=5)			IONP group Women (n=20) Men (n=2)			WAD group Women (n=24) Men (n=3)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (years)	30	8	21-51	35	8	25-54	33	10	18-50
Height (cm)	172	8	155-188	171	6	158-183	170	5	160-180
Weight (kg)	69	10	56-100	73	16	53-128	71	10	51-92
NDI	0	0	0	29	10	12,-49	38	18,74	12,-80

3.3 Instrumentation and measurements

3.3.1 Equipment

A wireless 12 channel KinePro EMG unit was used to record surface EMG with the sampling frequency of 1600 Hz (Figure 2). The signal was amplified on the measurement unit, then digitized and filtered with a basic high pass filter of 30 Hz. This cut-off frequency was chosen to remove movement artifacts. The data of each surface EMG unit were then transmitted with radio waves to a computer-connected base unit (KINE, Hafnarfjordur, Iceland).

Figure 2. A wireless 12 channel KinePro electromyography unit.

A three-dimensional tracking device (Fastrak) was synchronized with the EMG unit. Three-dimensional data were collected at 40 Hz with the Polhemus three-Space Fastrak device (Polhemus Colchester, VT (Figure 3)). The manufacturer has reported an accuracy of 0.8 mm and 0.15° for this device which consists of a global transmitter, three sensors, and a digitizing stylus, hardwired to a System Electronic Unit (SEU). The SEU determined the relative orientation and position of the digitizer and the sensors through the electromagnetic field emitted by the global transmitter. Information collected by the Fastrak system was sent to a computer with a software system developed by KINE (Hafnarfjordur, Iceland).

Figure 3. Polhemus Three-Space Fastrak device.

3.3.2 Body segments and joint coordinate systems

The current study utilized the definition of body segments and joint coordinate systems for the upper extremity proposed by the Standardization and Terminology Committee of the International Society of Biomechanics. The coordinate systems were defined using the proposed digitized anatomical landmarks. The Euler angle sequences from the standard were applied for all motion descriptions, except for clavicular axial rotation, which was set at zero (Karduna et al., 2005; Karduna et al., 2000; Wu et al., 2005) (see Appendix 2). The digitizing stylus connected to the magnetic tracking device was used to digitize the coordinates of these landmarks. All landmarks were palpable except for the center of glenohumeral rotation (GH). The GH was estimated by moving the humerus through short arcs (<45 degrees) of midrange glenohumeral motion. The GH was defined as the point on the humerus that moved the least with respect to the scapula when the humerus was moved and was calculated using a least-squares algorithm (Biryukova et al., 2000; Harryman et al., 1990). Based on standard matrix transformation methods, the global axes defined by the sensors of the Fastrak device were converted to anatomically defined axes derived from the digitized bony landmarks (Karduna et al., 2001).

3.3.3 Evaluation of cervical alignment

The cervical- and thoracic alignment was measured two-dimensionally. This study utilized coordinates provided by the digitizer to measure cervical alignment and distinguished between the alignment of the upper cervical spine (cranial angle) and the lower cervical spine (cervical angle) (Edmondston et al., 2007; Straker et al., 2009). To evaluate cranial and the cervical angles the corner of the right eye, the tragus of the right ear and the spinous process of the 7th cervical vertebra were digitized. The coordinates of these anatomical landmarks were used to calculate the cranial and the cervical angels illustrated in Figure 4.

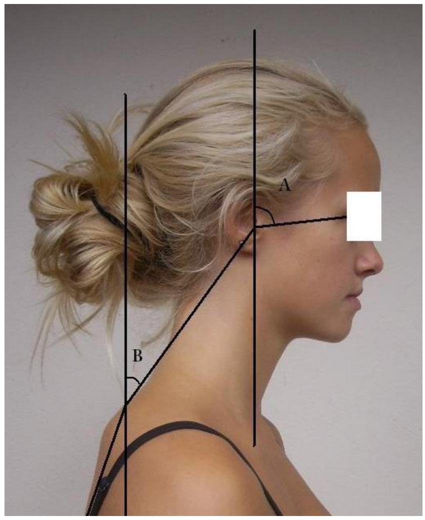


Figure 4. Angle definition: The corner of the right eye (canthus), the tragus of the right ear (tragus) and the spinous process of the 7th cervical vertebra (vertebra prominence) were digitized. The cranial angle (A) is formed by the line of the canthus to tragus with respect to vertical plane. The cervical angle (B) is formed by the line of tragus to C7 with respect to the vertical plane.

3.3.4 Evaluation of the thoracic curve

To measure the mid-thoracic curve (MTC) the digitized coordinates of the spinous processes ranging from T2 to T11 were used. A curve was drawn along the thoracic spinous processes and a straight line directly between the spinous processes T2 and T11 (Figure 5). The longest perpendicular distance (h) between the curve and the straight line was calculated using the coordinates. The MTC was calculated using the formula presented in Figure 5. The line labeled length (l) is the straight line distance between spinous processes T2 and T11. The line labeled height (h) is perpendicular to l and intersects the curve at a digitized point of the mid thoracic process that visually demonstrated the top of the curve (Bullock et al., 2005). This method in evaluating the thoracic curve has shown a good intra and inter-rater reliability with an ICC level of 0,99 (Kristinsson, 2008).

Formula for the MTC.

$$mtc = 4\ x \left[\arctan\left(\frac{2\ x\ h}{l} \right) \right]$$

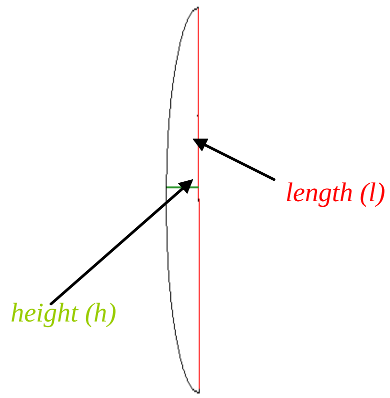


Figure 5. Illustration and calculation measuring the mid-thoracic curve (MTC).

3.3.5 Experimental procedure

The anatomical landmarks were palpated and marked (Karduna et al., 2001). Three Fastrak sensors were attached to each subject. Using adhesive tape, the first sensor was attached to the skin of the sternum (distal to the sternal notch) and the second sensor to the flat part of the acromion. The second sensor evaluated the clavicular and scapular rotations. The third sensor, attached to an elastic strap (Mylatex wrap, 45 cm, Chattanooga group, USA), was placed distally on the posterior aspect of the humerus proximal to the epicondyles. These placements have been used previously (Ludewig & Cook, 2000), and validated for these measurements by comparing surface sensor measurement to sensor fixed to pins drilled directly in the scapula. The average root-mean square error for clavicular and scapular rotations was within 3 degrees between 30 and 120 degrees of arm elevation in the scapular plane (Karduna et al., 2001).

The area of EMG electrode placement was cleaned with alcohol swabs to lower the electrical impedance. The SENIAM recommendations for electrode location were followed for trapezius. Electrodes were placed in line with the muscle fibers over the following locations: upper trapezius, at the midpoint of the lead line between the acromion and the spinous process of C7, in the direction of the line between the acromion and C7; middle trapezius, between the medial border of the scapula and the spine, at the level of T3, in the direction of the line between T5 and the acromion; lower trapezius at 2/3 on the line from the trigonum spinea to T8, in the direction of the line between T8 and the acromion (Hermens et al., 2000; Hermens et al., 2009). The electrodes for the serratus anterior were placed parallel to the muscle fibers right in front of the anterior border of latissimus dorsi at rib levels 6-8 (Basmajian & Blumenstein, 1989). When the electrode placement was completed the signal quality of all the muscles was tested.

Figure 6. Experimental setup. Two electrodes were placed over the serratus anterior. The data from the upper electrode was used in the study.

The height of the chair used in the study was adjusted for each subject and a 15 degree obliquely aligned cushion was used to facilitate neutral spinal curves. The subject was instructed to sit in a comfortable upright position so the sacrum was in contact with the back of the chair with feet placed parallel on the floor (Figure 6). A flat vertical surface was positioned along the lateral aspect of the subjects' arm to act as a guide to maintain a scapular plane, defined as 30 degrees anterior to the frontal plane. The back of the hand gently contacted the vertical surface. With a metronome set at 60 beats per minute each subject performed an arm elevation to a count of three seconds and lowering along the same path to a count of three, in a continuous movement. Before and in-between each elevation and lowering of the arm the subject was instructed to relax for 3 seconds. The following instructions were given to each subject: "focus on a point on the chart in front of you". "Allow your hands, shoulders and arms to assume the position they would normally assume by the sides". The subject was instructed to maintain this position throughout the digitization and the GH estimation procedure. Following this, the raw data from the sensors were converted into anatomically defined rotations (Karduna et al., 2001). Following two practice trials synchronized EMG and kinematic data were simultaneously collected during two elevations of each arm. Both arms were tested, but only one arm at a time. The order of testing was randomized. As both arms were tested, the Fastrak sensors on the scapula and the arm had to be moved to the opposite side.

4 DATA ANALYSIS

4.1 Scapular orientation with arm by the side

Scapular orientation was described using two clavicular rotations (elevation/ depression and retraction/ protraction), and three scapular rotations (upward/ downward rotation, internal/ external rotation and anterior/ posterior tilt), as dependant variables (Figure 1). A software program (KINE, Hafnarfjordur, Iceland) calculated the orientation of each clavicular and scapular rotation.

The software program demonstrated an image of the orientation of the clavicle and scapula during measurements. Visual inspection of the recordings demonstrated a wrong location of the angulus inferior on the scapula during eight measurements, where the y coordinate demonstrated a negative value, instead of a positive value above 20. What appears to have caused the erroneous position of angulus inferior, according to the manufacturer, is that the digitizer was not in the +X hemisphere when the SEU was powered on and therefore didn't know what its origin hemisphere was. As these data had to be excluded in the data analysis only twenty-three subjects were included in the WAD group (20 women and 3 men), twenty-one in the IONP group (19 women and 2 men) and twenty in the control group (17 women and 3 men).

The R version 2.8.0 (The R Foundation for Statistical Computing ISBN 3-099951-07-0) was used for statistical analysis. The age, weight and height between the three groups were compared by analysis of variance (ANOVA) and the distribution of each group was evaluated. For each group, means and 95% confidence intervals were calculated for each of the five dependant variables on each side demonstrating scapular orientation. As the Shapiro test did not reject normal distribution of the data, parametric tests were used for statistical analysis. Initial analyses were performed to test for possible group differences in the dependent measures by using a general linear model one-way ANOVA and the Tukey honest significant difference' method (TukeyHSD) was used to determine the main effects of the ANOVA. The significance level for all tests was set at .05.

4.2 Scapular orientation during arm elevation

Scapular orientation during arm elevation was described using the same clavicular and scapular rotations as described above. A software program (KINE, Hafnarfjordur, Iceland) calculated each clavicular and scapular rotation at 30, 60, 90 and 120 degrees of arm elevation. Interpolation was used to retrieve these data. The data were averaged for the two repetitions of humeral elevation for each participant.

Due to faulty data (described above) only twenty-three subjects were included in the WAD group (20 women and 3 men), twenty-one in the IONP group (19 women and 2 men) and twenty in the control group (17 women and 3 men).

The SPSS version 18 (Statistical Package for the Social Sciences, Version 17, SPSS Inc. 2009, Chicago, IL) was used for statistical analysis. The age, weight and height between the three groups were compared by ANOVA and the distribution of each group was evaluated. For each group, means and standard errors were calculated for the dependant variables bilaterally demonstrating scapular orientation. All data satisfied normality assumptions and parametric tests were subsequently used in all analysis.

To compare scapular orientation among the three groups, a mixed model three way ANOVA was used with one between subject factor (three groups: IONP, WAD and controls) and two within subject factors, side (representing arm dominance) and angle (30, 60, 90, 120 degrees of humeral elevation). A full factorial model was used. In the presence of an interaction, differences were tested at each level of the interacting variable. The significance level for all tests was set at .05.

4.3 Muscle recruitment

The main parameter of interest was the onset of muscle activation when elevation of the arm began. The onset of muscle activation was only measured ipsilaterally. Kinematic and EMG data were synchronized as they were sampled by the computer. The data were imported into Excel (Microsoft, Redmond, WA, USA) where the exact time when elevation of the arm began was displayed in seconds. The EMG data were rectified, imported into Excel in raw text form and processed with an Excel macro onset filter (KINE, Hafnarfjordur, Iceland) with a threshold adjusted at two standard deviations above a resting value (measured when arms where resting by the sides) for more than 50 milliseconds (Hodges & Bui, 1996; Silfies et al., 2009). The muscle onset was determined when the root mean square of each muscle had reached that threshold. The time interval between the moment the arm started to elevate and the time when each muscle had reached the threshold was calculated with a computer program and displayed in seconds (KINE, Hafnarfjordur, Iceland).

The R version 2.8.0 (The R Foundation for Statistical Computing ISBN 3-099951-07-0) was used for statistical analysis. The age, weight and height between the three groups were compared by ANOVA and the distribution of each group was evaluated. For each group, means and standard error were calculated for the four dependant variables on each side. They were onset of muscle activation for three parts of trapezius and serratus anterior on the side of elevation. To meet the criteria for normal distribution the data had to be transformed by first adding the absolute value of the smallest value for each electrode and then raising to the power of .45. As the Shapiro test did not reject normal distribution of the residuals (P =.27), parametric tests were used for statistical analysis.

The onset of muscle activation among the three groups was compared by using general linear model one-way ANOVA and the TukeyHSD was used to determine the main effects of the ANOVA. As the original data were not normally distributed and had to be transformed for parametric analysis, non parametric analyses were also performed to verify the results. The Kruskal-Wallis and Mann-Whitney tests were used to evaluate possible group differences in the dependent measures. The significance level for all tests was set at .05

4.4 Alignment of the cervical and thoracic spine

The main parameter of interest was the alignment of the cervical and thoracic spine with the arms by the sides. Two variables were related to the alignment of the cervical spine; the cranial angle and the cervical angle (Figure 4); and one for the thoracic spine (MTC) (Figure 5). The calculations for the alignment of the cervical and thoracic spine were performed automatically by the use of an excel software program except for the peak of the MTC that was selected manually by visual inspection (Bullock et al., 2005).

The R version 2.8.0 (The R Foundation for Statistical Computing ISBN 3-099951-07-0) was used for statistical analysis. The age, weight and height between the three groups were compared by ANOVA and the distribution of each group was evaluated. For each group, means and 95% confidence intervals were calculated for the three dependant variables demonstrating cervical and thoracic alignment. As the Shapiro test did not reject normal distribution of the data, parametric tests were used for statistical analysis. Initial analyses were performed to test for possible group differences in the dependent measures by using general linear model one-way ANOVA and the TukeyHSD was used to determine the main effects of the ANOVA. The significance level for all tests was set at .05.

4.5 Influence of the level of pain and disability

The scores on the NDI and the VAS were compared between the symptomatic groups by independent t-test. The significance level was set at .05. The Pearson correlation between the dependant variables and the scores on the NDI and the VAS were assessed with symptomatic groups combined and separately for the IONP group and the WAD group. Based on the large number of correlations a threshold of .5 was established as a “meaningful” correlation.

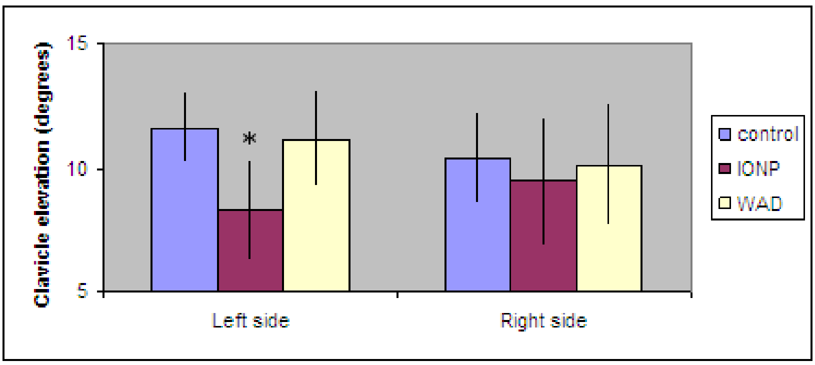
5 RESULTS

5.1 Scapular orientation with arm by the side

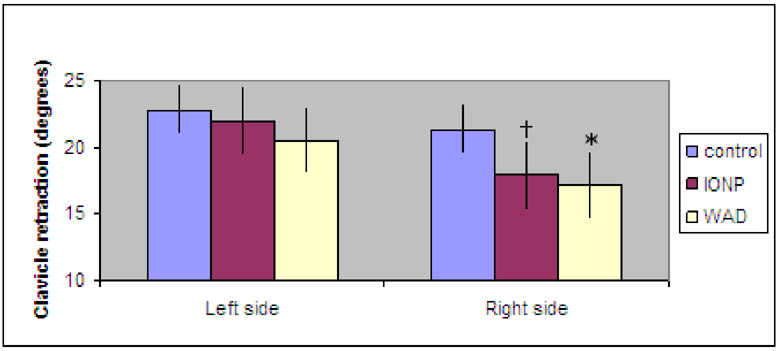
There was no significant difference in age, weight and height between the three groups but a significant difference was found in the level of pain and disability between the symptomatic groups, where the WAD had a significantly higher pain (VAS) (P = .03) and disability level (NDI) (P = .04) compared to the IONP group.

The ANOVA revealed on the left side a significant difference in clavicular elevation (P = .01), scapular tilt (P < .01) and scapular upward rotation (P < .03) between the three groups. Post hoc comparisons revealed a significantly reduced clavicular elevation in the IONP group (P = .02) and a significantly reduced scapular upward rotation in the WAD group (P = .03) compared to the control group. A different manifestation was observed between the symptomatic groups demonstrated by a significantly increased scapular anterior tilt in the WAD group compared to the IONP group (P < .01) and the control group (P = .01).

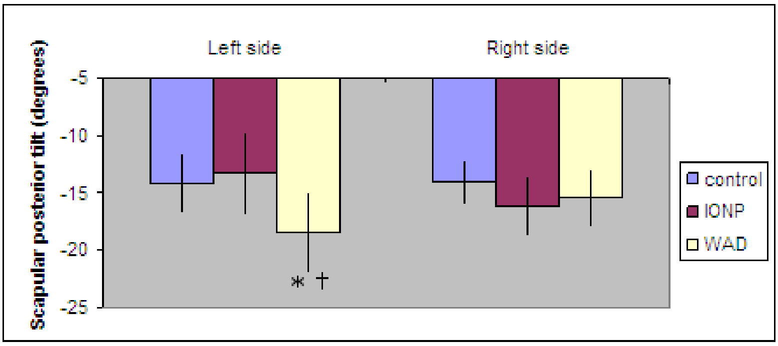
The ANOVA revealed on the right side a significant difference in clavicular retraction between the three groups (P < .03). Post hoc comparison revealed a significantly reduced clavicular retraction in the IONP group (P = .04) and the WAD group (P < .02) compared to the control group. Summary group data are demonstrated in Figure 7.



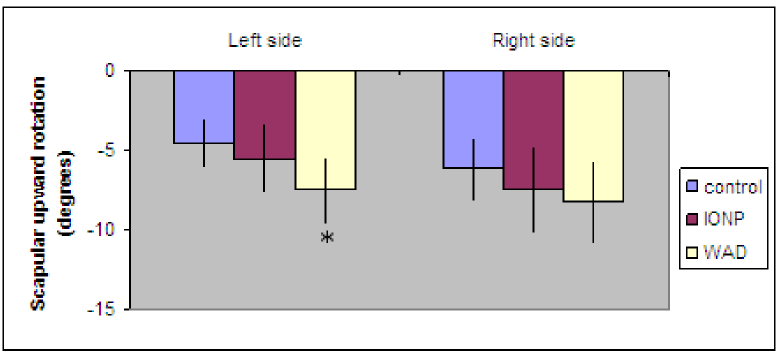
7A. *statistically significant difference between IONP and control (P<0.05)



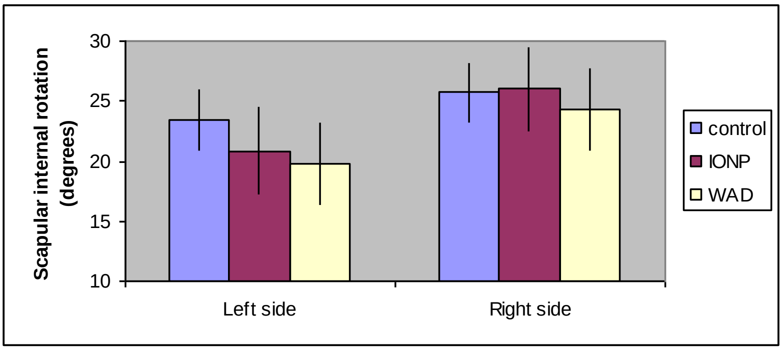
7B. † statistically significant difference between IONP and control (P<0.05) *statistically significant difference between WAD and control (P<0.05)



7C. Scapula is anterior tilted in all groups. Greater value demonstrates increased posterior tilt (+) and a lesser value increased anterior tilt (-). *statistically significant difference between WAD and control (P<0.05). † statistically significant difference between WAD and IONP (P<0.05)



7D. Scapula is downwardly rotated in all groups. Greater value demonstrates upward rotation (+) and a lesser value downward rotation (-). *statistically significant difference between WAD and control (P<0.05)



7E. No significant difference between the groups

Figure 7 (A-E). Mean and the 95% confidence interval of the clavicular elevation (A), clavicular retraction (B), scapular posterior tilt (C), scapular upward rotation (D) and internal rotation (E) in the three groups. IONP=insidious onset neck pain. WAD=whiplash associated disorders.

5.2 Scapular orientation during arm elevation

There was no significant difference in age, weight and height between the three groups but a significant difference was found in the level of pain and disability between the symptomatic groups, where the WAD had a significantly higher pain (VAS) (P = .03) and disability level (NDI) (P = .04) compared to the IONP group.

Based on visual inspection of the graphs the general pattern in the three groups during arm elevation was for the clavicle to elevate and retract and the scapula to upwardly rotate and posteriorly tilt. The scapula also internally rotated until the arm had been elevated up to 90 degrees and then externally rotated until the arm reached 120 degrees.

For clavicular elevation there was a main effect of side [F (1, 62) = 4.437; P < .05] due to a 1.7 degree (0.8) overall greater clavicular elevation of the left side compared to the right side. There was also an angle by group interaction [F (3.357, 104.07) = 3.708; P = .01] and group differences were therefore assessed for each angle. Post hoc comparisons revealed a significantly greater clavicular elevation in the WAD group compared to the control group at the 90 degree angle (P < .05) and compared to both the IONP group (P < .05) and the control group (P < .01) at the 120 degree angle. No significant difference was observed at any angle between the IONP group and the control group (Figure 8).

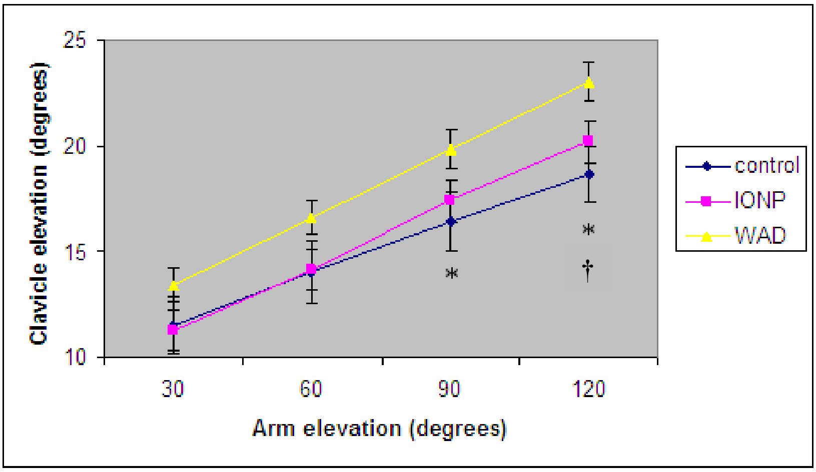


Figure 8. Mean (SEM) clavicular elevation during arm elevation. IONP=insidious onset neck pain, WAD=whiplash associated disorders. *statistically significant difference between WAD and control (*P*<0.05) †statistically significant difference between WAD and IONP (*P*<0.05)

For clavicular retraction there was a significant angle by side interaction, whereby the participants responded differently for sides [F (1.236, 48.366) = 14.875, *P* < .05]. Post hoc comparison revealed significant differences between the right and left sides at the 30 (*P* < .01), 60 (*P* < .01) and 90 degree angles (*P* < .01), where a reduced clavicular retraction was observed on the right side compared to the left side. However, there was no significant difference at 120 degrees (*P* = .2) (Figure 9).There was no significant main effect of group [F (2, 61) = 2.742, *P* = .07]. Despite being a non-significant finding the tendency was explored by post hoc comparison which revealed significant differences between the IONP group and the control group. The IONP group, on average had 3.3 (1.5) degrees less clavicular retraction across angles and sides than the control group (/*P*/ = .04) and the WAD group on average had 2.9 (1.5) degrees less clavicular retraction across angles and sides than the controls (/*P*/ = .06).

For scapular tilt the groups responded differently for sides [F (2, 61) = 4.492, *P* = .01]. Group differences, therefore, were assessed for each side. Post hoc comparisons revealed no significant differences between the symptomatic groups and the control group on either side, but a significant overall difference was observed between the 2 symptomatic groups on the left side (*P* < .05) where the WAD group, on average demonstrated less scapular posterior tilt than the IONP group (Figure 10). Whereas the control group demonstrated no interlimb differences (*P* = .56), the IONP group demonstrated a 3.5 degree greater scapular posterior tilt on the left side ($P < .01$). Conversely, the WAD group scapular posterior tilt was greater by 3.5 degree on the right side, although this did not reach statistical significance ($P = .06$).

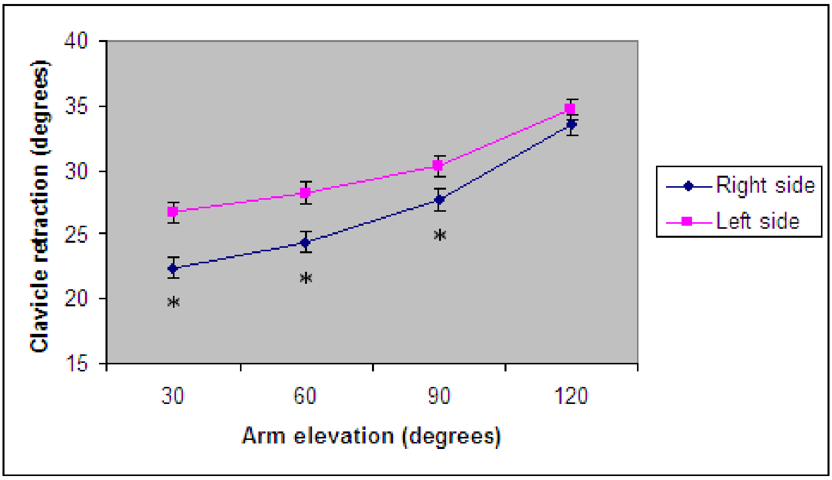


Figure 9. Mean (SEM) clavicular retraction during arm elevation for the right and left sides. *significant interlimb difference (*P*<0.01).

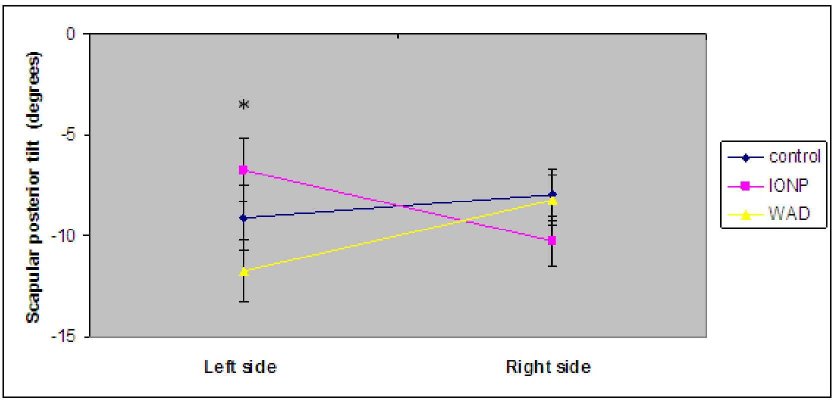
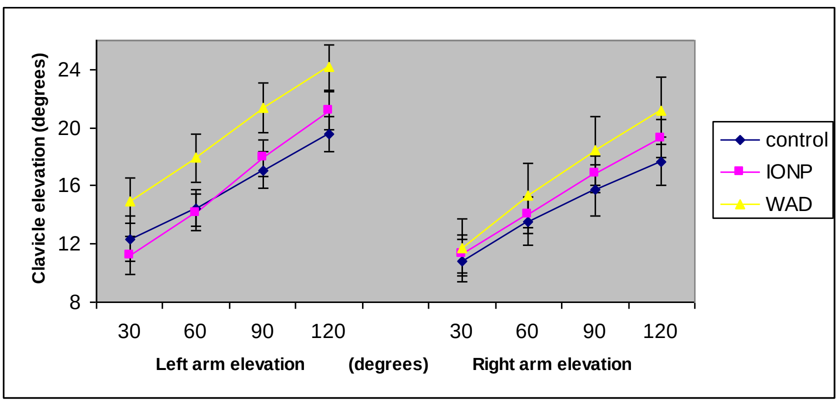


Figure 10. Mean (SEM) posterior tilt of the scapula through arm elevation for the left and right sides. IONP=insidious onset neck pain. WAD= whiplash associated disorders. *statistically significant difference between WAD and IONP (*P* <0.05).

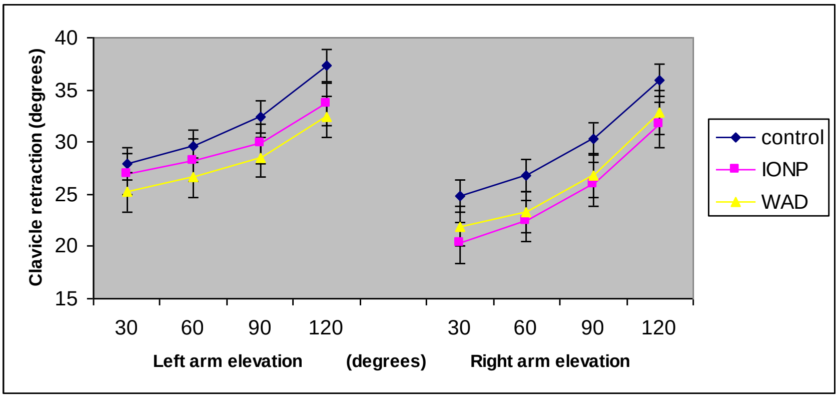
There were no group main effects or interactions for scapular upward rotation and internal rotation. Summary kinematic group data are illustrated in Table 3, Figures 11 and 12.

Table 3. **Summary group data, demonstrating the mean (degrees) and SEM during arm elevation**. Clavicular elevation was significantly increased in the WAD group compared to the control group at the 90 and 120 degree angle but only at the 120 degree angle compared to the IONP group. Clavicular retraction was significantly reduced in all groups on the right side compared to the left side at the 30, 60 and 90 degree angle, but not the 120 degree angle. Scapular tilt was significantly different between the IONP and WAD group on the left side where the WAD group demonstrated reduced posterior tilt and the IONP group increased posterior tilt.

		Left side						Right side					
		control (n=20) mean	SEM	IONP (n=21) mean	SEM	WAD (n=23) mean	SEM	control (n=20) mean	SEM	IONP (n=21) mean	SEM	WAD (n=23) mean	SEM
Clavicle elevation (+)													
	30	12.3	1.6	11.2	1.6	15.0	1.6	10.9	1.4	11.3	2.0	11.8	2.0
	60	14.5	1.2	14.2	1.7	17.9	1.7	13.6	1.6	14.0	2.3	15.3	2.2
	90	17.1	1.3	17.9	1.7	21.4	1.7	15.7	1.7	16.8	2.4	18.4	2.4
	120	19.6	1.2	21.2	1.7	24.1	1.6	17.7	1.7	19.3	2.4	21.2	2.3
Clavicle retraction (+)													
	30	27.9	1.4	27.0	2.0	25.2	1.9	24.8	1.4	20.4	1.9	21.9	1.9
	60	29.6	1.4	28.3	2.0	26.6	1.9	26.8	1.4	22.4	2.0	23.3	1.9
	90	32.5	1.4	29.8	1.9	28.5	1.9	30.3	1.5	26.0	2.1	26.8	2.1
	120	37.3	1.5	33.6	2.1	32.4	2.0	35.9	1.6	31.7	2.2	32.8	2.2
Scapular posterior tilt (+)													
	30	-12.6	1.7	-11.2	2.4	-15.3	2.4	-11.3	1.3	-14.3	1.8	-11.6	1.8
	60	-10.8	1.8	-8.7	2.5	-13.2	2.4	-9.8	1.4	-11.6	2.0	-10.1	1.9
	90	-9.4	1.8	-6.2	2.5	-11.7	2.4	-7.4	1.4	-9.1	2.0	-8.3	1.9
	120	-4.2	1.8	-0.9	2.5	-6.8	2.5	-5.3	1.7	-5.4	2.4	-4.8	2.3
Scapular upward rotation (+)													
	30	0.0	1.4	-0.8	1.9	-0.7	1.9	-2.0	1.6	-2.6	2.2	-3.6	2.1
	60	6.5	1.5	5.3	2.1	5.8	2.0	5.6	1.6	3.4	2.3	2.9	2.2
	90	14.9	1.5	13.3	2.2	14.2	2.1	13.5	1.6	11.0	2.2	10.9	2.2
	120	24.6	1.7	23.3	2.4	24.1	2.3	21.9	1.6	19.2	2.3	20.1	2.3
Scapular internal rotation (+)													
	30	25.7	1.4	23.0	2.0	23.0	1.9	27.7	1.3	28.6	1.8	26.4	1.8
	60	27.2	1.3	24.5	1.8	25.8	1.8	29.1	1.3	30.4	1.8	28.6	1.8
	90	28.6	1.3	25.9	1.8	28.0	1.8	30.2	1.4	31.5	1.9	30.0	1.9
	120	25.4	1.2	23.1	1.7	25.1	1.7	26.7	1.3	28.1	1.8	26.8	1.8

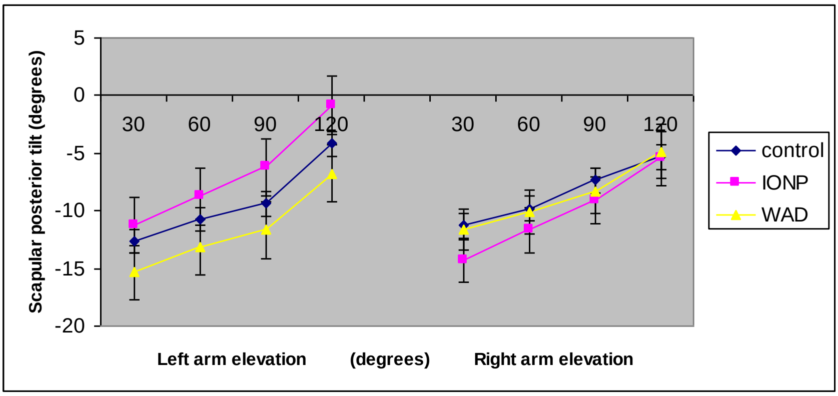


11A.

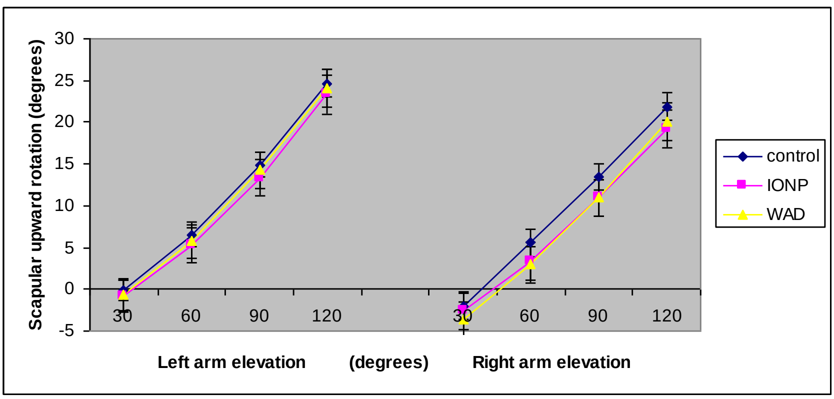


11B.

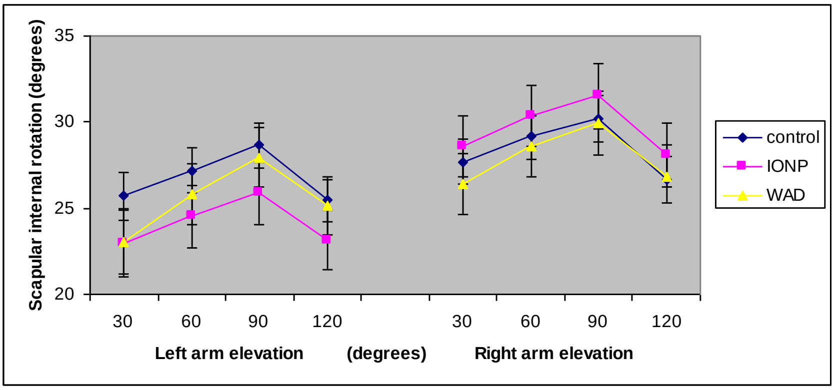
Figure 11 (A-B). Summary kinematic group data, demonstrating the mean (SEM) of the: Clavicular elevation (A) and clavicular retraction (B).



12A.



12B.



12C.

Figure 12 (A-C). Summary kinematic group data, demonstrating the mean (SEM) of the: Scapular posterior tilt (A), scapular upward rotation (B) and scapular internal rotation (C).

5.3 Muscle recruitment

There was no significant difference in age, weight and height between the three groups but a significant difference was found in the level of pain and disability between the symptomatic groups, where the WAD had a significantly higher pain (VAS) (P = .03) and disability level (NDI) (P = .04) compared to the IONP group.

The ANOVA revealed a significant difference in the onset of muscle activation for the right (P < .01) and left (P < .01) serratus anterior between the three groups. Post hoc comparison for the right side revealed a significantly delayed onset of muscle activation in the IONP group (P =.02), and in the WAD group (P < .01) compared to the control group. For the left side there was also a significantly delayed onset of muscle activation in the IONP group (P < .01), and in the WAD group (P = .02) compared to the control group. There was no significant difference found between the two symptomatic groups.

The Kruskal-Wallis test revealed a significant difference between the three groups in the onset of the right serratus anterior (P = .01) and in the left serratus anterior (P < .01). The Mann-Whitney test for the right side revealed a significantly delayed onset of muscle activation of the serratus anterior in the IONP group (P =.04), and in the WAD group (P < .01) compared to the control group. For the left side there was also a significantly delayed onset of muscle activation of the serratus anterior in the IONP group (P < .01), and in the WAD group (P = .02) compared to the control group.

No significant difference was found in the activation of the trapezius between the three groups. Figure 13 demonstrates the mean and standard error of the onset of muscle activation in the three groups.

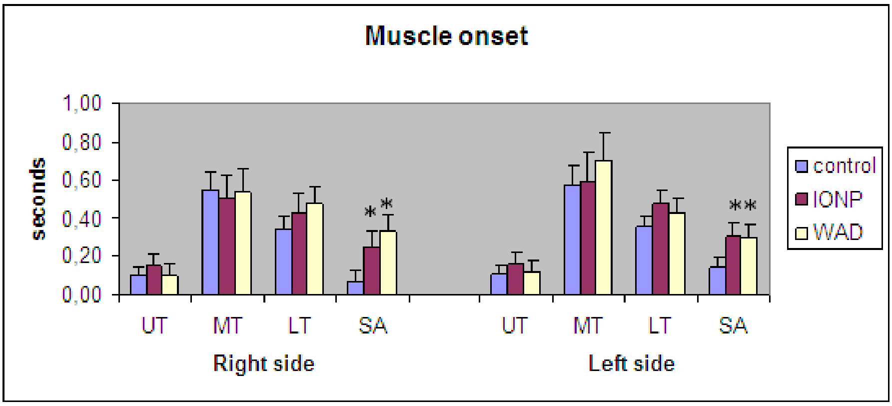


Figure 13. Mean (SEM) of the Upper Trapezius (UT), Middle Trapezius (MT), Lower Trapezius (LT) and the Serratus Anterior (SA) in the control group, IONP group and the WAD group. *statistically significant difference between the symptomatic groups compared to the control group (*P* < .05).

5.4 Alignment of the cervical and thoracic spine

There was no significant difference in age, weight and height between the three groups but a significant difference was found in the level of pain and disability between the symptomatic groups, where the WAD had a significantly higher pain (VAS) ($P = .03$) and disability level (NDI) ($P = .04$) compared to the IONP group.

The ANOVA revealed a significant difference in the cranial angle ($P < .01$) and a tendency was observed in the cervical angle ($P = .07$) between the three groups. Post hoc comparison showed a significantly smaller cranial angle in the IONP group ($P = .02$) and the WAD group ($P = .03$) compared to the control group. Despite being a non-significant finding the tendency for the cervical angle was explored by post hoc comparison. The WAD group tended to have smaller cervical angle than the IONP group ($P = .07$). No difference was found in the mid-thoracic curve ($P = .99$) between the three groups. Summary group data are demonstrated on Figure 14 except for MTC where no visual difference was observed.

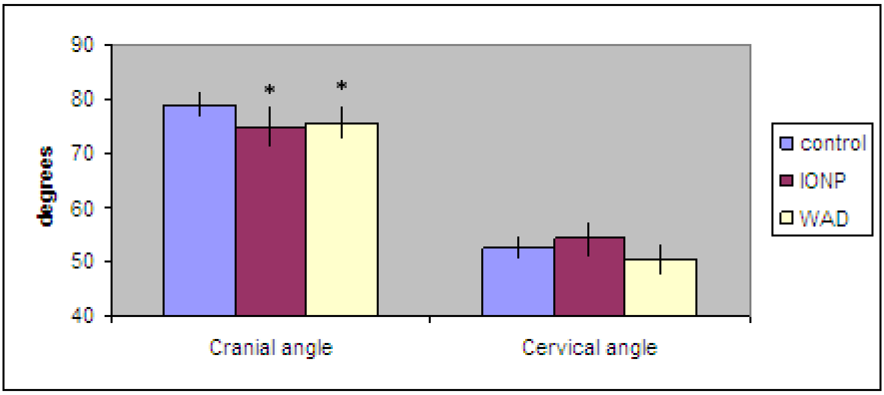


Figure 14. Columns demonstrating the mean and the 95% confidence intervals of the cranial angle and cervical angle in the three groups. *statistically significant difference between the symptomatic groups compared to the control group (*P* < .05).

5.5 Influence of the level of pain and disability

The correlation between the scapular tilt on the left side in the WAD group and the scores on the NDI was .36 and the VAS was .49. The correlation between the other dependant variables and the scores on the NDI and VAS was below .30 (r < .3) when the groups were combined and when they were assessed separately.

6 DISCUSSION

The results of this research revealed altered scapular orientation and altered activity in the scapular stability muscles in patients with cervical spine disorders compared to asymptomatic people. A different manifestation was found between the two symptomatic groups in some measures of scapular orientation suggesting that a difference may exist in the impairments experienced by these two groups of patients. Both symptomatic groups demonstrated reduced cranial angle but no difference was found in the lower cervical or thoracic alignment between the three groups. The hypotheses tested in this research were all supported except for the hypothesis of an altered thoracic alignment in these patients which was refuted.

6.1 Scapular orientation with arm by the side

The symptomatic groups demonstrated a reduced right clavicular retraction and the WAD group a reduced left scapular upward rotation, compared to the control group. On the left side the IONP group showed a reduced clavicular elevation compared to the controls but the WAD group an increased scapular anterior tilt compared to the controls and the IONP group (Figure 7). The different manifestation that was revealed between the two symptomatic groups is an important finding suggesting that a difference may exist in impairments between these groups. A different manifestation has been reported in the alignment of the shoulder girdle between two groups of patients with shoulder problems where patients with instability demonstrated less elevated shoulders and patients with impingement syndrome more elevated shoulders on the symptomatic side compared to the asymptomatic side (Warner et al., 1992). Speculations concerning the side to side differences between the groups will be discussed in the next section.

The reduced clavicular retraction observed on the right side in the symptomatic groups is consistent with previous reports that a reduced clavicular retraction is more common in patients with neck pain compared to asymptomatic subjects (Braun, 1991; Szeto et al., 2002; Yip et al., 2008). This may lead to increased compressive forces in the articulations of the cervical and thoracic spine, inducing tension in the muscles in the area (Harrison et al., 2004; Szeto et al., 2002; Yip et al., 2008). The reduced clavicular retraction may also affect the muscle activity of the trapezius and the serratus anterior as a recent study has shown that this orientation influences the scapular stability muscles during loaded shoulder flexion with changes in EMG activity in the upper and lower trapezius and the serratus anterior muscle (Weon et al., 2009). A reduced clavicular retraction has also been associated with reduced median nerve sliding and paresthesias (Julius et al., 2004).

The reasons for the reduced clavicular retraction may be connected to a decreased ability of the trapezius to retract and maintain the normal position of the scapula. The middle trapezius functions as a scapula retractor and the transverse orientated fibers of the upper and lower trapezius assist this action (Johnson et al., 1994). Reduced extensibility in the pectoralis minor is also important due to its attachment to the medial border of the coracoid process on the scapula but the pectoralis major influence on the scapula may not be so significant while the arms are resting by the sides (Ludewig & Cook, 2000; Sahrmann, 2002).

The interesting results were the reduced left clavicular elevation in the IONP group and the increased anterior tilt and reduced scapular upward rotation of the left scapula in the WAD group. These findings have not been reported previously in patients with neck pain. The increased anterior tilt of the scapula in the WAD group may be associated with forward head posture (Thigpen et al., 2010), short overactive pectoralis minor muscle associated with inefficiency in the serratus anterior and lower trapezius muscles that fail to control the anterior tilt of the scapula (Borstad & Ludewig, 2005; Ludewig & Cook, 2000; Sahrmann, 2002). The reduced clavicular elevation observed in the IONP group is consistent with previous reports in patients with tension-type headache where 48% of patients with tension-type headache had mild low set shoulders and 9.1% severe (see introduction) (Nagasawa et al., 1993). This may reflect inefficiency of the upper trapezius which fails to control normal clavicular elevation against gravity (Mottram et al., 2009b; Sahrmann, 2002) or an imbalance between the upper and lower trapezius muscles where the activity of the lower trapezius may dominate the activity of the upper trapezius (Ludewig et al., 1996).

The reduced scapular upward rotation reflects either long, inefficient upper trapezius and serratus anterior muscles or short overactive levator scapula and rhomboid muscles which would simultaneously elevate and retract the clavicle, and downwardly rotate the scapula (Sahrmann, 2002). The reduced clavicular elevation in the IONP group and the reduced scapular upward rotation in the WAD group is concurrent with Sahrmann's (2002) statement that the most common alignment impairments of the shoulder girdle in patients with shoulder pain is the downwardly rotated alignment of the scapula and the depressed alignment of the clavicle. It should be noted that a reduced clavicular elevation as well as a reduced scapular upward rotation (without increased elevation of the clavicle) maintains a lengthened position of the upper trapezius which induces excessive strain on the muscle and increases muscle tenderness (Azevedo et al., 2008). A lengthened position of the upper trapezius may induce tension to the levator scapula and the rhomboid muscles which may inflict compressive, rotational and shear forces on the cervical and thoracic spine. This may be an important mechanism for maintenance, recurrence or exacerbation of neck pain (Behrsin & Maguire, 1986; Jull, 1997; Jull et al., 2008; Jull et al., 2004b; Mottram et al., 2009b). This corresponds to studies demonstrating reduced neck symptoms when patients with neck pain rotate the neck when the shoulder girdle is passively elevated (Van Dillen et al., 2007).

6.2 Scapular orientation during arm elevation

A significantly reduced clavicular retraction was demonstrated in the symptomatic groups and the control group on the right side compared the left side, at the 30, 60 and 90 degree angle, but not the 120 degree angle. The WAD group demonstrated an increased elevation of the clavicle, compared to the control group and the IONP group. A tendency for a reduced clavicular retraction on the right side was observed in the IONP group compared to the control group. A different finding was demonstrated between the two symptomatic groups in clavicular elevation and left scapular tilt suggesting that a difference may exist between the essences of the impairments between these two groups of patients. The impairments demonstrated in the WAD group are similar to those reported in patients with shoulder problems (Ludewig & Cook, 2000; Ludewig & Reynolds, 2009; Lukasiewicz et al., 1999; McClure et al., 2006).

For clavicular retraction an interaction was demonstrated with side and angle. This finding corresponds to former studies, where clavicular retraction is typically reduced on the dominant side compared to the non-dominant side (Sobush et al., 1996) which may be related to more use of the dominant arm compared to the non-dominant arm. The tendency for a reduced clavicular retraction observed in the IONP group is consistent with previous reports that a protracted resting position of the shoulder girdle is more common in patients with neck pain compared to asymptomatic people (Braun, 1991; Szeto et al., 2002). This alignment has been associated with increased cervical curves and been correlated with increased pain and disability in patients with neck pain (Braun, 1991; Szeto et al., 2002).

It is considered that reduced clavicular retraction may indicate short overactive pectoral muscles and inefficiency in the trapezius muscle to retract the scapula and resist the activity of the serratus anterior. The middle trapezius is the main retractor but the transverse orientated fibers of the upper- and lower trapezius assist the action (Johnson et al., 1994; Wickham et al., 2009). Reduced extensibility and over activity in the pectoralis minor through attachment to the coracoid process and the pectoralis major through attachment to the humerus may influence the retraction of the scapula (Sahrmann, 2002).

A different finding was revealed between the two symptomatic groups in clavicular elevation and left scapular posterior tilt where the WAD group demonstrated increased clavicular elevation and decreased left scapular posterior tilt compared to the IONP group. This finding corresponds to a coupling between clavicular elevation and scapular tilt where increased elevation of the clavicle is coupled with reduced posterior tilt of the scapula (Teece et al., 2008). This disturbance may reflect inefficiency in the serratus anterior as well as the lower trapezius that fails to attain normal posterior tilt and prevent excessive elevation of the scapula (Ludewig & Cook, 2000; Ludewig & Reynolds, 2009; Sahrmann, 2002). The contribution of the middle trapezius may also be important to reduce clavicular elevation as it has been demonstrated that a voluntary reduction of the upper trapezius activity when the arm is elevated, increases mainly the activity of the rhomboids, the middle trapezius and the serratus anterior (Palmerud et al., 1998). The reduced posterior tilt is considered to be associated with a short, overactive pectoralis minor (Sahrmann, 2002). However, increased activity in the levator scapulae and the rhomboid muscles (Ludewig et al., 1996) may explain the increased scapular posterior tilt observed in the IONP group (Sahrmann, 2002).

The increased clavicular elevation demonstrated in the WAD group may be explained by the increased activity of the upper trapezius in patients with WAD compared to patients with IONP (Falla et al., 2004; Fredin et al., 1997; Nederhand et al., 2002) but may also be connected in some way to “neural guarding” as the upper trapezius may contract to reduce compression on the brachial plexus (Coppieters et al., 2001).

The side to side difference in scapular tilt in the IONP group is also an important finding as asymmetric motion patterns are considered to be evidence of altered scapular control (Warner et al., 1992). The reason why the decreased posterior tilt was only demonstrated on the left side (non-dominant) in the WAD group can not be related to increased symptoms on the left side, as the majority of patients had bilateral symptoms in the neck area. However, an increased EMG amplitude has been reported in the left upper trapezius but decreased in the right trapezius, during repetitive upper limb task in patients with cervical disorders compared to asymptomatic people (Falla et al., 2004a). The author of this thesis suggests that the side to side differences may be in some way connected to less usage and less awareness of the non-dominant arm compared to the dominant arm, in association with decreased proprioception around the shoulders in these patients (Sandlund et al., 2006).

These results suggest that an altered dynamic stability of the scapula may be present in patients with cervical spine disorders and demonstrate a difference in the impairments between patients with IONP and WAD. The results suggest that similar disturbances may be found in patients with WAD, as in patients with shoulder disorders (Ludewig & Reynolds, 2009), but imply that patients with IONP may have different impairments than those that have previously been reported.

6.3 Muscle recruitment

Both symptomatic groups demonstrated a significantly delayed onset of muscle activation of the serratus anterior compared to the control group. This is an important result as research on the serratus anterior in patients with shoulder disorders has concluded that this muscle is the main stabiliser of the scapula during upper limb tasks (Kibler & McMullen, 2003). This finding may have implications for scapular stability in these patients as the delayed activity in the serratus anterior may reflect inconsistent or poorly coordinated muscle activation that may reduce the quality of neuromuscular performance (Inman et al., 1996; Kibler & McMullen, 2003; Mottram, 1997; Wadsworth & Bullock-Saxton, 1997).

Aforementioned study conducted by Falla et al. (2007a) demonstrated how experimental pain in healthy subjects' resulted in reorganization of the activity of trapezius during shoulder flexion. On the painful side decreased activity was demonstrated in the upper trapezius but increased activity in the lower trapezius. However, the upper trapezius on the contralateral side to the pain demonstrated increased activity. These findings demonstrate that pain in the upper trapezius changes the motor control in the upper and lower trapezius not only on the painful side but also on the contralateral side (Falla et al., 2007a). Therefore "null effects" may influence the results for trapezius in this current study as some patients may demonstrate a delayed onset which is disintegrated by an early onset in others.

The delayed onset of muscle activation of the serratus anterior in patients with cervical spine disorders corresponds to what has previously been reported in patients with shoulder disorders (Wadsworth & Bullock-Saxton, 1997). The similarity found in both cervical and shoulder disorders indicates that the delayed activity in the serratus anterior may be a general response to a chronic pain condition in the cervical or shoulder area. The fact that no difference was found between the two symptomatic groups does therefore not confirm homogeneity of the symptomatic groups, but rather suggests that the disturbance in muscle activity occurs as a general response to chronic pain condition in the area. This hypothesis is supported by studies reporting bilateral delayed onset of muscle activation in the scapular muscles of patients with unilateral shoulder disorders (Cools et al., 2003; Wadsworth & Bullock-Saxton, 1997).

It has been argued that the presence of pain in the neck area may lead to altered activity in the scapular muscles due to changes in the "feed-forward" response of the nervous system (Falla, 2004) or due to selective reflexive inhibition (Sterling et al., 2001). This altered activity may occur to minimize the activation of the painful muscles (Nederhand et al., 2003) or may reflect effort to compensate for inhibited muscles (Jull et al., 2004a).

6.4 Alignment of the cervical and thoracic spine

The symptomatic groups demonstrated a reduced cranial angle compared to the control group, and a tendency for a difference in the cervical angle was observed between the symptomatic groups. No difference was found in the thoracic alignment between the three groups.

The reduced cranial angle observed in the symptomatic groups (Figure 14) is consistent with previous reports that a forward head posture, a combination of lower cervical flexion, upper cervical extension and protraction of the shoulder girdle, is more common in patients with neck pain compared to asymptomatic subjects (Braun, 1991; Paris, 1990; Szeto et al., 2002; Yip et al., 2008). This may lead to increased compressive forces in the articulations of the cervical and thoracic spine and induce tension in the stability muscles in the area (Harrison et al., 2004; Szeto et al., 2002; Yip et al., 2008).

The differences in the cranial angle may be caused by an increased lordotic alignment of the Atlas, which is the main lordotic segment in the cervical spine (Kristjansson, 2004). The decreased cranial angle and differences in the cervical lordosis may reflect altered muscle activity in the deep cervical flexors observed in patients with neck pain. Interestingly an increased activity has been observed in the sternocleidomastoid and the anterior scalenes with altered motor control strategies of the deep cervical flexors (Falla et al., 2004b; Falla & Farina, 2005; Jull et al., 2004a; Jull et al., 2004b; Szeto et al., 2005a). It has been suggested that the changes in the alignment of the cervical spine, noted in the WAD group is a compensation strategy for the reduced weight bearing capacity of the cervical spine after motor vehicle collisions (Kristjansson, 2004). Altered activity in the cervical flexors, in patients with WAD may develop because of pain and the aforementioned biomechanical changes (Kristjansson, 2004).

6.5 Influence of the level of pain and disability

The fact that the correlation between the dependant variables and the scores on the NDI and the VAS was not higher ($r < 0.5$) suggests that pain or impairment in the neck area may partly be associated with dynamic stability of the scapula that is probably multifactorial in its genesis.

It should be noted that the patients that participated in the research all had a disabling neck pain that had lasted more than 6 months which is considered to be a chronic pain condition and quite serious for that matter. So as long as the symptoms have reached score of at least 10 on the NDI and lasted more than six months, there does not seem to be any augmentation of the disturbances with higher level of pain and disability.

There was a significant difference in the pain and disability level between the symptomatic groups where the WAD group demonstrated higher scores compared to the IONP group. Excluding those WAD participants who had severe disability (NDI > 50) in effort to attune the level of pain and disability in the symptomatic groups, influenced the scapular anterior tilt and the scapular upward rotation in the WAD group but did not affect the different manifestation observed between the symptomatic groups.

6.6 Clinical importance

The results of this study confirm the presence of an altered dynamic stability of the scapula in patients with cervical spine disorders and demonstrate a difference in the impairments between patients with IONP and WAD. The results suggest that similar disturbances may be found in patients with WAD, as in patients with shoulder disorders (Jull et al., 2008) but imply that patients with IONP may have different impairments than those that have previously been reported in patients with shoulder problems.

The reduced clavicular elevation in the IONP and the increased clavicular elevation in the WAD group may reflect differences in the muscle activity level of the upper trapezius in these two groups of patients (Falla et al., 2004a; Nederhand et al., 2002; Nederhand et al., 2003). The combination of reduced clavicular elevation and increased scapular posterior tilt demonstrated in the IONP group on the left side supports recent suggestions that increased clavicular elevation is coupled with increased scapular anterior tilt and vice versa (Teece et al., 2008). The increased scapular posterior tilt in the IONP group may therefore correspond to the decreased clavicular elevation but may also occur due to increased activity in the levator scapulae and the rhomboid muscles, to compensate for inefficient upper trapezius (Ludewig et al., 1996; Sahrmann, 2002).

One of the most important finding is the reduced clavicular elevation and the reduced scapular upward rotation in patients with cervical spine disorders which may reflect long inefficient upper trapezius (Mottram et al., 2009b). These findings highlight the need to explore the relationship between the alignment of the shoulder girdle and altered muscle function. This information may have important implications for clinical practice as current therapeutic guidelines, intended to restore normal stability of the scapula, often include exercises that reduce the upper trapezius activity but increase the activity of the lower trapezius and serratus anterior. These guidelines are based on results of shoulder studies which demonstrate increased clavicular elevation and upper trapezius activity during upper limb tasks (Cools et al., 2007a; Cools et al., 2007b; Cools et al., 2003; Ludewig & Cook, 2000; Ludewig & Reynolds, 2009). The results of this research demonstrate that these therapeutic guidelines, developed for patients with shoulder problems, are in many cases, not appropriate for patients with cervical spine disorders and might further increase the impairments. They also confirm the need to identify disturbances in the scapular alignment in each subject to provide appropriate treatment (Comerford & Mottram, 2010a; Jull et al., 2008; Sahrmann, 2002). Based on these findings it is suggested that guidelines intended to restore normal scapular function in patients with shoulder disorders, as well as the general application of stretches intended to elongate and reduce the activity in the upper trapezius should be reconsidered before they are applied to patients with cervical spine disorders.

The altered stability of the scapula in patients with cervical spine disorders reflected by deficit in the coordinate activity of the scapular stability muscles and altered scapular orientation has the potential to induce aberrant forces on the cervical and thoracic spine, sustaining symptomatic mechanical dysfunction in the area and may be responsible for maintaining periods of recurrence or exacerbation of neck pain (Behrsin & Maguire, 1986; Jull et al., 2008).

6.7 Limitations

Five factors are considered a limitation of the study. First, the fact that the measurements were done in sitting, since a difference in the sitting position between the three groups may have led to differences observed. However, the sitting position was standardized by adjusting the height of the chair for each subject, by using an obliquely aligned cushion, by ensuring that the sacrum was in contact with the back of the chair and by placing the feet parallel on the floor. As the results demonstrate an equivalent alignment of the thoracic spine in all three groups (P = .99) it may be concluded that the sitting position was similar in all three groups and therefore did not affect the results of the study. Secondly, the results present mean values for each group, but a great variability was observed within each group. Therefore these findings may not be generalized to all patients with neck pain. Thirdly, evaluating for restriction in extensibility in the pectoralis minor muscle may have provided information about the relationship of a restriction to altered alignment of the shoulder girdle (Borstad & Ludewig, 2005). Fourthly, during arm elevation, surface sensors may be distorted by skin motion which is however considered minimal within the first 120 degrees of arm elevation (Karduna et al., 2001). Fifthly, there is a possibility of cross talk when surface EMG is used. However, fine wire electrodes measuring only few muscle fibers are not considered a good choice investigating large muscle groups as the scapular stability muscles where a more global evaluation of muscle activity is needed. Careful placement of electrodes in line with orientation of muscle fibers is the best way to avoid crosstalk from nearby muscles; however the possibility of a crosstalk has to be taken into consideration even though the best common practice to avoid it was used.

6.8 Future directions

Further studies are needed to provide information concerning the contribution of the scapular muscles in maintaining normal scapular orientation with arms by the sides and during arm elevation, in patients with cervical spine disorders. Information is needed to find out if the upper trapezius demonstrates proportionally a reduced activity when the arms are by the sides in patients with IONP compared to asymptomatic people, and whether the activity proportionally increases when the arm is elevated or is also low during arm elevation and the contribution of levator scapulae and the rhomboid muscles is increased. Fine wire electrodes, measuring the activity of the levator scapulae and the rhomboid muscles, while surface EMG measure the activity of the trapezius and the serratus anterior would provide further information about the contribution of each muscle. The findings that point to a long inefficient upper trapezius, call for therapeutic approaches that emphasize on a more efficient activity in the muscle in posture and ways to improve the endurance of the muscle in maintaining proper orientation of the scapula along with other parts of the trapezius and the serratus anterior. A more controlled muscle activity and coordination during upper limb activities in the upper trapezius may also be required. Studies are therefore needed to develop exercises which address inefficiency in all parts of the trapezius as well as the serratus anterior. Future studies are also needed to determine whether the association between altered activity in the scapular stability muscles and neck pain is a primary or a secondary phenomenon.

7 CONCLUSIONS

The results of this research demonstrate an altered stability of the scapula in patients with cervical spine disorders which may be an important mechanism in the maintenance, recurrence or exacerbation of symptoms. A different manifestation was observed between the symptomatic groups suggesting that a difference may exist between the essences of the impairments between these two groups of patients. The fact that the correlation between the dependant variables and the scores on the NDI and the VAS was not higher ($r < .5$) suggests that pain or impairment in the neck area may partly be associated with stability of the scapula that is probably multifactorial in its genesis.

7.1 Scapular orientation with arm by the side

The symptomatic groups demonstrated a reduced right clavicular retraction and the WAD group a reduced left scapular upward rotation compared to the control group. There was a significant difference in the scapular orientation between the IONP group and the WAD group. The IONP group revealed a reduced elevation of the left clavicle compared to the control group but the WAD group revealed increased anterior tilt of the left scapula compared to the control group and the IONP group.

7.2 Scapular orientation during arm elevation

The WAD group demonstrated increased elevation of the clavicle compared to the control group and the IONP group. A different finding was demonstrated between the two symptomatic groups in clavicular elevation and left scapular tilt. A significantly reduced clavicular retraction was demonstrated in the symptomatic groups and the control group on the dominant side compared the non-dominant side, at the 30, 60 and 90 degree angle, but not the 120 degree angle. The IONP group demonstrated a tendency for a less retracted position of the right clavicle compared to the control group.

7.3 Muscle recruitment

A significantly delayed onset of muscle activation in the serratus anterior was demonstrated in the symptomatic groups compared to the control group. This disturbance may reflect inconsistent or poorly coordinated muscle activation that diminishes the quality of neuromuscular performance, altering the normal stability of the scapula in these patients. The results revealed no difference between the two symptomatic groups.

7.4 Alignment of the cervical and thoracic spine

The symptomatic groups demonstrated a reduced cranial angle compared to the control group and a tendency was found for a reduced cervical angle in the WAD group compared to the IONP group. The decreased cranial angle and differences in the cervical lordosis may reflect altered muscle activity in the deep cervical flexors observed in patients with neck pain. No difference was found in the thoracic alignment between the three groups.

REFERENCES

Azevedo DC, de Lima Pires T, de Souza Andrade F, & McDonnell MK (2008). Influence of scapular position on the pressure pain threshold of the upper trapezius muscle region. *Eur J Pain*, *12*(2), 226-232.

Bagg SD, & Forrest WJ (1988). The biomechanical analysis of scapular rotation during arm abduction in the scapular plane. *Am J Phys Med Rehabil, 67,* 238-245.

Basmajian JV, & Blumenstein R (1989). *Biofeedback: Principles and practices for clinicians*.Baltimore: Williams and Wilkins.

Behrsin J, & Maguire K (1986). Levator scapulae action during shoulder movement: A possible mechanism for shoulder pain of cervical origin. *Aust J Physiother, 32*(2), 101-106.

Bergmark A (1989). Stability of the lumbar spine. A study in mechanical engineering. *Acta Orthop Scand, 230 (Suppl)*, 20-24.

Biryukova EV, Roby-Brami A, Frolov AA, & Mokhtari M (2000). Kinematics of human arm reconstructed from spatial tracking system recordings. *J Biomech, 33*(8), 985-995.

Borstad JD, & Ludewig PM (2005). The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther, 35*(4), 227-238.

Braun BL (1991). Postural differences between asymptomatic men and women and craniofacial pain patients. *Arch Phys Med Rehabil, 72*, 653-656.

Bullock MP, Foster NE, & Wright CC (2005). Shoulder impingement: The effect of sitting posture on shoulder pain and range of motion. *Man Ther, 10*(1), 28-37.

Comerford MJ, & Mottram SL (2001). Functional stability re-training: Principles and strategies for managing mechanical dysfunction. *Man Ther, 6*(1), 3-14.

Comerford MJ, & Mottram SL (2010a). *Diagnosis of uncontrolled movement, subgroup classification and motor control retraining of the shoulder girdle*. Ludlow, UK: KC International.

Comerford MJ, & Mottram SL (2010b). *Understanding movement & function assessment and retraining of uncontrolled movement: Theory and concepts in a clinical reasoning framework*. Ludlow, UK: KC International.

Cools AM, Declercq GA, Cambier DC, Mahieu NN, & Witvrouw EE (2007a). Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports, 17*(1), 25-33.

Cools AM, Dewitte V, Lanszweert F, Notebaert D, Roets A, Soetens B, et al. (2007b). Rehabilitation of scapular muscle balance: Which exercises to prescribe? *Am J Sports Med, 35*(10), 1744-1751.

Cools AM, Witvrouw EE, Declercq GA, Danneels LA, & Cambier DC (2003). Scapular muscle recruitment patterns: Trapezius muscle latency with and without impingement. *Am J Sports Med, 31*(4), 542-549.

Coppieters MW, Stappaerts KH, Staes FF, & Everaert DG (2001). Shoulder girdle elevation during neurodynamic testing: An assessable sign? *Man Ther, 6*(2), 88-96.

Crosbie J, Kilbreath SL, Hollmann L, & York S (2008). Scapulohumeral rhythm and associated spinal motion. *Clin Biomech, 23*(2), 184-192.

Dumas J-P, Arsenault AB, Boudreau G, Magnoux E, Lepage Y, Bellavance A, et al. (2001). Physical impairments in cervicogenic headache: Traumatic vs. Nontraumatic onset. *Cephalgia, 21*, 884-893.

Edmondston SJ, Chan HY, Ngai GC, Warren ML, Williams JM, Glennon S, et al. (2007). Postural neck pain: An investigation of habitual sitting posture, perception of 'good' posture and cervicothoracic kinaesthesia. *Man Ther, 12*(4), 363-371.

Edmondston SJ, Henne SE, Loh W, & Ostvold E (2005). Influence of cranio-cervical posture on three-dimensional motion of the cervical spine. *Man Ther, 10*(1), 44-51.

Elliott J, Sterling M, Noteboom JT, Darnell R, Galloway G, & Jull G (2008). Fatty infiltrate in the cervical extensor muscles is not a feature of chronic, insidious-onset neck pain. *Clin Radiol, 63*(6), 681-687.

Falla D (2004). Unravelling the complexity of muscle impairment in chronic neck pain. *Man Ther, 9*(3), 125-133.

Falla D, Bilenkij G, & Jull G (2004a). Patients with chronic neck pain demonstrate altered patterns of muscle activation during performance of a functional upper limb task. *Spine, 29*(13), 1436-1440.

Falla D, & Farina D (2005). Muscle fiber conduction velocity of the upper trapezius muscles during dynamic contraction of the upper limb in patients with chronic neck pain. *Pain, 116*, 138-145.

Falla D, Farina D, & Graven-Nielsen T (2007a). Experimental muscle pain results in reorganization of coordination among trapezius muscle subdivisions during repetitive shoulder flexion. *Exp Brain Res, 178*(3), 385-393.

Falla D, Jull G, & Hodges PW (2004b). Feedforward activity of the cervical flexor muscles during voluntary arm movements is delayed in chronic neck pain. *Exp Brain Res, 157*, 43-48.

Falla D, O'Leary S, Fagan A, & Jull G (2007b). Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. *Man Ther, 12*(2), 139-143.

Fayad F, Hoffmann G, Hanneton S, Yazbeck C, Lefevre-Colau MM, Poiraudeau S, et al. (2006). 3-d scapular kinematics during arm elevation: Effect of motion velocity. *Clin Biomech, 21*(9), 932-941.

Field S, Treleaven J, & Jull G (2008). Standing balance: A comparison between idiopathic and whiplash-induced neck pain. *Man Ther, 13*(3), 183-191.

Finley MA, & Lee RY (2003). Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. *Arch Phys Med Rehabil, 84*(April), 563-568.

Fredin Y, Elert J, Britschgi N, Nyberg V, Vaher A, & Gerdle B (1997). A decreased ability to relax between repetitive muscle contractions in patients with chronic symptoms after whiplash trauma of the neck. *J Musculoskeletal Pain, 5*(2), 55-70.

Gandeviaa SC, McCloskeya DI, & Burkea D (1992). Kinaesthetic signals and muscle contraction. *Trends Neurosci*, *15*(2), 62-65.

Glousman R, Jobe FW, Tibone J, Moynes D, Antonelly D, & Perry J (1988). Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *J Bone Joint Surg Am, 70A*(2), 220-226.

Goff B (1972). The application of recent advances in neurophysiology to miss r rodd's concept of neuromuscular facilitation. *Physiotherapy, 58*(2), 409-415.

Hanten WP, Olson SL, Russell JL, Lucio RM, & Campbell AH (2000). Total head excursion and resting head posture: Normal and patient comparisons. *Arch Phys Med Rehabil, 81*(1), 62-66.

Harrison DD, Harrison DE, Janik TJ, Cailliet R, Ferrantelli JR, Haas JW, et al. (2004). Modeling of the sagittal cervical spine as a method to discriminate hypolordosis: Results of elliptical and circular modeling in 72 asymptomatic subjects, 52 acute neck pain subjects, and 70 chronic neck pain subjects. *Spine, 15*(29), 2485-2492.

Harrison DD, Janik TJ, Troyanovich SJ, & Holland B (1996). Comparisons of lordotic cervical spine curvatures to a theoretical ideal model of the static sagittat cervical spine. *Spine, 21*(6), 667-675.

Harrison DE, Harrison DD, Troyanovich SJ, & Harmon S (2000). A normal spinal position: It's time to accept the evidence. *J Manipulative Physiol Ther, 23*(9), 623-644.

Harryman DT 2nd, Sidles JA, Clark JM, McQuade KJ, Gibb TD, & Matsen FA 3rd (1990). Translation of the humeral head on the glenoid with passive glenohumeral motion. *J Bone Joint Surg Am, 72*(9), 1334-1343.

Hartling L, Brison RJ, Ardern C, & Pickett W (2001). Prognostic value of the quebec classification of whiplash-associated disorders. *Spine, 26*(1), 36-41.

Hermens HJ, Freriks B, Disselhorst-Klug C, & Rau G (2000). Development of recommendations for semg sensors and sensor placement procedures. *J Electromyogr Kinesiol, 10*, 361-374.

Hermens HJ, Freriks B, Merletti R, Hägg G, Stegeman D, & Blok J. (2009). Seniam 8: European recommendations for surface electromyography. www.seniam.org.

Hodges PW, & Bui BH (1996). A comparison of computer-based methods for the determination of onset of muscle contraction using electromyography. *Electroencephalogr Clin Neurophysiol., 101*, 511–519.

Hodges PW, & Richardson CA (1996). Inefficient muscular stabilitzation of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. *Spine, 21*(22), 2640-2650.

Inman VT, Saunders M, & Abbott LC (1996). Observation of the function of the shoulder joint. *Clin Orthop Relat Res, 330*(September), 3-12.

Janda V (1994). Muscles and motor control in cervicogenic disorders: Assessment and management. In: Grant R, ed. Physical therapy of the cervical and thoracic spine. New York: Churchill Livingstone.

Janda V (1996). Evaluation of muscle imbalance. In: Liebenson C, ed. Rehabilitation of the spine, Baltimore: Williams & Wilkins.

Johansson H, Windhorst U, Djupsjöbacka M, & Passatore M (2003). Chronic work-related myalgia: Neuromuscular mechanisms behind work-related chronic muscle pain syndromes (Vol. II). Umeå, Sweden: Gävle University Press.

Johnson GM, Bogduk N, Nowitzke A, & House D (1994). Anatomy and action of trapezius muscle. *Clin Biomech, 9*, 44-50.

Johnston V, Jull G, Souvlis T, Jimmieson NL. Neck movement and muscle activity characteristics in female office workers with neck pain. *Spine, 33*(5):555-563.

Julius A, Lees R, Dilley A, & Lynn B (2004). Shoulder posture and median nerve sliding. *BMC Musculoskelet Disord, 5*(23).

Jull G (1997). Management of cervical headache. *Man Ther, 2*(4), 182-190.

Jull G, Kristjansson E, & Dall'Alba P (2004a). Impairment in the cervical flexors: A comparison of whiplash and insidious onset neck pain patients. *Man Ther, 9*(2), 89-94.

Jull G, Sterling M, Falla D, Treleaven J, & O'Leary S (2008). Whiplash headache and neck pain: Research-based directions for physical therapies. Edinburgh, UK: Churchill Livingstone, Elsevier.

Jull GA, Falla D, Treleaven J, Sterling M, & O'Leary S (2004b). A therapeutic exercise approach for cervical disorders. In: Boyling J and Jull G, ed. Grieve's Modern manual therapy: The vertebral column (3 ed.). Edinburgh, UK: Churchill Livingstone, Elsevier science.

Karduna A, Kerner PJ, & Lazarus MD (2005). Contact forces in the subacromial space: Effects of scapular orientation. *J Shoulder Elbow Surg 14,* 393-399.

Karduna A, McClure P, & Michener LA (2000). Scapular kinematics: Effects of altering the euler angle sequence of rotations. *J Biomech, 33*(9), 1063-1068.

Karduna AR, McClure PW, Michener LA, & Sennett B (2001). Dynamic measurements of three-dimensional scapular kinematics: A validation study. *J Biomech Eng, 123*(2), 184-190.

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

Kibler WB (1998). The role of the scapula in athletic shoulder function. *Am J Sports Med, 26*(2), 325-337.

Kibler WB, Ludewig PM, McClure PW, Uhl TL, & Sciascia A (2009). Scapular summit 2009. *J Orthop Sports Phys Ther, 39*(11), A1-A13.

Kibler WB, & McMullen J (2003). Scapular dyskinesis and its relation to shoulder pain. *J Am Acad Orthop Surg, 11*, 142-151.

Kon Y, Nishinaka N, Gamada K, Tsutsui H, & Banks SA (2008). The influence of handheld weight on the scapulohumeral rhythm. *J Shoulder Elbow Surg, 17*(6), 943-946.

Kristinsson BM (2008). Áreyðanleiki og réttmæti mælingar brjóstbakssveigju fólks með þvívíddargreini og samanburður aðferðarinnar við Cobb hornið. Lokaverkefni til B.S. prófs við Háskóla Íslands (BS thesis).

Kristjansson E, & Jonsson H Jr (2002). Is the sagittal configuration of the cervical spine changed in women with chronic whiplash syndrome? A comparative computer-assisted radiographic assessment. *J Manipulative Physiol Ther, 25*(9), 550-555.

Kristjansson EB (2004). *Clinical characteristics of whiplash associated disorder (wad), grades i-ii: Investigation into the stability system of the cervical spine.*, University of Iceland, Reykjavík. PhD Thesis.

Kuhn JE, Plancher KD, & Hawkins RJ (1995). Scapular winging. *J Am Acad Orthop Surg, 3*, 319-325.

Ludewig PM, Behrens SA, Meyer SM, Spoden SM, & LA, W. (2004). Three-dimensional clavicular motion during arm elevation: Reliability and descriptive data. *J Orthop Sports Phys Ther, 34*(3), 140-149.

Ludewig PM, & Cook TM (2000). Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther, 80*(3), 276-291.

Ludewig PM, Cook TM, & Nawoczenski DA (1996). Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *J Orthop Sports Phys Ther*, *24*(2), 57-65.

Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, & LaPrade RF (2009). Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Joint Surg Am, 91*(2), 378-389.

Ludewig PM, & Reynolds JF (2009). The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther, 39*(2), 90-104.

Lukasiewicz AC, MCClure P, Michener L, Pratt N, & Senett B (1999). Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther, 29*(10), 574-586.

Madeleine P, Mathiassen SE, & Arendt-Nielsen L (2008). Changes in the degree of motor variability associated with experimental and chronic neck-shoulder pain during a standardised repetitive arm movement. *Exp Brain Res, 185*(4), 689-698.

Magee DJ (1987). *Orthopedic physical assessment*. Philadelphia, PA: WB Saunders company.

McClure PW, Michener LA, & Karduna AR (2006). Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther*, *86*(8), 1075-1090.

Michener LA, McClure PW, & Karduna AR (2003). Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech, 18*(5), 369-379.

Michiels I, & Grevenstein J (1995). Kinematics of shoulder abduction in the scapular plane: On the influence of abduction velocity and external load. *Clin Biomech, 10*, 137-143.

Mottram S, Warner M, Chappell P, Morrissey D, & Stokes M (2009a). Impaired control of scapular rotation during a clinical dissociation test in people with a history of shoulder pain. *Man Ther, 14*(Supplement 1), S20.

Mottram SL (1997). Dynamic stability of the scapula. *Man Ther, 2*(3), 123-131.

Mottram SL, Woledge RC, & Morrissey D (2009b). Motion analysis study of a scapular orientation exercise and subjects' ability to learn the exercise. *Man Ther, 14*(1), 13-18.

Nagasawa A, Sakakibara T, & Takahashi A (1993). Roentgenographic findings of the cervical spine in tension-type headache. *Headache, 33*(2), 90-95.

Nederhand MJ, Hermens HJ, IJzerman MJ, Turk DC, & Zilvold G (2002). Cervical muscle dysfunction in chronic whiplash-associated disorder grade 2: The relevance of the trauma. *Spine, 27*(10), 1056-1061.

Nederhand MJ, Hermens HJ, IJzerman MJ, Turk DC, & Zilvold G (2003). Chronic neck pain disability due to an acute whiplash injury. *Pain, 102*, 63-71.

Palmerud G, Sporrong H, Herberts P, & Kadefors R (1998). Consequences of trapezius relaxation on the distribution of shoulder muscle forces: An electromyographic study. *J Electromyogr Kinesiol, 8*(3), 185-193.

Panjabi MM, Miura T, Cripton PA, Wang JL, Nain AS, & DuBois C (2001). Development of a system for in vitro neck muscle force replication in whole cervical spine experiments. *Spine, 26*(20), 2214-2219.

Paris SV (1990). Cervical symptoms of forward head posture. *Top Geriatr Rehabil, 5*(4), 11-19.

Pink M, Jobe FW, Perry J, Brown A, Scovazzo ML, & Kerrigan J (1993). The painful shoulder during butterfly stroke. An electromyographic and cinematographic analysis of twelve muscles. *Clin Orthop Relat Res, 288*, 60-72.

Ruwe PA, Pink M, Jobe FW, Perry J, & Scovazzo M (1994). The normal and the painful shoulders during the breaststroke. Electromyographic and cinematographic analysis of twelve muscles. *Am J Sports Med, 22*(6), 789-796.

Sahrmann SA (2002). Diagnosis and treatment of movement impairment syndromes. St. Louis: Mosby Inc.

Sandlund J, Djupsjöbacka M, Ryhed B, Hamberg J, & Björklund M (2006). Predictive and discriminative value of shoulder proprioception tests for patients with whiplash-associated disorders. *J Rehabil Med, 38*, 44-49.

Scott D, Jull G, & Sterling M (2005). Widespread sensory hypersensitivity is a feature of chronic whiplash-associated disorder but not chronic idiopathic neck pain. *Clin J Pain, 21*(2), 175-181.

Scovazzo ML, Brown A, Pink M, Jobe FW, & Kerrigan J (1991). The painful shoulder during freestyle swimming. *Am J Sports Med, 19*(6), 577-582.

Silfies SP, Mehta R, Smith SS, & Karduna AR (2009). Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. *Arch Phys Med Rehabil, 90*(7), 1159-1169.

Sobush DC, Simoneau GG, Dietz KE, Levene JA, Grossman RE, & Smith WB (1996). The lennie test for measuring scapular position in healthy young adult females: A reliability and validity study. *J Orthop Sports Phys Ther, 23*(1), 39-50.

Spitzer WO, Skovron ML, Salmi LR, Cassidy JD, Duranceau J, Suissa S, et al. (1995). Scientific monograph of the quebec task force on whiplash-associated disorders: Redefining "Whiplash" and its management. *Spine, 15*(20), 1S-73S.

Sterling M, Jull G, & Wright C (2001). The effect of musculoskeletal pain on motor activity and control. *J Pain, 2*(3), 135-145.

Straker LM, O'Sullivan PB, Smith AJ, & Perry MC (2009). Relationships between prolonged neck/shoulder pain and sitting spinal posture in male and female adolescents. *Man Ther, 14*, 321-329.

Swift TR, & Nichols FT (1984). The droopy shoulder syndrome. *Neurology, 34*(2), 212-215.

Szeto GPY, Straker LM, & O'Sullivan PB (2005a). A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work - 1: Neck and shoulder muscle recruitment patterns. *Man Ther, 10*, 270-280.

Szeto GPY, Straker LM, & O'Sullivan PB (2005b). A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work - 2: Neck and shoulder kinematics. *Man Ther, 10*, 281-291.

Szeto GPY, Straker LM, & Raine S (2002). A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Appl Ergon, 33*, 75-84.

Teece RM, Lunden JB, Lloyd AS, Kaiser AP, Cieminski CJ, & Ludewig PM (2008). Three-dimensional acromioclavicular joint motions during elevation of the arm. *J Orthop Sports Phys Ther, 38*(4), 181-190.

Thigpen CA, Padua DA, Michener LA, Guskiewicz K, Giuliani C, Keener JD, et al. (2010). Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *J Electromyogr Kinesiol, Jan 21. [Epub ahead of print]*.

Van Dillen LR, McDonnell MK, Susco TM, & Sahrmann SA (2007). The immediate effect of passive scapular elevation on symptoms with active neck rotation in patients with neck pain. *Clin J Pain, 23*(8), 641-647.

Vernon H, & Mior S (1991). The neck disability index: A study of reliability and validity. *J Manipulative Physiol Ther, 14*(7), 409-415.

Wadsworth DJS, & Bullock-Saxton JE (1997). Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. *Int J Sports Med, 18*, 618-624.

Warner, J.J., Micheli, L.J., Arslania, L.E. (1992). Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and inpingement syndrome: A study using Moire topographic analysis. *Clin Orthop, 285*,191-199.

Weon JH, Oh JS, Cynn HS, Kim YW, Kwon OY, & Yi CH (2009). Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. *J Bodyw Mov Ther*.

Westgaard RH, Vasseljen O, & Holte A (2001). Trapezius muscle activity as a risk indicator for shoulder and neck pain in female service workers with low biomechanical exposure. *Ergonomics, 44*(3), 339-353.

Wickham J, Pizzari T, Stansfeld K, Burnside A, & Watson L (2010). Quantifying 'normal' shoulder muscle activity during abduction. *J Electromyogr Kinesiol, 20*(2), 212-222.

Williams PL, & Warwick R (1980). Gray's anatomy, 36th edition. Edinburgh: Churchill Livingstone.

Wu G, van der Helm FCT, Veeger HEJ, Makhsous M, Van Roy P, Anglin C, et al. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion - part ii: Shoulder, elbow, wrist and hand. *J Biomech, 38*, 981-992.

Yip CHT, Chiu TTW, & Poon ATK (2008). The relation between head posture and severity and disability of patients with neck pain. *Man Ther, 13,* 148-154.

APPENDIX 1

Númer þátttakanda ________

Ríkjandi hendi__________

Aldur __________

Kyn ___________

Hæð ___________

Þyngd __________

Mat á hreyfistarfsemi herðablaðs hjá einstaklingum með langvarandi einkenni í hálsi og herðum

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Leiðbeinandi: Eyþór Kristjánsson sjúkraþjálfari MT, PhD.

I Grunnupplýsingar

Vinsamlega merktu X við annaðhvort A eða B:

_____A Ég hef haft verki í hálsi og/eða herðum en hef ekki orðið fyrir hálshnykks áverka eftir bílslys

_____B Ég hef haft verki í hálsi og/eða herðum eftir hálshnykksáverka

_____B- ég hafði enga verki í hálsi fyrir hálshnykksáverkann

II Spurningalisti um hálsverki

Vinsamlega merktu við það svar sem lýsir vandamáli þínu best.

Verkur

_____0 Ég hef enga verki sem stendur

_____1 Verkir eru vægir sem stendur

_____2 Verkir eru nokkrir sem stendur

_____3 Verkir er þó nokkrir sem stendur

_____4 Verkir er mjög miklir sem stendur

_____5 Verkir gætu ekki verið verri sem stendur

Hirðing eigin líkama (þvottur, klæðnaður o.fl.)

_____0 Ég sinni eigin þörfum eðlilega án þess að verkir versni

_____1 Ég sinni eigin þörfum eðlilega en það eykur verkina

_____2 Verkirnir versna það mikið er ég sinni eigin þörfum að ég verð að fara mér hægt og varlega

_____3 Ég sinni að mestu eigin þörfum en þarf þó svolitla aðstoð við það

_____4 Ég þarf aðstoð að mestu leyti til að sinna eigin þörfum

_____5 Ég get ekki klæðst eða þvegið mér vegna svo mikilla verkja að ég er mikinn hlutann dagsins í rúminu

Burður

_____0 Ég get lyft upp þungum hlutum án þess að verkir aukist

_____1 Ég get lyft þungum hlutum en verkirnir aukast við það

_____2 Vegna verkja get ég ekki tekið upp þunga hluti af gólfinu en get lyft þeim ef þeir eru vel staðsettir, t.d. á borði

_____3 Vegna verkja get ég ekki lyft þungum hlutum en get lyft léttum og meðalþungum hlutum ef þeir eru staðsettir þægilega

_____4 Ég get eingöngu lyft mjög léttum hlutum

_____5 Ég get hvorki lyft upp hlutum né borið þá

Lestur

_____0 Ég get lesið að vild án verkja í hálsi

_____1 Ég get lesið að vild en finn fyrir verkjum í hálsi

_____2 Ég get lesið að vild en finn fyrir þó nokkrum verkjum í hálsi

_____3 Ég get ekki lesið að vild vegna verkja í hálsi

_____4 Ég get varla lesið vegna mikilla verkja í hálsi

_____5 Ég get ekki lesið neitt vegna verkja í hálsi

Höfuðverkir

_____0 Ég fæ enga höfuðverki

_____1 Ég fæ milda höfuðverki sem koma sjaldan

_____2 Ég fæ mikla höfuðverki sem koma sjaldan

_____3 Ég fæ milda höfuðverki sem koma oft

_____4 Ég fæ mikla höfuðverki sem koma oft

_____5 Ég er nánast alltaf með höfuðverki

Einbeiting

_____0 Ég get einbeitt mér að fullu þegar ég vil, án erfiðleika

_____1 Ég get einbeitt mér að fullu þegar ég vil, með nokkrum erfiðleikum

_____2 Ég á í smá vandræðum með að einbeita mér þegar ég vil

_____3 Ég á í þó nokkrum vandræðum með að einbeita mér þegar ég vil

_____4 Ég á í miklum vandræðum með að einbeita mér þegar ég vil

_____5 Ég get alls ekki einbeitt mér

Vinna

_____0 Ég get unnið vinnu mín án þess að verkir versni

_____1 Ég get unnið vinnu mína, en verkir versna við það

_____2 Ég get unnið hálfa vinnu þrátt fyrir verkina

_____3 Ég get unnið 2-4 klst. þrátt fyrir verkina

_____4 Ég get unnið minna en 2 klst. vegna verkjanna

_____5 Ég get ekkert stundað vinnu vegna verkjanna

Akstur

_____0 Ég get ekið bifreið að vild án þess að verkir versni

_____1 Ég get ekið bifreið að vild en verkir versna við það

_____2 Ég get ekið bifreið í meira en 4 klst. þrátt fyrir verki

_____3 Ég get ekið bifreið í 2-4 klst. þrátt fyrir verki

_____4 Ég get ekið bifreið í minna en 2 klst. vegna verkja

_____5 Ég get ekki ekið bifreið vegna verkja

Svefn

_____0 Ég á í engum vandræðum með svefn

_____1 Svefninn raskast nánast ekkert (minna en 1 klukkustund á nóttu)

_____2 Svefninn raskast svolítið (1-2 klukkustundir á nóttu)

_____3 Svefninn raskast þó nokkuð (2-3 klukkustundir á nóttu)

_____4 Svefninn raskast mikið (3-5 klukkustundir á nóttu)

_____5 Ég ligg andvaka á nóttunni vegna verkja

Félagslíf

_____0 Ég lifi eðlilegu félagslífi án þess að verkir aukist

_____1 Ég lifi eðlilegu félagslífi en verkirnir aukast við það

_____2 Verkirnir koma í veg fyrir mikla hreyfingu, t.d. dans, en að öðru leyti lifi ég eðlilegu félagslífi

_____3 Verkirnir hafa talsverð áhrif á félagslíf mitt og ég fer minna út en áður

_____4 Verkirnir hafa veruleg áhrif á félagslíf mitt og ég fer mun minna út en áður

_____5 Verkirnir koma alveg í veg fyrir allt félagslíf

III Kvarði fyrir hálsverki (verkir síðustu 7 daga)

Merktu við með krossi á línuna, magn verkja þegar þeir eru í hámarki

0 1 2 3 4 5 6 7 8 9 10

Engin verkur mestu mögulegu verkir

Merktu við með krossi á línuna, magn verkja þegar þeir eru í lágmarki

0 1 2 3 4 5 6 7 8 9 10

Engin verkur mestu mögulegu verkir

Merktu við með krossi á línuna, magn verkja að jafnaði

0 1 2 3 4 5 6 7 8 9 10

Engin verkur mestu mögulegu verkir

APPENDIX 2

Digitized anatomical landmarks

Thorax:

C7: Processus spinosus of the 7th cervical vertebra

T8: Processus spinosus of the 8th thoracic vertebra

IJ: Deepest point of Incisura Jugularis (suprasternal notch)

PX: Processus Xiphoideus, most caudal point of the sternum

Clavicle:

SC: Most ventral point on the sternoclavicular joint

AC: Most dorsal point on the acromioclavicular joint

Scapula:

TS: Trigonum Spinae Scapulae, the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine

AI: angulus inferior most caudal point of the scapula

AA: Angulus acromialis most laterodorsal point of the scapula

Humerus:

EL: Most caudal point on lateral epicondyle

EM: Most caudal point on medial epicondyle

The coordinate system

Thorax coordinate system

Ot: The origin coincident with IJ.

Yt: The line connecting the midpoint between PX and T8 and the midpoint between IJ and C7, pointing upward.

Zt: The line perpendicular to the plane formed by

IJ, C7, and the midpoint between PX and T8, pointing to the right.

Xt: The common line perpendicular to the Zt- and

Yt-axis, pointing forwards.

Joint coordinate system and motion of the thorax relative to the

global coordinate system:

e1: The axis coincident with the Zg-axis of the global coordinate system.

Rotation (aGT): flexion (negative) or extension (positive).

e3: The axis fixed to the thorax and coincident with the Yt-axis of the thorax coordinate system.

Rotation (gGT): axial rotation to the left (positive) or to the right (negative).

e2: The common axis perpendicular to e1 and e3, i.e., the rotated Xt-axis of the thorax.

Rotation (bGT): lateral flexion rotation of the thorax, to the right is positive, to the left is negative.

Clavicle coordinate system:

Oc: The origin coincident with SC

Zc: The line connecting SC and AC pointing to AC

Xc: The line perpendicular to Zc and Yt, pointing forward (Yt: the line connecting the midpoint between processus xiphoideus and the midpoint between incisura jugularis and C7, pointing upward.

Yc: The common line perpendicular to the Xc and Zc, pointing upward

<u>Joint coordinate system and motion for the clavicle relative to the thorax:</u>

e1: The axis fixed to the thorax and coincident with the Yt-axis of the thorax.

Rotation: retraction (negative) or protraction (positive).

e2: The axis fixed to the clavicle and coincident with the Zc-axis of the clavicle coordinate system

Rotation: axial rotation of the clavicle: rotation of the top backwards is positive, forward is negative. This rotation will not be evaluated.

e3: The common axis perpendicular to e1 and e3, the rotated Xc axis.

Rotation: elevation (negative) or depression (positive).

<u>Scapula coordinate system</u>

Os: the origin coincident with AA.

Zs: the line connecting TS and AA, pointing to AA.

Xs: the line perpendicular to the plane formed by AI, AA and TS, pointing forward.

Ys: the common line perpendicular to the Xs- and Zs- axis, pointing upward.

Joint coordinate system and motion for the scapula relative to the thorax:

e1: the axis fixed to the thorax and coincident with the Yt-axis of the thorax coordinate system.

Rotation: retraction (negative) or protraction (positive)

e3: the axis fixed to the scapula and coincident with the Zs-axis of the scapular coordinate system (scapular spine).

Rotation: anterior (negative) or posterior (positive) tilt.

e2: the common axis perpendicular to e1 and e3.

Rotation: lateral (negative) or medial (positive) rotation.

Humerus coordinate system

Oh: the origin coincident with GH.

Yh: the line connecting GH and the midpoint of EL and EM pointing to GH

Xh: the line perpendicular to the plane formed by EL, EM, and GH, pointing forward.

Zh: the common line perpendicular ti the Yh- and Zh-axis, pointing to the right.

Joint coordinate system and motion for the humerus relative to the thorax:

e1: the axis fixed to the thorax and coincident with the Yt-axis of the thorax coordinate system.

Rotation: plane of elevation, 0°is abduction, 90°is forward flexion.

e3:axial rotation around the y axis

Rotation: axial rotation, internal- (positive) or external rotation (negative) e2: the axis fixed to the humerus and coincident with the Xh-axis of the humerus coordinate system.

Rotation: elevation (negative)

(Wu, van der Helm et al. 2005).

Paper I.

Delayed onset of muscle activation of the serratus anterior during unilateral arm elevation in patients with cervical disorders

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ABSTRACT

Objectives*:* To investigate whether there is a pattern of altered activity in the trapezius and serratus anterior (SA) in patients with insidious onset neck pain (IONP) and whiplash associated disorder (WAD) compared to asymptomatic people.

Background*:* Altered activity in the axioscapular muscles is considered to be an important feature in patients with cervical disorders. The recruitment of the trapezius and SA during arm elevation has not been investigated in these patients until now.

Design*:* Controlled laboratory study using a cross-sectional design.

Setting: Research Centre of Movement Science at the Department of Physiotherapy, University of Iceland.

Methods: Surface electromyography was used to measure the onset of muscle activation of the upper, middle, and lower trapezius as well as the SA during unilateral arm elevation in patients with IONP (n=22) and WAD (n=27). An asymptomatic group was selected for baseline measurements (n=23).

Results: There were no group main effects or interaction effects for upper, middle and lower trapezius. With no interaction, the main effect for serratus anterior was statistically significant among the groups [F (2,70) = 5.214, p. < .01]. Post hoc comparison revealed a significantly delayed onset of muscle activation in the IONP group ($P < .05$), and in the WAD group ($P < .01$) compared to the asymptomatic group.

Conclusions: This finding may have implications for scapular stability in these patients as the delayed activity in the SA may reflect inconsistent or poorly coordinated muscle activation that may reduce the quality of neuromuscular performance.

Key words: Neck pain, whiplash, onset, scapula, EMG.

INTRODUCTION

Scapular control includes the ability to maintain normal orientation of the scapula with the arms by the side and during all activities of the upper limb. The muscular system is primarily responsible for scapular control as the sternoclavicular joint is the only bony-ligament attachment of the shoulder girdle to the trunk [1]. All muscles that are attached to the shoulder girdle contribute to its stability, but in different degrees [2]. So far the literature has focused on contributions of the trapezius and serratus anterior muscles in maintaining scapular orientation and the activity and extensibility of the pectoralis minor, levator scapulae and rhomboids that may compromise the muscle balance [1-4]. It is considered that normal stability of the scapula requires optimal function of the trapezius and the serratus anterior that depends not only on the force production but also on neuromuscular control and recruitment of the muscles. The precise co-ordinated activity that occurs at the right moment, creating the right amount of force, maintained for the right length of time is considered necessary for normal scapular control [1,2]. The proper firing pattern and recruitment requires coupling of the upper-, middle- and lower trapezius with the serratus anterior muscle that results in “force couples” to stabilize the scapula [1,4,5]. The co-ordination is built on proprioception which is linked to the sensation of position and movement of the joints, the sensation of force, effort and heaviness associated with the muscular activity; and the perceived timing of muscle contraction [2,6]. Muscle recruitment deficits are manifested by an altered pattern of recruitment or an altered timing (early or delayed muscle onset) [2].

Biomechanical reasoning indicates that altered activity in the axioscapular muscles may induce detrimental load on the cervical spine [7-9]. Studies have shown that increased tension in muscle such as the levator scapulae through its attachment to the upper four cervical segments may directly induce compressive, rotational and shear forces on cervical motion segments [7]. Increased tension in the upper trapezius has also the potential to produce compression or tissue distortion through its superior attachment [10]. Altered activity in the axioscapular muscles may therefore create or sustain symptomatic mechanical dysfunction in the cervical spine, and influence the recurrence of neck pain [7-9,11].

Altered activity in the axioscapular muscles is considered to be an important feature in patients with cervical disorders. Current therapeutic guidelines for these patients include analyzes of the function of these muscles followed by appropriate training if a dysfunction is detected [1,9,11,12].

The presence of pain in the neck area has been associated with an altered activity in the trapezius muscle [13]. Electromyography studies in patients with neck pain have reported altered activity in the upper and lower trapezius during upper limb tasks [13,14] but the recruitment properties of the trapezius and function of the serratus anterior has until now not been investigated in these patients.

Due to lack of research in this field, therapeutic guidelines intended to restore normal scapular function in patients with cervical disorder are based on the results of shoulder studies [11]. It is considered that similar disturbances may be found in these patients, as in patients with shoulder disorders, but this has not been confirmed [11].

The aim of this study was to investigate whether there is a pattern of altered activity in the trapezius and serratus anterior during arm elevation in patients with insidious onset neck pain (IONP) and whiplash associated disorder (WAD) compared to asymptomatic subjects. The hypothesis was that patients with cervical disorders demonstrate a pattern of altered activity in these muscles.

METHOD

Participants

This study was approved by the Bioethics Committee of Landspitali University Hospital and all participants signed a consent form. Since a difference may exist in the impairment between patients with IONP and WAD [15-18] this study included two groups of patients: Group1 with IONP and Group 2 with WAD, grade II, following a motor vehicle accident [19] WAD grade II is described as neck complaint of pain, stiffness, or tenderness and musculoskeletal signs which include decreased range of motion and point tenderness [19]. Twenty two patients with IONP (20 women and 2 men) and twenty seven patients with WAD (24 women and 3 men) were recruited at physical therapy clinics on a voluntary basis, in the Reykjavik municipal area. A sample of convenience consisting of twenty three asymptomatic people (18 women and 5 men) served as controls

(Table 1). All subjects were right handed. The majority of those referred were women and the men referred were more frequently excluded because of shoulder problems and because of history of an injury to the upper extremity (especially due to clavicle fractures). Therefore, our symptomatic samples randomly included mostly women. The subjects in the control group were selected to match the subjects in the symptomatic groups, according to their height, weight, age and gender and physical activity level. Physical activity level was assessed by asking whether the subject engaged in some kind of physical activity on regular bases (sports, exercises etc.). If the answer was yes the subject was asked what kind of physical activity and how many times per week. Demographic information (height, weight, age, gender and physical activity level) was collected. Disability was measured by the Neck Disability Index (NDI), which is a self reporting instrument for the assessment of activities of daily living of sufferers of disabling neck pain [20]. Pain intensity was evaluated with a 10-cm Visual Analogue Scale (VAS) anchored by no pain and pain as bad as it can be. The VAS was used to indicate the average intensity of neck pain experienced over the past seven days.

Inclusion criteria for the pain groups were: age 18 to 55, a score of at least 10 on the NDI and neck symptoms that had lasted more than six months. Score below 10 (of 100) on the NDI are scored as 'no disability' [20] and symptoms that have lasted more than six months are considered chronic [21]. Participants were allocated to one of the two following groups: Group 1 consisted of patients with IONP with no history of any accident or whiplash injury. Group 2 consisted of patients diagnosed with a WAD that had no prior history of symptoms in the neck area before the motor vehicle accident. Group 3 included the controls, age range 18 to 55, with neither cervical or shoulder dysfunction. The cervical spine was examined by a physical therapist trained in Manual Therapy, to confirm the presence or absence of cervical segmental joint dysfunction in patients with neck pain and controls, respectively. The glenohumeral joints were examined for pain, restriction, and impingement signs [22]. Exclusion criteria for all the groups were: any known pathology or impairment in the shoulder joint, history of head injury or spinal fractures, systemic pathology and serious psychological condition.

Equipment

EMG data was collected using four sensors from Kine, Hafnarfjordur, Iceland. The signal is pre-amplified using amplifier with input impedance of 10 Giga Ohm and a common mode rejection ratio of 110 dB. The signal is sampled at 1600 Hz, after going through a band pass filter with a cut-of frequency 16 Hz and 482 Hz (3dB). The signal is digitized at approximately 3 mm from the skin, and transmitted wirelessly in digital form (with crc ensuring corruption free transmission). After reception, the signal is filtered using high pass filtering with cut-off frequency at 30 Hz to remove movement artifacts. Attached to the sensors were disposable disc shaped (10 mm Ø) triode surface electrodes (Ag-AgCl) with an interelectrode distance of 20 mm (Thought Technology Ltd., Quebec, Canada).

Three-dimensional kinematic data were collected at 40 Hz with a three-Space Fastrak (Polhemus, Colchester, VT). The manufacturer has reported an accuracy of 0.8 mm and 0.15° for this device. The Fastrak system used in this study consisted of a global transmitter attached to a back of a chair and a sensor mounted on the posterior aspect of the arm, in line with the long axis of humerus. The electronic unit determined the relative orientation and position of the sensor through the electromagnetic field emitted by the global transmitter. Both the sensor and the global transmitter were hardwired to the Fastrak electronic unit that collected information about the position of the arm. The information was sent to a computer with a software system synchronized with the EMG. The coordinate system of the global transmitter was used in this study as the only component needed from the Fastrak system was the exact time the sensor on the humerus started to move into elevation relative to the global transmitter.

Experimental procedure

The overall flow of the experiment procedure was as follows. The subject was instructed to sit in a comfortable upright position such that the sacrum was in contact with the back of the chair with feet placed parallel on the floor. The global transmitter was attached to the back of the chair and the Fastrak sensor was placed on the posterior aspect of humerus in vertical line with olecranon. The area of EMG electrode placement was cleaned with alcohol swabs to lower the electrical impedance. The SENIAM recommendation for electrodes location was followed for trapezius. Electrodes were placed in line with the muscle fibers over the following locations: upper trapezius, at the midpoint of the lead line between the acromion and the spinous process of C7, in the direction of the line between the acromion and the C7; middle trapezius, between the medial border of the scapula and the spine, at the level of T3, in the direction of the line between T5 and the acromion; lower trapezius at 2/3 on the line from the trigonum spinea to the T8, in the direction of the line between T8 and the acromion [23,24]. The electrodes for the serratus anterior were placed parallel to the muscle fibers right in front of the anterior border of latissimus dorsi at rib levels 6-8 (Figure 1) [25]. When the electrode placement was completed the signal quality of all the muscles was tested.

Both arms were tested, but only one arm at a time. The order of testing was randomized. The following instructions were verbalized to each subject: “Visually focus on a point directly ahead on the chart in front of you. Allow your hands, shoulders and arms to assume the position they would normally assume while you sit in a relaxed fashion”. The subject was instructed to maintain the position [26]. A flat vertical surface was positioned along the lateral aspect of the subjects’ arm to act as a guide to maintain the arm motion in the scapular plane, defined 30 degrees anterior to the frontal plane. The back of the hand gently contacted the vertical surface. To control the speed of the arm elevation a metronome set at 60 beats per minute was used and each subject exercised an elevation of a straight arm to a count of three seconds and lowering along the same path to a count of three, without stopping at top level. Before and in-between each elevation and lowering of the arm the subject was instructed to relax for 3 seconds. Following the practice trials synchronized EMG and kinematic data were simultaneously collected during elevation of the arm [27].

Analysis

The main parameter of interest was the onset of muscle activation of the trapezius and the serratus anterior when elevation of the arm began. The onset of muscle activation was only measured ipsilaterally. Kinematic and EMG data were synchronized as they were sampled by the computer. The kinematic data was imported into excel where the exact time when elevation of the arm began was displayed in seconds. The EMG data were rectified, imported into excel in raw text form and processed with an excel macro onset filter (KINE, Hafnarfjordur, Iceland) with a threshold adjusted at two standard deviations above a resting value for more than 50 milliseconds [28,29]. The muscle onset was determined when the RMS of each muscle had reached that threshold. The time interval between the moment the arm started to elevate and the time when each muscle had reached the threshold was calculated with a computer program and displayed in seconds.

Statistics

The R version 2.8.0 (The R Foundation for Statistical Computing ISBN 3-099951-07-0) was used for statistical analysis. The age, weight and height between the three groups were compared by ANOVA. For each group, means and standard deviations were calculated for the four dependant variables on each side. They were onset of muscle activation for three parts of trapezius and serratus anterior on the side of elevation. To meet the criteria for normal distribution the data had to be transformed by first adding the absolute value of the smallest value for each electrode and then raising to the power of 0.45. As the Shapiro test did not reject normal distribution of the residuals (p=0.27), parametric tests were used for statistical analysis. To compare the onset of muscle activation among the three groups, a mixed model of a ANOVA was used with one between subject factor (three groups: IONP, WAD and controls) and one within subject factor (sides, representing arm dominance). The Tukey honest significant difference' method was used to determine the main effects of the ANOVA. Interaction effects for sides were tested first to determine any potential influence on group effects. In the absence of interactions, main effects of group (collapsed across sides) were of interest.

The correlation between the dependant variables and the scores on the NDI and the VAS was also assessed. The significance level for all tests was set at 0.05.

RESULTS

There was no significant difference in age, weight and height between the three groups (Table 1). Figure 2 and 3 demonstrate the mean (SEM) of the onset of muscle activation in the three groups.

There were no group main effects or interaction effects for upper, middle and lower trapezius. With no interaction, the main effect for serratus anterior was statistically significant among the groups [F (2,70) = 5.214, p. < .01]. Post hoc comparison revealed a significantly delayed onset of muscle activation in the IONP group ($P < .05$), and in the WAD group ($P < .01$) compared to the asymptomatic group. No statistical difference was observed between the symptomatic groups ($P = .93$).

The correlation between the EMG onset of the serratus anterior muscle and the scores on the NDI and VAS was below 0.3 on both sides.

DISCUSSION

The results of this study support the hypothesis of altered activity in the scapular muscles in patients with cervical disorders compared to asymptomatic subjects. A significantly delayed onset of muscle activation of the serratus anterior has not been reported previously in these patients. This is an important result as research on the serratus anterior in patients with shoulder disorders has concluded that this muscle is the main stabilizer of the scapula during upper limb tasks [4]. This finding may have implications for scapular stability in these patients as the delayed activity in the serratus anterior may reflect inconsistent or poorly coordinated muscle activation that may reduce the quality of neuro-muscular performance [1,4,5,30]. This deficit in the coordinate activity has the potential to induce aberrant forces on the cervical and thoracic spine, sustaining symptomatic mechanical dysfunction in the area and may be responsible for maintaining periods of recurrence or exacerbation of neck pain [7,11].

It has been demonstrated that injection of hypertonic saline in the upper trapezius causing experimental pain in healthy subjects' results in reorganization of the activity of trapezius during shoulder flexion. On the painful side a decreased activity was demonstrated in the upper trapezius but an increased activity in the lower trapezius. However, the upper trapezius on the contralateral side to the pain demonstrated an increased activity. These findings demonstrate that pain in the upper trapezius changes the motor control in the upper and lower trapezius not only on the painful side but also on the contralateral side [13]. Therefore “null effects” may influence the results for trapezius in this current study as some patients may demonstrate a delayed onset which is disintegrated by an early onset in others.

The delayed onset of muscle activation of the serratus anterior in patients with cervical disorders corresponds to what has previously been reported in patients with shoulder disorders [30]. The similarity found in both cervical- and shoulder disorders indicate that the delayed activity in the serratus anterior may be a general response to a chronic pain condition in the cervical- or shoulder area. The fact that no difference was found between the two symptomatic groups does therefore not confirm homogeneity of the symptomatic groups, but rather suggest that the disturbance in muscle activity occurs as a general response to chronic pain condition in the area. This hypothesis is supported by studies reporting bilateral delayed onset of muscle activation in the scapular muscles in patients with unilateral shoulder disorder [30,31].

The reason for the delayed onset of muscle activation may be due to a change in the “feed-forward” response of the nervous system or due to selective reflexive inhibition that changes the automatic muscular control strategy, compromising the muscle balance around the scapula [31-33].

The fact that the correlation between the dependant variables and the scores on the NDI and the VAS was not higher ($r < 0.3$) suggests that pain or impairment in the neck area may partly be associated with onset of muscle activation of the scapular muscles that is probably multifactorial in its genesis. However, future studies are needed to determine whether the association between altered activity in the scapular muscles and neck pain is a primary or a secondary phenomenon.

The main limitation of the present study concerns the possibility of cross talk when surface EMG is used. However fine wire electrodes measuring only few muscle fibers are not considered a good choose investigating large muscle groups as the trapezius and the serratus anterior where a more global evaluation of muscle activity is needed. Careful placement of electrodes in line with orientation of muscle fibers is the best way to avoid crosstalk from nearby muscles; however the possibility of a crosstalk has to be taken into consideration even though best common practice to avoid it was used. Secondly, the results present mean values for each group, but a great variability was observed within each group. Therefore these findings may not be generalized to all patients with neck pain.

CONCLUSIONS

Patients with IONP and WAD demonstrated a significantly delayed onset of muscle activation of the serratus anterior during unilateral arm elevation. This finding may have implications for scapular stability in these patients. The results revealed no difference between the two symptomatic groups suggesting that the disturbance in muscle activity occurs as a general response to chronic pain condition in the neck area.

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REFERENCES

[1] Mottram SL. Dynamic stability of the scapula. Man Ther 1997;2:123-131.

[2] Comerford MJ, Mottram SL. Diagnosis of Uncontrolled Movement, Subgroup classification and Motor control Retraining of the Shoulder Girdle. Ludlow, UK: KC International, 2010.

[3] Sahrmann SA. Diagnosis and treatment of movement impairment syndromes. St. Louis: Mosby Inc., 2002.

[4] Kibler WB, McMullen J. Scapular dyskinesis and its relation to shoulder pain. J Am Acad Orthop Surg 2003;11:142-151.

[5] Inman VT, Saunders M, Abbott LC. Observation of the function of the shoulder joint. Clin Orthop Relat Res 1996;330:3-12.

[6] Gandeviaa SC, McCloskeya DI, Burkea D. Kinaesthetic signals and muscle contraction. Trends Neurosci 1992;15:62-65.

[7] Behrsin J, Maguire K. Levator scapulae action during shoulder movement: A possible mechanism for shoulder pain of cervical origin. Aust J Physiother 1986;32:101-106.

[8] Janda V. Muscles and motor control in cervicogenic disorders: Assessment and management. In: Grant R, ed. Physical therapy of the cervical and thoracic spine. New York: Churchill Livingstone, 1994.

[9] Jull GA, Falla D, Treleaven J, Sterling M, O'Leary S. A therapeutic exercise approach for cervical disorders. In: Boyling J and Jull G, ed. Grieve's modern manual therapy: The vertebral column. Edinburgh, UK: Churchill Livingstone, Elsevier science, 2004.

[10] Williams PL, Warwick R. Gray's Anatomy, 36th edition. Edinburgh: Churchill Livingstone, 1980.

[11] Jull G, Sterling M, Falla D, Treleaven J, O'Leary S. Whiplash headache and neck pain: Research-based directions for physical therapies. Edinburgh, UK: Churchill Livingstone, Elsevier, 2008.

[12] Jull G. Management of cervical headache. Man Ther 1997;2:182-190.

[13] Falla D, Farina D, Graven-Nielsen T. Experimental muscle pain results in reorganization of coordination among trapezius muscle subdivisions during repetitive shoulder flexion. Exp Brain Res 2007;178:385-393.

[14] Szeto GPY, Straker LM, O'Sullivan PB. EMG median frequency changes in the neck-shoulder stabilizers of symptomatic office workers when challenged by different physical stressors. 2005;15:544-555.

[15] Elliott J, Sterling M, Noteboom JT, Darnell R, Galloway G, Jull G. Fatty infiltrate in the cervical extensor muscles is not a feature of chronic, insidious-onset neck pain. Clin Radiol 2008;63:681-687.

[16] Falla D, Bilenkij G, Jull G. Patients with chronic neck pain demonstrate altered patterns of muscle activation during performance of a functional upper limb task. Spine 2004;29:1436-1440.

[17] Nederhand MJ, Hermens HJ, IJzerman MJ, Turk DC, Zilvold G. Cervical muscle dysfunction in chronic whiplash-associated disorder grade 2: the relevance of the trauma. Spine 2002;27:1056-1061.

[18] Kristjansson E, Jonsson H Jr. Is the sagittal configuration of the cervical spine changed in women with chronic whiplash syndrome? A

comparative computer-assisted radiographic assessment. J Manipulative Physiol Ther 2002;25:550-555.
[19] Spitzer WO, Skovron ML, Salmi LR, Cassidy JD, Duranceau J, Suissa S, Zeiss E. Scientific monograph of the Quebec Task Force on Whiplash-Associated Disorders: redefining "whiplash" and its management. Spine 1995;15:1S-73S.
[20] MacDermid JC, Walton DM, Avery S, Blanchard A, Etruw E, McAlpine C, Goldsmith CH. Measurement properties of the neck disability index: a systematic review. J Orthop Sports Phys Ther 2009;39:400-417.
[21] Hartling L, Brison RJ, Ardern C, Pickett W. Prognostic value of the Quebec Classification of Whiplash-Associated Disorders. Spine 2001;26:36-41.
[22] Magee DJ. Orthopedic physical assessment. Philadelphia, PA: WB Saunders company, 1987.
[23] Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. J Electromyogr Kinesiol 2000;10:361-374.
[24] Hermens HJ, Freriks B, Merletti R, Hägg G, Stegeman D, Blok J. SENIAM 8: European recommendations for surface electromyography. www.seniam.org. Roessingh Research and Development, 2009.
[25] Basmajian JV, Blumenstein R. Biofeedback: Principles and Practices for Clinicians. Baltimore: Williams and Wilkins, 1989.
[26] Karduna A, McClure P, Michener LA. Scapular kinematics: effects of altering the Euler angle sequence of rotations. J Biomech 2000;33:1063-1068.
[27] Thigpen CA, Gross MT, Karas SG, Garrett WE, Yu B. The repeatability of scapular rotations across three planes of humeral elevation. Res Sports Med 2005:181-198.
[28] Hodges PW, Bui BH. A comparison of computer-based methods for the determination of onset of muscle contraction using electromyography. Electroencephalogr Clin Neurophysiol. 1996;101:511–519.
[29] Silfies SP, Mehta R, Smith SS, Karduna AR. Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. Arch Phys Med Rehabil 2009;90:1159-1169.
[30] Wadsworth DJS, Bullock-Saxton JE. Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. Int J Sports Med 1997;18:618-624.
[31] Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement. Am J Sports Med 2003;31:542-549.
[32] Falla D. Unravelling the complexity of muscle impairment in chronic neck pain. Man Ther 2004;9:125-133.
[33] Sterling M, Jull G, Wright C. The effect of musculoskeletal pain on motor activity and control. J Pain 2001;2:135-145.

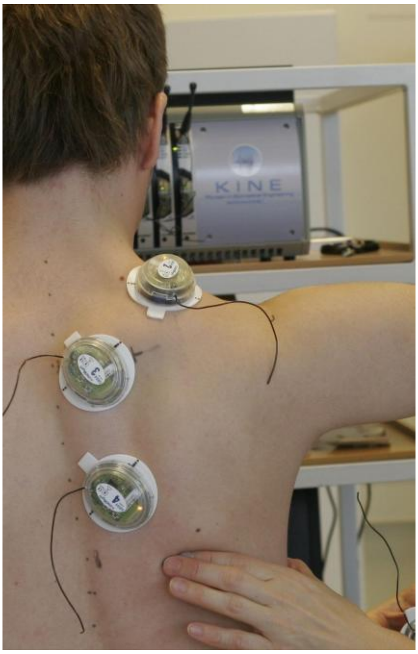

Figure 1. Electrode location and experimental set up. Disposable disc shaped (10 mm Ø) triode surface electrodes were placed at the trapezius and serratus anterior. The signal was digitized at approximately 3 mm from the skin, and transmitted wirelessly in digital form. A flat vertical surface was positioned along the lateral aspect of the subjects' arm to act as a guide to maintain the arm motion in the scapular plane.

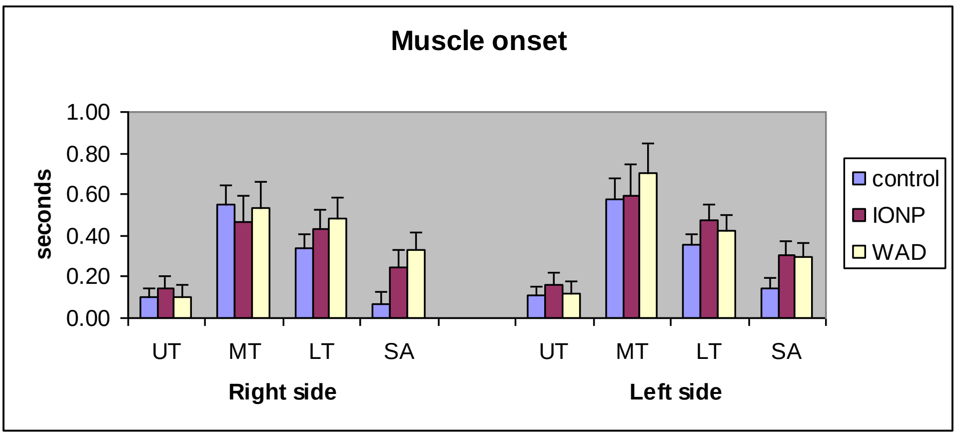

Figure 2. Comparison of the mean (+SEM) of the Upper Trapezius (UT), Middle Trapezius (MT), Lower trapezius (LT) and the Serratus Anterior (SA). IONP=insidious onset neck pain, WAD=whiplash associated disorder.

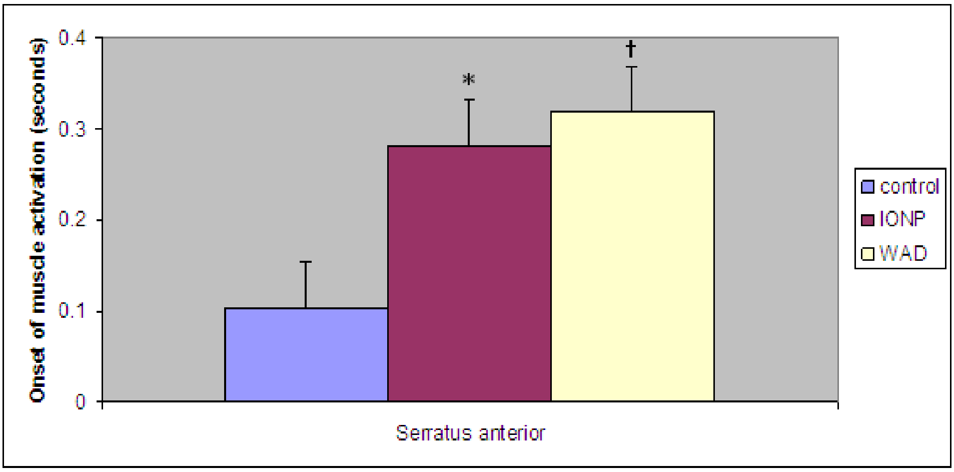

Figure 3. Mean for both sides (+SEM). IONP=insidious onset neck pain, WAD=whiplash associated disorder.
***statistically significant difference between IONP and control (*P*<0.05)**
†statistically significant difference between WAD and control. (*P*<0.05)

Table 1. Demographic details of participants.

	control group			IONP group			WAD group		
	Women (n=18) Men (n=5)			Women (n=20) Men (n=2)			Women (n=24) Men (n=3)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (years)	30	7	21-51	35	8	25-54	33	9	18-50
Height (cm)	171	7	155-188	170	6	158-183	170	5	160-180
Weight (kg)	70	10	56-100	73	16	53-12	70	10	51-92
NDI	0	0	0	29	10	12-49	38	18	12-80

Paper II.

ORIGINAL RESEARCH

Altered alignment of the shoulder girdle and cervical spine in patients with insidious onset neck pain and whiplash associated disorder

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ABSTRACT

Clinical theory suggests that altered alignment of the shoulder girdle has the potential to create or sustain symptomatic mechanical dysfunction in the cervical and thoracic spine. The alignment of the shoulder girdle is described by two clavicle rotations; elevation and retraction and three scapular rotations: upward rotation, internal rotation and anterior tilt. Elevation and retraction has until now only been assessed in patients with neck pain. The aim of the study was to determine whether there is a pattern of altered alignment of the shoulder girdle, and the cervical and thoracic spine in patients with neck pain.

A three-dimensional device measured clavicle and scapular orientation, and cervical and thoracic alignment in patients with insidious onset neck pain (IONP) and whiplash-associated disorder (WAD). An asymptomatic control group was selected for baseline measurements.

The symptomatic groups revealed a significantly reduced clavicle retraction and scapular upward rotation as well as decreased cranial angle. A difference was found between the symptomatic groups on the left side where the WAD group revealed an increased scapular anterior tilt and the IONP group a decreased clavicle elevation. These changes may be an important mechanism for maintenance and recurrence or exacerbation of symptoms in patients with neck pain.

Keywords

Neck pain, whiplash, scapula, posture

INTRODUCTION

Clinical theory suggests that altered alignment of the shoulder girdle has the potential to create or sustain symptomatic mechanical dysfunction in the cervical and thoracic spine by inducing compressive, rotational and shear forces to the tissues (Behrsin & Maguire, 1986; Janda, 1994; Jull et al., 2008; Jull et al., 2004b). Until now the alignment of the shoulder girdle in patients with cervical disorders has only been investigated by measuring the upward and forward displacement of the acromion with reference to the 7th cervical spinous process or by angular measurements using these landmarks. These studies evaluating the protraction/retraction and elevation/depression of the shoulder girdle do not take into consideration the alignment of the thoracic cage nor do they measure scapular orientation (Braun, 1991; Szeto et al., 2002; Yip et al., 2008).

This study applies the definition of body segment and joint coordinate system proposed by the Standardization and Terminology Committee of the International Society of Biomechanics. This includes measuring three dimension orientation of the shoulder girdle described by two clavicle rotations; elevation and retraction and three scapular rotations: upward rotation, internal rotation and anterior tilt (Figure 1)(Karduna et al., 2001; Wu et al., 2005).

The alignment of the shoulder girdle varies considerably between individuals within the general population. In general, the clavicles should be symmetrical, elevate around 6 degrees and retract around 20 degrees at the sternoclavicular joint (Ludewig et al., 2009). The scapula sits between the second and the seventh rib on the posterior thoracic wall (Williams & Warwick, 1980), approximately 8 cm lateral to the spinous processes (Sobush et al., 1996). The optimum alignment of the scapula with the arms by the side has been described as the mid position of the scapula between the individual available range of upward and downward rotation, external and internal rotation and posterior and anterior tilt (Mottram et al., 2009). This has been described as the 'scapula neutral position'. There is minimal support from the passive osteo-ligamentous system in this position so the myofascial structures, in particular the trapezius and the serratus anterior are considered to have an important role (Mottram et al., 2009).

Potential mechanisms that can alter the alignment of the shoulder girdle include pain, tightness in the soft tissues, imbalances in muscle activity or strength, muscle fatigue and the cervical and thoracic curves (Kebaetse et al., 1999; Michener et al., 2003; Sahrmann, 2002). The presence of pain is associated with altered muscle activity in the trapezius and the serratus anterior muscles (Falla et al., 2007a; Falla et al., 2004a; Ludewig & Cook, 2000; Sterling et al., 2001). Paralysis of these muscles due to injury to the accessory nerve and the long thoracic nerve, illustrates their contribution in maintaining optimum scapular orientation. Trapezius paralysis results in a scapular orientation characterized by a reduced elevation and retraction of the clavicle, and increased upward rotation of the scapula. Serratus anterior paralysis results in increased elevation of the clavicle, medial translation and downward rotation of the scapula (Kuhn et al., 1995). Tightness and over activity of both the levator scapula and the rhomboid muscles tend to adduct, downwardly rotate and elevate the most medial part of the scapula (Behrsin & Maguire, 1986; Sahrmann, 2002). The pectoralis minor, the biceps brachii (caput brevis) and the coracobrachialis muscles, which attach to the coracoid process, can create forward pull on the scapula causing anterior tilting of the scapula and protraction of the clavicle and along with the pectoralis major; the pectoralis minor may also cause downward rotation of the scapula (Kibler & McMullen, 2003; Williams & Warwick, 1980).

Changes in the cervical and thoracic alignment (Kibler & McMullen, 2003) as well as slouched posture are also known to contribute to altered alignment of the scapula (Finley & Lee, 2003; Kebaetse et al., 1999). Altered cervical alignment is considered to be an important mechanism influencing cervical (Edmondston et al., 2005; Szeto et al., 2005b) and scapular kinematics (Kibler & McMullen, 2003; Thigpen et al., 2010). Evidence is emerging demonstrating that cervical alignment is associated with efficient function of the deep cervical flexors (Falla et al., 2007b), the trapezius and the serratus anterior muscles (Weon et al., 2009). However, there is conflicting evidence as to whether there is a difference in cervical alignment between patients with neck pain and asymptomatic subjects (Edmondston et al., 2007; Harrison et al., 2004; Yip et al., 2008). Association between prolonged neck pain and more flexed cervicothoracic posture has been reported in adolescents (Straker et al., 2009) but association has not been found between changes in the thoracic curve and cervical spine disorders in adults (Szeto et al., 2005a).

The aim of the study was to determine whether there is a pattern of altered alignment of the shoulder girdle, and the cervical and thoracic spine, at rest, in patients with cervical spine disorders. The hypothesis is that patients with cervical spine disorders demonstrate an altered alignment of the shoulder girdle and the alignment of the cervical and thoracic spine.

METHODS

Subjects

The current study included patients with insidious onset neck pain (IONP) and patients with whiplash associated disorder (WAD) grade II, following a motor vehicle accident (Spitzer et al., 1995), since a difference may exist in impairments between these groups. A difference has been observed between these two groups of patients in the sagital configuration of the cervical spine (Kristjansson & Jonsson, 2002), the fatty infiltration in the cervical extensor muscles (Elliott et al., 2008), the activity of the trapezius muscle and the level of pain and disability (Falla et al., 2004a; Nederhand et al., 2002). Twenty one subjects with IONP (19 women and 2 men) and twenty three subjects with WAD (20 women and 3 men) were recruited at physical therapy clinics, on a voluntary basis, in the Reykjavik municipal area. This study was approved by the Bioethics Committee of Landspitali University Hospital and all subjects signed a consent form. A sample of convenience consisting of twenty asymptomatic subjects (17 women and 3 men) served as a control group (Table 1). All subjects were right handed. The subjects in the control group were selected to match the subjects in the symptomatic groups, according to their height, weight, age, gender and physical activity level. Physical activity level was assessed by asking whether the subject engaged in some kind of physical activity on regular bases (sports, exercises etc.). If the answer was yes the subject was asked what kind of physical activity and how many times per week. Demographic information (height, weight, age, gender and physical activity level) were collected. Disability was measured by the Neck Disability Index (NDI), which is a self reporting questionnaire (Vernon & Mior, 1991). Pain intensity was evaluated with a 10-cm Visual Analogue Scale (VAS) anchored by no pain and pain as bad as it can be. The VAS was used to indicate the average intensity of neck pain experienced over the past seven days.

Inclusion criteria for the pain groups were: age 18 to 55, a score of at least 10 on the NDI, and neck symptoms of more than six months duration. Score below 10 on the NDI are scored as 'no disability' (Vernon & Mior, 1991) and symptoms that have lasted more than six months are considered chronic (Hartling et al., 2001). Subjects were allocated to one of two groups: Group 1 included subjects with IONP that had no history of any accident or whiplash injury; group 2 included subjects diagnosed with a WAD that had no prior history of symptoms in the neck area before the accident. A third group included the controls (Group 3) which were between age 18 to 55 with neither cervical nor shoulder dysfunction. The cervical spine was examined by a trained physical therapist to confirm the presence or absence of cervical segmental joint dysfunction in patients with neck pain and controls, respectively. The glenohumeral joints were examined for pain, restriction, and impingement signs (Magee, 1987). Subjects were excluded if they had any known pathology or impairment in the shoulder joint, history of head injury or spinal fractures, systematic pathology and serious psychological condition.

Prior to initiating the study, a sample of 20 subjects per group was calculated to provide 80% power to detect differences of 3 degrees between the groups. Calculations were based on our judgment of what are clinically meaningful differences.

Instrumentation and measurements

Equipment: Three-dimensional kinematic data were collected at 40 Hz with the Polhemus 3-Space Fastrak device (Polhemus Colchester, VT), which has an accuracy of 0.8 mm and 0.15°. The device consisted of a global transmitter, three sensors, and a digitizing stylus, all of which were hardwired to a system electronic unit. The electronic unit determined the relative orientation and position of the digitizer and the sensors through the electromagnetic field emitted by the global transmitter. Information collected by the Fastrak system was sent to a computer with a software system developed by KINE (Hafnarfjordur, Iceland).

Evaluation of the alignment of the shoulder girdle: For evaluation of the alignment of the shoulder girdle, the study utilized the definition of body segment and joint coordinate system for the upper extremity proposed by the International Society of Biomechanics. These coordinate systems were defined using digitized anatomical landmarks to evaluate clavicle and scapular orientation (Wu et al., 2005). The digitizing stylus connected to the magnetic tracking device was used to digitize manually the coordinates of the landmarks listed in Table 2. All landmarks were palpable except for the center of glenohumeral rotation (GH). The GH was estimated by moving the humerus through short arcs (<45 degrees) of midrange glenohumeral motion. The GH was defined as the point on the humerus that moved the least with respect to the scapula when the humerus was moved and was calculated using a least-squares algorithm (Biryukova et al., 2000; Harryman et al., 1990). Based on standard matrix transformation methods the global axes defined by the sensors of the Fastrak device were converted to anatomically defined axes derived from the digitized bony landmarks (Karduna et al., 2001).

Evaluation of cervical- and thoracic alignment: The cervical- and thoracic alignment was measured two-dimensionally. This study utilized coordinates provided by the digitizer to measure cervical alignment and distinguished between the alignment of the upper cervical spine (cranial angle) and the lower cervical spine (cervical angle) (Edmondston et al., 2007; Straker et al., 2009). To evaluate cranial and the cervical angles the corner of the right eye, the tragus of the right ear and the spinous process of the 7^{th} cervical vertebra were digitized. The coordinates of these anatomical landmarks were used to calculate the cranial and the cervical angels illustrated in Figure 2. To measure the mid-thoracic curve (MTC) the digitized coordinates of the spinous processes ranging from T2 to T11 were used. A curve was drawn along the thoracic spinous processes and a straight line directly between the spinous processes T2 and T11 (Figure. 3). The longest perpendicular distance (h) between the curve and the straight line was calculated using the coordinates. The MTC was calculated using the formula presented on Figure 3. The line labeled length (l) is the straight line distance between spinous processes T2 and T11. The line labeled height (h) is perpendicular to l and intersects the curve at a digitized point of the mid thoracic process that visually demonstrated the top of the curve (Bullock et al., 2005). This method in evaluating the thoracic curve has shown a good intra and inter-rater reliability with a ICC level of 0,99 (Kristinsson, 2008).

Experimental procedure: The anatomical landmarks were palpated and marked. Three Fastrak sensors were attached to each subject. Using an adhesive tape the first sensor was attached to the skin of the sternum (distal to the sternal notch) and the second sensor to the flat part of the acromion. The second sensor evaluated the clavicle and scapular rotations. The third sensor, attached to an elastic strap (Mylatex wrap, 45 cm, Chattanooga group, USA), was placed distally on posterior aspect of humerus proximal to the epicondyles. These placements have been used previously and validated for these measurements (Karduna et al., 2001; Ludewig & Cook, 2000). The height of the chair used in the study was adjusted for each subject and a 15 degree obliquely aligned cushion was used to facilitate neutral spinal curves.

The subject was instructed to sit in a comfortable upright position such that the sacrum was in contact with the back of the chair with the feet placed parallel on the floor (Figure 4). The following instructions were verbalized to each subject: “Visually focus on a point, directly ahead, on the chart in front of you”. “Allow your hands, shoulders and arms to assume the position they would normally assume by the side”. The subject was instructed to maintain this position throughout the digitization and the GH estimation procedures. Following this, the raw data from the sensors were converted into anatomically defined rotations (Karduna et al., 2001). The right and left sides were assessed separately. Two measurements were conducted on each subject on both sides (the Fastrak sensors on the scapula and the arm had to be moved to the opposite side). The two measurements were averaged to get one measure for each side. The order of testing was randomized (sides and groups).

The subjects were not aware that the alignment of the spine and the shoulder girdle was measured. They were informed that the function of the upper body was evaluated by using surface EMG electrodes (not part of this study). The alignments measurements were conducted before the subject elevated the arm several times.

Data analysis

The R version 2.8.0 (The R Foundation for Statistical Computing ISBN 3-099951-07-0) was used for statistical analysis. The age, weight and height between the three groups were compared by ANOVA. The main parameter of interest was the alignment of the shoulder girdle and cervical and thoracic spine with the arms resting by the side. The data for the alignment of the shoulder girdle was described using two clavicle rotations; elevation/depression and retraction/protraction and three scapular rotations: upward/downward rotation, internal/external rotation and anterior/posterior tilt, as dependant variables (Figure 1). A software program (KINE, Hafnarfjordur, Iceland) calculated the orientation of each clavicle and scapular rotation.

Three variables were related to the alignment of the cervical and thoracic spine; the cranial angle, cervical angle and mid-thoracic curve (Figure 2 and 3). The calculation for the alignment of the cervical and thoracic spine was performed automatically by the use of an excel software program (Bullock et al., 2005). For each group, means and standard deviations were calculated for the five dependant variables on each side demonstrating alignment of the shoulder girdle and the three dependant variables demonstrating cervical and thoracic alignment. As the Shapiro test did not reject normal distribution of the data, parametric tests were used for statistical analysis. Initial analyses were performed to test for possible group differences, in the dependent measures, by using general linear model one-way analysis of variance and the Tukey honest significant difference' method was used to determine the main effects of the ANOVA. The correlation between the dependant variables and the scores on the NDI and the VAS was also assessed. The significance level for all tests was set at 0.05.

RESULTS

There was no significant difference in age, weight and height between the three groups or between the results of men and women within each group (Table 1). The ANOVA revealed on the right side a significant difference in clavicle retraction ($P < 0.03$) and on the left side a significant difference in clavicle elevation ($P = 0.01$), scapular tilt ($P < 0.01$) and scapular upward rotation ($P < 0.03$) between the three groups. A significant difference was also observed in the cranial angle ($P < 0.01$) and a tendency in the cervical angle ($P = 0.07$) but no difference was found in the mid-thoracic curve ($P = .99$) between the three groups. The correlation between the dependant variables and the scores on the NDI and VAS were found weak ($r < 0.50$). Summary group data is demonstrated on Table 3 and Figure 5.

Post hoc comparison on the right side revealed a significantly reduced clavicle retraction in the IONP group ($P = 0.04$) and in the WAD group ($P < 0.02$) compared to the control group. On the left side there was a significantly reduced scapular upward rotation in the WAD group ($P < 0.03$) and reduced clavicle elevation in the IONP group ($P = 0.02$) compared to the control group. A different manifestation was observed between the symptomatic groups for the left side demonstrated by a significantly increased scapular anterior tilt in the WAD group compared to the control group ($P = 0.01$) and the IONP group ($P < 0.01$).

Post hoc comparison of the cranial angle showed significantly decreased cranial angle in the IONP group ($P = 0.02$) and the WAD group ($P = 0.03$) compared to the control group.

DISCUSSION

The results of this study support the hypothesis of altered alignment of the shoulder girdle and the cervical spine in patients with neck pain compared to asymptomatic subjects. The weak correlation between the alignment of the cervical spine and shoulder girdle, and the level of pain and disability, suggests that pain or impairment in the neck area may partly be associated with alignment that is probably multifactorial in its genesis.

The side to side differences in the asymptomatic group corresponds to former studies, where clavicle elevation and retraction is typically reduced on the dominant side compared to the non-dominant side (Sobush et al., 1996) and scapular upward rotation is increased on the non-dominant side compared to the dominant side (Crosbie et al., 2008). As the majority of patients that participated in this study had bilateral symptoms in the neck area, the side to side differences can not be related to increased symptoms on the left side but rather to less usage and less awareness of the non-dominant arm compared to the dominant arm (Sandlund et al., 2006).

The reduced clavicle retraction and cranial angle observed in the symptomatic groups are consistent with previous reports that a forward head posture, a combination of lower cervical flexion, upper cervical extension and reduced clavicle retraction, is more common in patients with neck pain compared to asymptomatic subjects (Braun, 1991; Szeto et al., 2002; Yip et al., 2008). This may lead to increased compressive forces in the articulations of the cervical and thoracic spine, inducing tension in the muscles in the area (Harrison et al., 2004; Szeto et al., 2002; Yip et al., 2008) and affecting the muscle activity of the trapezius and the serratus anterior (Weon et al., 2009). Reduced median nerve sliding and paresthesias has also been associated with reduced clavicle retraction (Julius et al., 2004).

The reduced clavicle retraction may be connected to a decreased ability of trapezius to retract and maintain the normal position of the scapula. The middle trapezius functions as a scapula retractor and the transverse orientated fibers of the upper and lower trapezius assist this action (Johnson et al., 1994). Reduced extensibility in the pectoralis minor muscle is of interest to because of its attachment to the medial border of the coracoid process on the scapula but the pectoralis major muscle influence may not be so significant while the arms are resting by the sides (Sahrmann, 2002).

The differences in the cranial angle may be caused by an increased lordotic alignment of the atlas, which is the main lordotic segment in the cervical spine (Kristjánsson, 2004). The decreased cranial angle and differences in the cervical lordosis may reflect altered muscle activity in the deep cervical flexors observed in patients with neck pain. Interestingly an increased activity has been observed in the sternocleidomastoid and the anterior scaleni muscles with altered motor control strategies of the deep cervical flexors (Falla et al., 2004b; Falla & Farina, 2005; Jull et al., 2004a; Jull et al., 2004b; Szeto et al., 2005a). It has been suggested that the increased cranial angle in the upper cervical spine, noted in the WAD group is a compensation strategy for the reduced weight bearing capacity of the cervical spine after motor vehicle collisions (Kristjánsson, 2004). Altered activity in the cervical flexors, in patients with WAD may develop because of pain and the aforementioned biomechanical changes (Kristjánsson, 2004).

The interesting results in this study were the increased anterior tilt and reduced upward rotation of the scapula and the reduced clavicle elevation. These findings have not been reported previously in patients with neck pain. The different manifestation that was revealed between the two symptomatic groups in clavicle elevation and scapular anterior tilt on the left side (non-dominant) is an important finding suggesting that a difference may exist in impairments between these groups. A different manifestation has been reported in the alignment of the shoulder girdle between patients with shoulder problems where patients with instability demonstrated less elevated shoulders and patients with impingement syndrome more elevated shoulders on the symptomatic side compared to the asymptomatic side (Warner et al., 1992). A difference in the activity of the upper trapezius has been reported between patients with WAD and IONP where patients with WAD had a tendency of higher and longer muscle activation patterns in trapezius during upper limb tasks (Nederhand et al., 2002), reduced ability to relax after tasks (Fredin et al., 1997), and demonstrated a significantly higher EMG amplitude in the muscle compared to patients with IONP (Falla et al., 2004a).

The increased anterior tilt of the scapula, in the WAD group, may be associated with forward head posture (Thigpen et al., 2010), short overactive pectoralis minor muscle associated with inefficiency in the serratus anterior and lower trapezius muscles that fail to control the anterior tilt of the scapula (Borstad & Ludewig, 2005; Ludewig & Cook, 2000; Sahrmann, 2002).

The reduced clavicle elevation observed in the IONP group is consistent with previous reports in patients with tension-type headache where an intermediate lateral projection of an X-ray spinogram was used to determine the position of the shoulder girdle. The lower cervical and upper thoracic spine is generally obscured by the shoulder girdle. The term “low-set shoulder” was referred to cases where the first thoracic vertebra (mild cases) and upper third or more of the second thoracic vertebra (severe cases) were clearly visualized. In the controls (n=225) a mild low-set shoulder was observed in 38% (n=86) of the subjects but severe in only 3.8% (n=8). In patients with tension-type headache (n=372) 48% (n=180) had mild low set shoulders and 9.1% (n=34) severe (Nagasawa et al., 1993). The reduced clavicle elevation may reflect inefficiency of the upper trapezius which fails to control normal clavicle elevation against gravity (Mottram et al., 2009; Sahrmann, 2002) or an imbalance between the upper and lower trapezius muscles where the activity of the lower trapezius may dominate the activity of the upper trapezius (Ludewig et al., 1996).

The combination of reduced clavicle elevation and reduced scapular anterior tilt demonstrated in the IONP group on the left side supports recent suggestions that increased clavicle elevation is coupled with increased scapular anterior tilt and vice versa (Teece et al., 2008). The reduced scapular anterior tilt in the IONP group on the left side may therefore correspond to the decreased clavicle elevation. However, the reduced anterior tilt may also occur due to increased activity in the levator scapulae and the rhomboid muscles, to compensate for inefficient upper trapezius (Ludewig et al., 1996; Sahrmann, 2002).

The reduced scapular upward rotation reflects either a long, inefficient upper trapezius and serratus anterior muscles or short overactive levator scapula and rhomboid muscles which would simultaneously elevate and retract the clavicle, and downwardly rotate the scapula (Sahrmann, 2002). The reduced clavicle elevation in the IONP group and the reduced scapular upward rotation in the WAD group is concurrent with Sahrmann’s (2002) statement that the most common alignment impairments of the shoulder girdle in patients with shoulder pain is the downwardly rotated alignment of the scapula and the depressed alignment of the clavicle. It should be noted that a reduced clavicle elevation as well as a reduced scapular upward rotation maintains a lengthen position of the upper trapezius which induces excessive strain on the muscle as well as the levator scapula and the rhomboid muscles. This lengthen position increases tenderness in the muscles (Azevedo et al., 2008) and inflicts compressive, rotational and shear forces on the cervical and thoracic spine which may be an important mechanism for maintenance for recurrence or exacerbation of neck pain (Behrsin & Maguire, 1986; Jull, 1997; Jull et al., 2008; Jull et al., 2004b; Mottram et al., 2009). This corresponds to studies demonstrating reduced neck symptoms when patients with neck pain rotate the neck when the shoulder girdle is passively elevated (Van Dillen et al., 2007).

The primary limitation of this study is that it describes the alignment of the spine and the shoulder girdle at rest only and therefore the findings can not be generalized to alignment during functional tasks especially when the upper limb is moving or loaded. This is also the case when activities are prolonged over time. Secondly, the fact that the measurement were done in sitting may be considered a limitation of the study, since a difference in the sitting position between the three groups may have led to differences observed. However, the sitting position was standardized by adjusting the height of the chair for each subject, by using an obliquely aligned cushion, by ensuring that the sacrum was in contact with the back of the chair and by placing the feet parallel on the floor. As the results demonstrate an equivalent alignment of the thoracic spine in all three groups (P=0.99) it may be concluded that the sitting position were similar in all three groups and therefore did not affect the results of the study. Thirdly, the results present mean values for each group but a great variability was observed within each group. Fourthly, evaluating for restriction in extensibility in the pectoralis minor muscle may have provided information about the relationship of a restriction to altered alignment of the shoulder girdle.

CONCLUSIONS

A reduced clavicle retraction, scapular upward rotation and cranial angle were observed in patients with neck pain compared to asymptomatic subjects. A different manifestation was observed between patients with IONP and WAD on the left side in clavicle elevation and scapular anterior tilt suggesting that a difference may exist in impairments between these groups. The WAD group revealed increased anterior tilt of the left scapula compared to the control group and the IONP group which revealed a reduced clavicle elevation on the left side compared to the control group.

REFERENCES

Azevedo, D.C., de Lima Pires, T., de Souza Andrade, F., & McDonnell, M.K. (2008). Influence of scapular position on the pressure pain threshold of the upper trapezius muscle region. *European Journal of Pain, 12*, 226-232.

Behrsin, J., & Maguire, K. (1986). Levator scapulae action during shoulder movement: A possible mechanism for shoulder pain of cervical origin. *The Australian Journal of Physiotherapy, 32*, 101-106.

Biryukova, E.V., Roby-Brami, A., Frolov, A.A., & Mokhtari, M. (2000). Kinematics of human arm reconstructed from spatial tracking system recordings. *Journal of Biomechanics, 33*, 985-995.

Borstad, J.D., & Ludewig, P.M. (2005). The effect of long versus short pectoralis minor resting length on scapular kinemetics in healthy individuals. *JOSPT, 35*, 227-238.

Braun, B.L. (1991). Postural differences between asymptomatic men and women and craniofacial pain patients. *Archives of Physical Medicine and Rehabilitation, 72*, 653-656.

Bullock, M.P., Foster, N.E., & Wright, C.C. (2005). Shoulder impingement: The effect of sitting posture on shoulder pain and range of motion. *Manual Therapy, 10*, 28-37.

Crosbie, J., Kilbreath, S.L., Hollmann, L., York, S. (2008). Scapulohumeral rhythm and associated spinal motion. *Clin Biomech*, *23*, 184-192.

Edmondston, S.J., Chan, H.Y., Ngai, G.C., Warren, M.L., Williams, J.M., Glennon, S., et al. (2007). Postural neck pain: An investigation of habitual sitting posture, perception of 'good' posture and cervicothoracic kinaesthesia. *Manual Therapy, 12*, 363-371.

Edmondston, S.J., Henne, S.E., Loh, W., & Ostvold, E. (2005). Influence of cranio-cervical posture on three-dimensional motion of the cervical spine. *Manual Therapy, 10*, 44-51.

Elliott, J., Sterling, M., Noteboom, J.T., Darnell, R., Galloway, G., & Jull, G. (2008). Fatty infiltrate in the cervical extensor muscles is not a feature of chronic, insidious-onset neck pain. *Clinical Radiology, 63*, 681-687.

Falla, D., Bilenkij, G., & Jull, G. (2004a). Patients with chronic neck pain demonstrate altered patterns of muscle activation during performance of a functional upper limb task. *Spine, 29*, 1436-1440.

Falla, D., & Farina, D. (2005). Muscle fiber conduction velocity of the upper trapezius muscles during dynamic contraction of the upper limb in patients with chronic neck pain. *Pain, 116*, 138-145.

Falla, D., Farina, D., & Graven-Nielsen, T. (2007a). Experimental muscle pain results in reorganization of coordination among trapezius muscle subdivisions during repetitive shoulder flexion. *Experimental Brain Research, 178*, 385-393.

Falla, D., Jull, G., & Hodges, P.W. (2004b). Feedforward activity of the cervical flexor muscles during voluntary arm movements is delayed in chronic neck pain. *Experimental Brain Research, 157*, 43-48.

Falla, D., O'Leary, E.F., Fagan, A., & Jull, G. (2007b). Recruitment of the deep cervical flexor muscles during a postural-correction exercise performed in sitting. *Manual Therapy, 12*, 139-143.
Finley, M.A., & Lee, R.Y. (2003). Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. *Archives of Physical Medicine and Rehabilitation, 84*, 563-568.
Fredin, Y., Elert, J., Britschgi, N., Nyberg, V., Vaher, A., Gerdle, B. (1997). A decreased ability to relax between repetitive muscle contractions in patients with chronic symptoms after whiplash trauma of the neck. *J Musculoskelet Pain*, *5*, 55-70.
Harrison, D.D., Harrison, D.E., Janik, T.J., Cailliet, R., Ferrantelli, J.R., Haas, J.W., et al. (2004). Modeling of the sagittal cervical spine as a method to discriminate hypolordosis: Results of elliptical and circular modeling in 72 asymptomatic subjects, 52 acute neck pain subjects, and 70 chronic neck pain subjects. *Spine, 15*, 2485-2492.
Harryman, D.T. 2nd, Sidles, J.A., Clark, J.M., McQuade, K.J., Gibb, T.D., & Matsen, F.A. 3rd. (1990). Translation of the humeral head on the glenoid with passive glenohumeral motion. *The Journal of Bone and Joint Surgery, 72*, 1334-1343.
Hartling, L., Brison, R.J., Ardern, C., & Pickett, W. (2001). Prognostic value of the quebec classification of whiplash-associated disorders. *Spine, 26*, 36-41.
Janda, V. (1994). Muscles and motor control in cervicogenic disorders: Assessment and management. In: Grant, ed. Physical therapy of the cervical and thoracic spine. New York: Churchill Livingstone.
Johnson, G.M., Bogduk, N., Nowitzke, A., & House, D. (1994). Anatomy and action of trapezius muscle. *Clinical Biomechanics, 9*, 44-50.
Julius, A., Lees, R., Dilley, A., & Lynn, B. (2004). Shoulder posture and median nerve sliding. *BMC Musculoskeletal Disorders, 5*.
Jull, G. (1997). Management of cervical headache. *Manual Therapy, 2*, 182-190.
Jull, G., Kristjansson, E., & Dall'Alba, P. (2004a). Impairment in the cervical flexors: A comparison of whiplash and insidious onset neck pain patients. *Manual Therapy, 9*, 89-94.
Jull, G., Sterling, M., Falla, D., Treleaven, J., & O'Leary, S. (2008). Whiplash headache and neck pain: Research-based directions for physical therapies. Edinburgh, UK: Churchill Livingstone, Elsevier.
Jull, G.A., Falla, D., Treleaven, J., Sterling, M., & O'Leary, S. (2004b). A therapeutic exercise approach for cervical disorders. In: Boyling j and jull g, ed. Grieve's modern manual therapy: The vertebral column. Edinburgh, UK: Churchill Livingstone, Elsevier Science (3 ed.).
Karduna, A., McClure, P., Michener, L., & Senett, B. (2001). Dynamic measurements of three-dimensional scapular kinematics: A validation study. *Journal of Biomechanics Eng., 123*, 184-190.
Kebaetse, M., McClure, P., & Pratt, N.A. (1999). Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Archives of Physical Medicine and Rehabilitation, 80*, 945-950.
Kibler, W.B., & McMullen, J. (2003). Scapular dyskinesis and its relation to shoulder pain. *The Journal of the American Academy of Orthopaedic Surgeons, 11*, 142-151.

Kristinsson, B.M. (2008). Áreyðanleiki og réttmæti mælingar brjóstbakssveigju fólks með þvívíddargreini og samanburður aðferðarinnar við Cobb hornið. *Lokaverkefni til B.S. prófs við Háskóla Íslands (BS Thesis), May*.

Kristjansson, E., & Jonsson, H. Jr. (2002). Is the sagittal configuration of the cervical spine changed in women with chronic whiplash syndrome? A comparative computer-assisted radiographic assessment. *Journal of Manipulative and Physiological Therapeutics, 25*, 550-555.

Kristjánsson, EB. (2004). *Clinical characteristics of whiplash associated disorder (WAD), grades I-II: Investigation into the stability system of the cervical spine.*, University of Iceland, Reykjavík. PhD Thesis.

Kuhn, J.E., Plancher, K.D., & Hawkins, R.J. (1995). Scapular winging. *The Journal of the American Academy of Orthopaedic Surgeons, 3*, 319-325.

Ludewig, P.M., & Cook, TM. (2000). Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Physical Therapy, 80*, 276-291.

Ludewig, P.M., Cook, T.M., & Nawoczenski, D.A. (1996). Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *JOSPT, 24*, 57-65.

Ludewig, P.M., Phadke, V., Braman, J.P., Hassett, D.R., Cieminski, C.J., & LaPrade, R.F. (2009). Motion of the shoulder complex during multiplanar humeral elevation. *The Journal of Bone and Joint Surgery, 91*, 378-389.

Magee, D.J. (1987). Orthopedic physical assessment. Philadelphia, PA: WB Saunders Company.

Michener, L.A., McClure, P.W., & Karduna, A.R. (2003). Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clinial Biomechanics, 18*, 369-379.

Mottram, S.L., Woledge, R.C., & Morrissey, D. (2009). Motion analysis study of a scapular orientation exercise and subjects' ability to learn the exercise. *Manual Therapy, 14*, 13-18.

Nagasawa, A., Sakakibara, T., & Takahashi, A. (1993). Roentgenographic findings of the cervical spine in tension-type headache. *Headache, 33*, 90-95.

Nederhand, M.J., Hermens, H.J., IJzerman, M.J., Turk, D.C., & Zilvold, G. (2002). Cervical muscle dysfunction in chronic whiplash-associated disorder grade 2: The relevance of the trauma. *Spine, 27*, 1056-1061.

Sahrmann, S.A. (2002). Diagnosis and treatment of movement impairment syndromes. St. Louis: Mosby Inc.

Sandlund, J., Djupsjöbacka, M., Ryhed, B., Hamberg, J., & Björklund, M. (2006). Predictive and discriminative value of shoulder proprioception tests for patients with whiplash-associated disorders. *Journal of Rehabilitation Medicine, 38*, 44-49.

Sobush, D.C., Simoneau, G.G., Dietz, K.E., Levene, J.A., Grossman, R.E., & Smith, W.B. (1996). The Lennie test for measuring scapular position in healthy young adult females: A reliability and validity study. *JOSPT, 23*, 39-50.

Spitzer, W.O., Skovron, M.L., Salmi, L.R., Cassidy, J.D., Duranceau, J., Suissa, S., et al. (1995). Scientific monograph of the Quebec task force on whiplash-associated disorders: Redefining "whiplash" and its management. *Spine, 15*, 1S-73S.

Sterling, M., Jull, G., & Wright, C. (2001). The effect of musculoskeletal pain on motor activity and control. *The Journal of Pain, 2*, 135-145.
Straker, L.M., O'Sullivan, P.B., Smith, A.J., & Perry, M.C. (2009). Relationships between prolonged neck/shoulder pain and sitting spinal posture in male and female adolescents. *Manual Therapy, 14*, 321-329.
Szeto, G.P.Y., Straker, L.M., & O'Sullivan, P.B. (2005a). A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work - 1: Neck and shoulder muscle recruitment patterns. *Manual Therapy, 10*, 270-280.
Szeto, G.P.Y., Straker, L.M., & O'Sullivan, P.B. (2005b). A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work - 2: Neck and shoulder kinematics. *Manual Therapy, 10*, 281-291.
Szeto, G.P.Y., Straker, L.M., & Raine, S. (2002). A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Applied Ergonomics, 33*, 75-84.
Teece, R.M., Lunden, J.B., Lloyd, A.S., Kaiser, A.P., Cieminski, C.J., Ludewig, P.M. (2008). Three-dimensional acromioclavicular joint motions during elevation of the arm. *J Orthop Sports Phys Ther*, *38*,181-190.
Thigpen, C.A., Padua, D.A., Michener, L.A., Guskiewicz, K., Giuliani, C., Keener, J.D., et al. (2010). Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *Journal of Electromyography and Kinesiology, Jan 21. [Epub ahead of print]*.
Van Dillen, L.R. McDonnell, M.K., Susco, T.M., & Sahrmann, S.A. (2007). The immediate effect of passive scapular elevation on symptoms with active neck rotation in patients with neck pain. *The Clinical Journal of Pain, 23*, 641-647.
Vernon, H., & Mior, S. (1991). The neck disability index: A study of reliability and validity. *Journal of Manipulative and Physiological Therapeutics, 14*, 409-415.
Warner, J.J., Micheli, L.J., Arslania, L.E. (1992). Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and inpingement syndrome: A study using Moire topographic analysis. *Clin Orthop*, *285*,191-199.
Weon, J.H., Oh, J.S., Cynn, H.S., Kim, Y.W., Kwon, O.Y,, & Yi, C.H. (2009). Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. *Journal of Bodyworks & Movement Therapies* (in press).
Williams, P.L., & Warwick, R. (1980). Gray's anatomy, 36th edition. Edinburgh: Churchill Livingstone.
Wu, G., van der Helm, F.C.T., Veeger, H.E.J., Makhsous, M., Van Roy, P., Anglin, C., et al. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion - Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics, 38*, 981-992.
Yip, C.H.T., Chiu, T.T.W., & Poon, A.T.K. (2008). The relation between head posture and severity and disability of patients with neck pain. *Manual Therapy, 13*, 148-154.

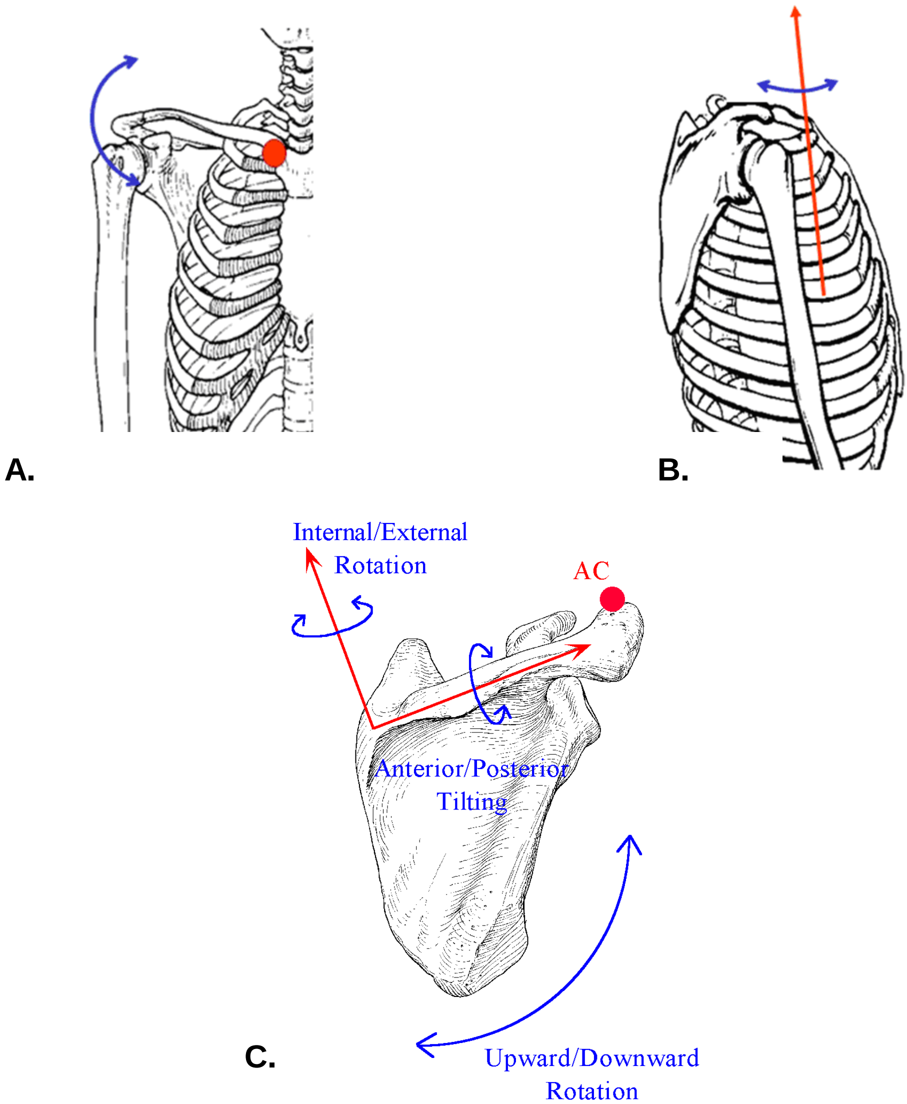


Figure 1 - Clavicle and scapular rotations

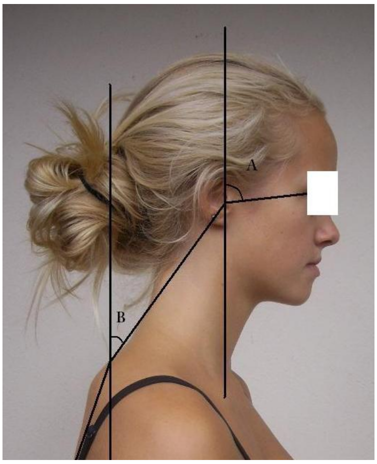


Figure 2 - Angle definitions: The corner of the right eye (canthus), the tragus of the right ear (tragus) and the spinous process of the 7th cervical vertebra (C7) were digitized. The cranial angle (A) is formed by the line of canthus to tragus with respect to vertical plane. The cervical angle (B) is formed by the line of tragus to C7 with respect to vertical plane.

Formula for the MTC.

$$mtc = 4\ x\ \left[\arctan\left(\frac{2\ x\ h}{l}\right)\right]$$

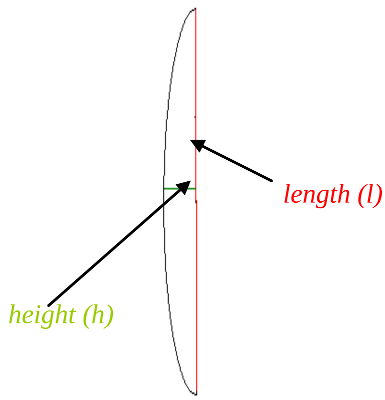
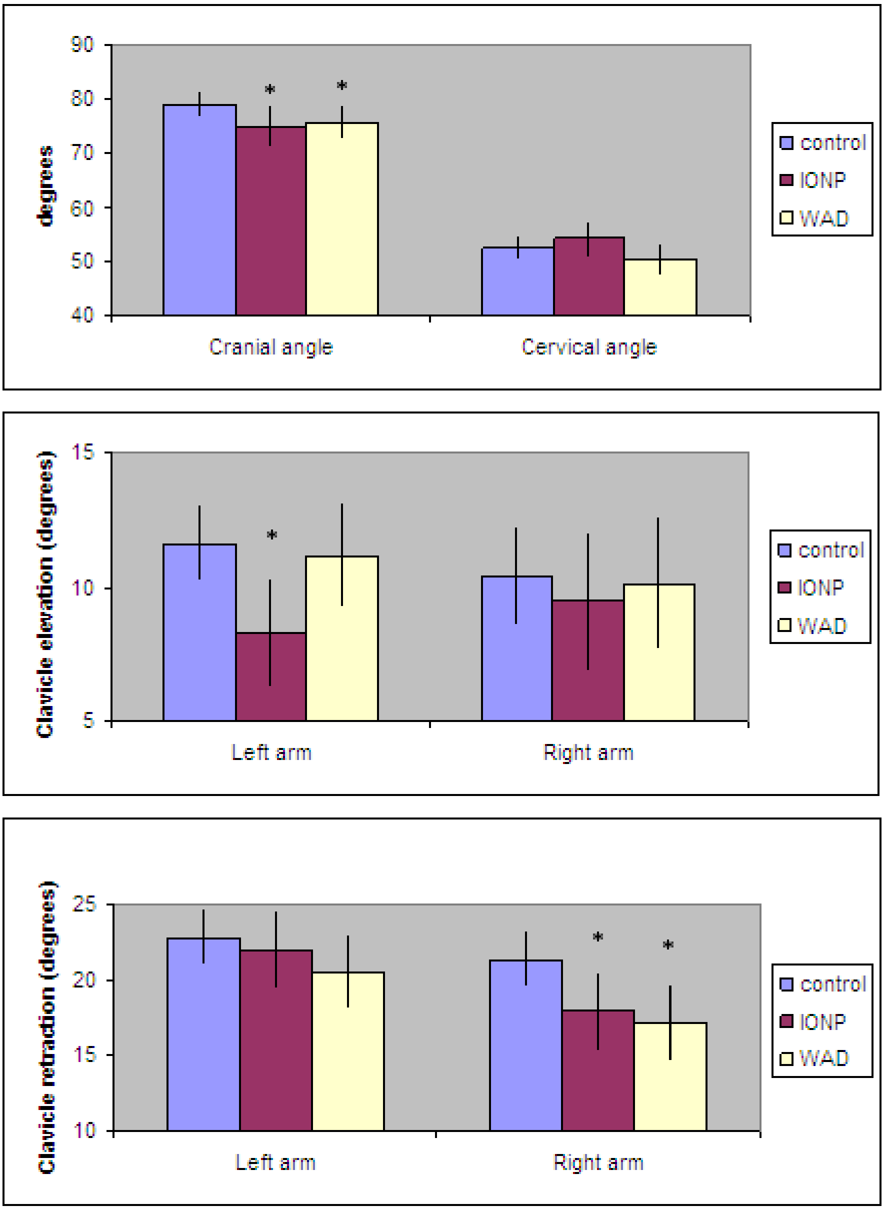


Figure 3 - Illustration and calculation measuring the mid-thoracic curve (MTC).

Figure 4 – Experimental setup. A sensor was attached to the skin of the sternum, to the flat part of the acromion and on the posterior aspect of the humerus. The EMG surface electrodes on the subject were not utilized in this study.


degrees
90
80
70
60
50
40
*
*
Cranial angle
Cervical angle
control
IONP
WAD
Clavicle elevation (degrees)
15
10
5
*
Left arm
Right arm
control
IONP
WAD
Clavicle retraction (degrees)
25
20
15
10
*
*
Left arm
Right arm
control
IONP
WAD

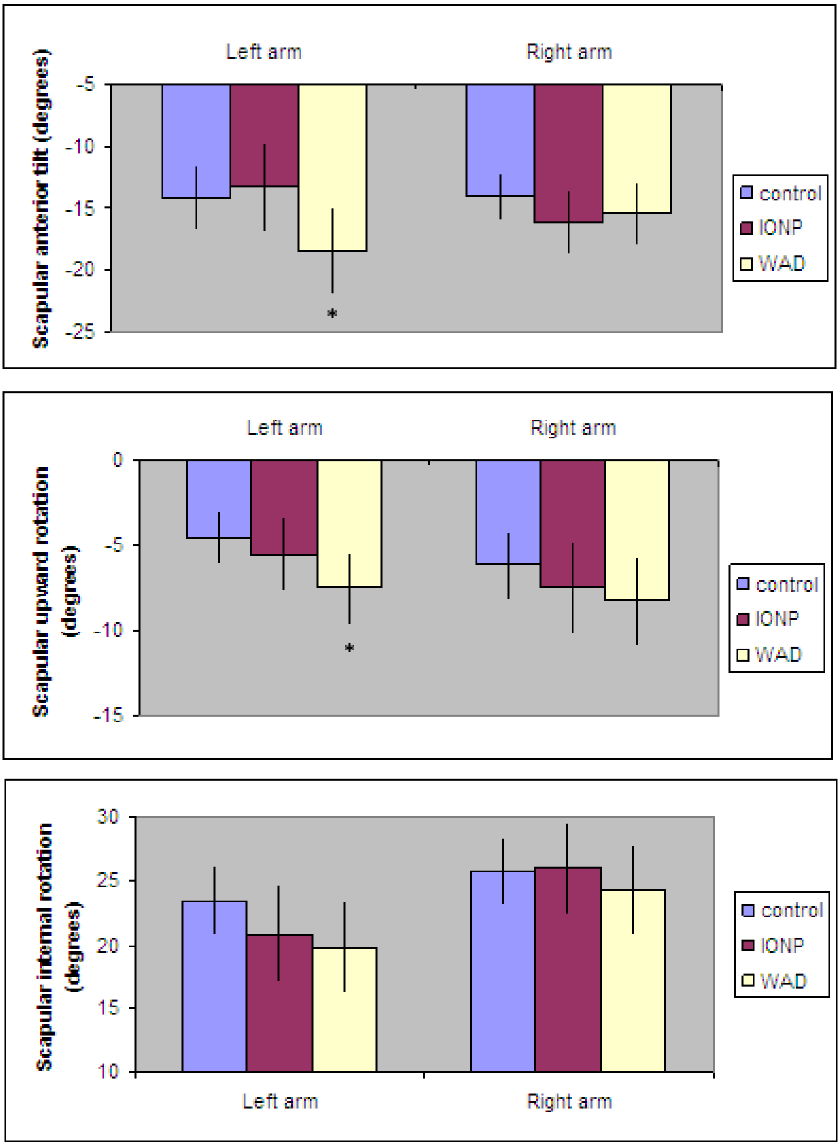


Figure 5 - Columns demonstrating the mean and the 95% confidence intervals of the cranial angle, cervical angle, clavicle elevation and retraction and scapular anterior tilt, upward rotation and internal rotation in the three groups. An asterisk indicates a *P* value of < 0.05.

	control group			IONP group			WAD group		
	Women (n=17) Men (n=3)			Women (n=19) Men (n=2)			Women (n=20) Men (n=3)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age (years)	29,70	7,75	21-51	35,23	8,41	25-54	33,37	9,58	18-50
Height (cm)	171,83	7,77	155-188	170,5	6,07	158-183	170,07	5,26	160-180
Weight (kg)	69,30	10,23	56-100	73,01	16,25	53-128	70,63	10,38	51-92
NDI	0	0	0	29,09	9,77	12-49	38	18,74	12-80

Table 1 - Demographic details of the three groups.

Thorax:
C7: Processus spinosus of the 7th cervical vertebra
T8: Processus spinosus of the 8th thoracic vertebra
IJ: Deepest point of Incisura Jugularis (suprasternal notch)
PX: Processus Xiphoideus, most caudal point of the sternum

Clavicle:
SC: Most ventral point on the sternoclavicular joint
AC: Most dorsal point on the acromioclavicular joint

Scapula:
TS: Trigonum Spinae Scapulae, the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine
AI: angulus inferior most caudal point of the scapula
AA: Angulus acromialis most laterodorsal point of the scapula

Humerus:
EL: Most caudal point on lateral epicondyle
EM: Most caudal point on medial epicondyle

Table 2. Digitized anatomical landmarks

	Left side			**Right side**		
	IONP/control *P*	**WAD/control** *P*	**IONP/WAD** *P*	**IONP/control** *P*	**WAD/control** *P*	**IONP/WAD** *P*
Elevation (+)	0.02*	0.99	0.20	0.99	1.00	0.99
Retraction (+)	0.99	0.70	0.92	0.04*	0.02*	0.99
Anterior tilt (-)	0.99	0.01*	0.00*	0.74	0.81	0.99
Upward rotation (+)	0.89	0.03*	0.77	0.69	0.26	0.99
Internal rotation (+)	0.75	0.20	0.99	1.00	0.89	0.88

Table 3 - Group comparison. The numbers demonstrate *P* values of the clavicle elevation and retraction, and scapular tilt, upward rotation and internal rotation. An asterisk indicates a *P* value of < 0.05

Paper III.

[RESEARCH REPORT]

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Altered Scapular Orientation During Arm Elevation in Patients With Insidious Onset Neck Pain and Whiplash-Associated Disorder

The musculature attaching the shoulder girdle to the axial skeleton is primarily responsible for scapular orientation, as the sternoclavicular joint is the only bony ligament attachment of the shoulder girdle to the trunk. The coordination of the trapezius and serratus anterior muscles is important in controlling scapular orientation during postural function and may be influenced by the activity and extensibility of the levator scapulae, rhomboids, and pectoral muscles, which may compromise the muscle balance.[35,36,41] Biomechanical reasoning indicates that altered activity in these muscles, affecting scapular orientation, may induce detrimental load on the cervical spine.[1,16,21] Increased tension in muscle, such as the levator scapulae through its attachment to the upper 4 cervical segments, may directly induce compressive, rotational, and shear forces on cervical motion segments. The upper trapezius also has the potential to produce tissue distortion through its superior attachment.[1,51] Altered activity in the axioscapular muscles may, therefore, create or sustain symptomatic mechanical dysfunction in the cervical spine and increase the recurrence of neck pain.[1,16,20] Altered activity in the axioscapular muscles and impairments in scapular orientation are considered to be important features in patients with cervical disorders.[19,20] Current therapeutic guidelines for these patients include the analysis and correction of the function of the axioscapular muscles, scapular orientation with arms by the side, and during upper limb activities.[18-20,35] The presence of pain in the neck area has been associated with altered activity in the scapular muscles.[5,11,45] However, scapular dynamic stability has not been investigated in patients with cervical disorders, and, due to lack of research in this field, therapeutic guidelines intended to restore normal scapular function in these patients are based on the results of shoulder studies.[19] It is considered that similar disturbances may be found in these patients, as in patients with shoulder disorders, but this has not been confirmed.[19]

During full arm elevation, the clavicle

STUDY DESIGN: Controlled laboratory study using a cross-sectional design.

OBJECTIVES: To investigate whether there is a pattern of altered scapular orientation during arm elevation in patients with insidious onset neck pain (IONP) and whiplash-associated disorder (WAD) compared to asymptomatic people.

BACKGROUND: Altered activity in the axioscapular muscles and impairments in scapular orientation are considered to be important features in patients with cervical disorders. Scapular orientation has until now not been investigated in these patients.

METHODS: A 3-dimensional tracking device measured scapular orientation during arm elevation in patients with IONP (n = 21) and WAD (n = 23). An asymptomatic group was selected for comparison (n = 20).

RESULTS: The groups demonstrated a significantly reduced clavicle retraction on the dominant side compared to the nondominant side. The WAD group demonstrated an increased elevation of the clavicle compared to the asymptomatic group and the IONP group, and reduced scapular posterior tilt on the nondominant side compared to the IONP group.

CONCLUSION: Altered dynamic stability of the scapula may be present in patients with cervical disorders, which may be an important mechanism for maintenance of recurrence or exacerbation of symptoms in these patients. Patients with cervical disorders may demonstrate a difference in impairments, based on their diagnosis of IONP or WAD. *J Orthop Sports Phys Ther 2010;40(12):784-791. doi:10.2519/jospt.2010.3405*

KEY WORDS: *control, kinetic, neck pain, stability, whiplash*

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undergoes posterior long-axis rotation, retraction, and elevation; and the scapula undergoes upward rotation and posterior tilt relative to the thorax, as well as both internal and external rotation (**FIGURE 1**).[29] Scapular upward rotation contributes to roughly one third of arm elevation, while two thirds occurs in the glenohumeral joint.[7,29]

Scapular dynamic stability has primarily been investigated in association with shoulder pathologies where a reduced clavicle retraction, scapular upward rotation, scapular posterior tilt, and increased clavicle elevation has most commonly been reported and linked to altered activity in the serratus anterior muscle, to imbalances of forces between the upper and lower parts of the trapezius muscle, and to short overactive muscles.[24,25,27,29-31,34,35] Increased cervical and thoracic curves[25] and a slouched posture are also known to affect scapular orientation.[12,23]

The aim of this study was to investigate whether there is a pattern of altered scapular orientation during arm elevation in patients with insidious onset neck pain (IONP) and whiplash-associated disorder (WAD) compared to asymptomatic people. The hypothesis was that patients with cervical disorders demonstrate a pattern of altered scapular orientation.

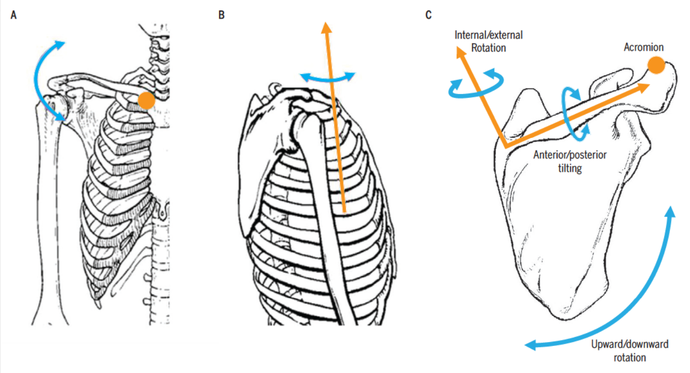

FIGURE 1. Clavicle elevation/depression (A), clavicle protraction/retraction (B), scapular anterior/posterior tilt, scapular upward/downward rotation, and scapular internal/external rotation (C).

TABLE 1 Age, Height, Weight, and the Level of Pain and Disability of the Participants Measured by the NDI*

	Control Group	IONP Group	WAD Group
Sex, (n women, men)	17, 3	19, 2	20, 3
Age (y)	29.7 ± 7.7 (21-51)	35.2 ± 8.4 (25-54)	33.3 ± 9.5 (18-50)
Height (cm)	171.8 ± 7.7 (155-188)	170.5 ± 6.1 (158-183)	170.1 ± 5.3 (160-180)
Weight (kg)	69.3 ± 10.2 (56-100)	73.0 ± 16.2 (53-128)	70.6 ± 10.3 (51-92)
NDI (0-100)	0 ± 0 (0)	29.1 ± 9.7 (12-49)	38.0 ± 18.7 (12-80)

Abbreviations: IONP, insidious onset neck pain; NDI, Neck Disability Index; WAD, whiplash-associated disorder.
** A higher score on the NDI indicates greater pain and disability. Data, except for sex of participants, are expressed as mean ± SD (range).*

METHODS

Participants

This study was approved by The Bioethics Committee of Landspitali University Hospital, and all participants signed a consent form. Because a difference may exist in impairment between patients with IONP and WAD,[8,10,26,37] this study included 2 groups of patients: group 1, with IONP, and group 2, with WAD grade II following a motor vehicle accident.[44] WAD grade II is described as neck complaint of pain, stiffness, or tenderness and musculoskeletal signs, which includes decreased range of motion and point tenderness.[44] Twenty-one participants with IONP (19 women and 2 men) and 23 participants with WAD (20 women and 3 men) were recruited at physical therapy clinics on a voluntary basis in the Reykjavik municipal area. A sample of convenience, consisting of 20 asymptomatic participants (17 women and 3 men), served as controls (**TABLE 1**). All participants were right-handed. The majority of those referred were women, and the men referred were more frequently excluded because of shoulder problems and history of an injury to the upper extremity (especially due to clavicle fractures). Therefore, our symptomatic samples included mostly women. The participants in the control group were selected to match the participants in the symptomatic groups, according to their height, weight, age, gender, and physical activity level. Physical activity level was assessed by asking whether the participants engaged in some kind of physical activity on a regular basis (sports, exercises, etc). If the answer was yes, the participant was asked what kind of physical activity and how many times per week.

Demographic information (height, weight, age, gender, and physical activity level) was collected. Disability was measured with the Neck Disability Index (NDI), which is a self-reporting instrument for the assessment of activities of daily living of individuals with neck pain. The index is considered to be a condition-specific disability rating instrument sensitive to the levels of severity of complaint. It consists of 10 items addressing functional activities, such as personal care, lifting, reading, working, driving, sleeping, and recreational activities, as well as pain intensity, concentration, and headache. There are 6 potential responses for each item, ranging from no disability (0) to total disability (5). The overall score (out of 50) is calculated by adding the responses of each individual item and multiplying by 2. The score is, therefore, presented as a percentage. A higher score indicates greater pain and disability. The interpretation intervals for scoring are as follows: 0 to 8 is no disability, 10 to 28 is mild disability, 30 to 48 is moderate disability, 50 to 68 is severe disability, above 68 is complete disability.[32] Pain intensity was evaluated with a 10-cm visual analogue scale (VAS), anchored by "no pain" and "pain as bad as it can be." The VAS was used to indicate the average intensity of neck pain experienced over the past 7 days.

Inclusion criteria for the pain groups were being 18 to 55 years of age, having a score of at least 10 on the NDI (range, 0-100), and having neck symptoms that had lasted more than 6 months. A score of below 10 on the NDI is scored as "no disability,"[32] and symptoms that have lasted more than 6 months are considered chronic.[15,32] Participants were allocated to 1 of the 3 following groups: group 1, patients with IONP with no history of any accident or whiplash injury; group 2, patients diagnosed with a WAD, who had no prior history of symptoms in the neck area before the motor vehicle accident; and group 3, the controls, who were 18 to 55 years of age and had neither cervical nor shoulder dysfunction. The cervical spine was examined by a physical therapist trained in manual therapy, to confirm the presence or absence of cervical segmental joint dysfunction in patients with neck pain and controls, respectively. The glenohumeral joints were examined for pain, restriction, and impingement signs.[33] Exclusion criteria for all the groups were any known pathology or impairment in the shoulder joint, history of head injury or spinal fractures, systemic pathology, and serious psychological condition.

TABLE 2 Digitized Anatomical Landmarks

Landmarks	Location
Thorax	
C7	Spinous process of the seventh cervical vertebra
T8	Spinous process of the eighth thoracic vertebra
IJ	Deepest point of suprasternal notch
PX	Xyphoid process, most caudal point of the sternum
Clavicle	
SC	Most ventral point on the sternoclavicular joint
AC	Most dorsal point on the acromioclavicular joint
Scapula	
TS	Base of the spine of the scapula, the midpoint of the triangular surface on the medial border of the scapula in line with the scapular spine
AI	Inferior angle, most caudal point of the scapula
AA	Acromion most laterodorsal point of the scapula
Humerus	
EL	Most caudal point on lateral epicondyle
EM	Most caudal point on medial epicondyle

Instrumentation and measurements

Equipment Three-dimensional kinematic data were collected at 40 Hz with the Polhemus 3-Space Fastrak device (Polhemus Inc, Colchester, VT). The manufacturer has reported an accuracy of 0.8 mm and 0.15° for this device, which consisted of a global transmitter, 3 sensors, and a digitizing stylus hardwired to a system electronic unit that determined the relative orientation and position of the digitizer and the sensors through the electromagnetic field emitted by the global transmitter. Information collected by the Fastrak system was sent to a computer with a software system developed by KINE (Hafnarfjordur, Iceland).

Body Segment and Joint Coordinate Systems The current study utilized the definition of body segment and joint coordinate systems for the upper extremity proposed by the Standardization and Terminology Committee of the International Society of Biomechanics (ISB standard). The coordinate systems were defined using the proposed digitized anatomical landmarks (**TABLE 2**). The Euler angle sequences from the ISB standard were applied for all motion descriptions, except for clavicle axial rotation, which was set at 0.[21,22,52]

The digitizing stylus connected to the magnetic tracking device was used to digitize the coordinates of these landmarks. All landmarks were palpable, except for the center of glenohumeral rotation (GH). The GH was estimated by moving the humerus through short arcs (<45°) of midrange glenohumeral motion. The GH was defined as the point on the humerus that moved the least with respect to the scapula when the humerus was moved and was calculated using a least-squares algorithm.[2,14] Based on standard matrix transformation methods, the global axes defined by the sensors of the Fastrak device were converted to anatomically defined axes derived from the digitized bony landmarks.[22]

Experimental Procedure The anatomical landmarks were palpated and marked.[22] Three Fastrak sensors were attached to each participant. Using an adhesive tape, the first sensor was attached to the skin of the sternum (distal to the sternal notch), and the second sensor to the flat part of the acromion. The second sensor evaluated the clavicle and scapular rotations. The third sensor, attached to an elastic strap (Mylatex wrap, 45 cm; Chattanooga Group, Chattanooga, TN), was placed distally on the posterior aspect of the humerus proximal to the epicondyles. These placements have been used previously[27] and validated for these measurements by comparing surface sensor measurement to sensor fixed to pins drilled directly in the scapula. The average root-mean-square error for clavicle and scapular rotations was within 3°, between 30° and 120° of arm elevation in the scapular plane.[22]

The participant was instructed to sit in a comfortable upright position, so that the sacrum was in contact with the back of the chair, with feet placed parallel on the floor (**FIGURE 2**). A flat, vertical surface was positioned along the lateral aspect of the participant's arm to act as a guide to maintain scapular plane, defined as being 30° anterior to the frontal plane. The back of the hand gently contacted the vertical surface. With a metronome set at 60 beats per minute, each participant performed an arm elevation to a count of 3 seconds and a lowering along the same path to a count of 3 seconds, in a continuous movement. Before and between each elevation and lowering of the arm, the participant was instructed to relax for 3 seconds. The following instructions were given to each participant: "Focus on a point on the chart in front of you," and "Allow your hands, shoulders and arms to assume the position they would normally assume by the side." The participant was instructed to maintain this position throughout the digitization and the GH estimation procedure. Following this, the raw data from the sensors were converted into anatomically defined rotations.[22] Kinematic data were collected during 2 elevations of each arm.[22,48] The order of testing was randomized. As both arms were tested, the Fastrak sensors on the scapula and the arm had to be moved to the opposite side when testing was completed on 1 side.

FIGURE 2. Experimental setup. A sensor was attached to the skin of the sternum, to the flat part of the acromion and on the posterior aspect of the humerus. The EMG surface electrodes on the subject were not utilized in this study.

Data Analysis

The main parameter of interest was scapular orientation during arm elevation in the scapular plane. The kinematic data for scapular orientation was described using 2 clavicle rotations (elevation/depression and protraction/retraction) and 3 scapular rotations (anterior/posterior tilt, upward/downward rotation, and internal/external rotation) as dependant variables, measured with the sensor located on the scapula (**FIGURE 1**). A software program (KINE, Hafnarfjordur, Iceland) calculated the scapular orientation of each clavicle and scapular rotation at 30°, 60°, 90°, and 120° of arm elevation. Interpolation was used to retrieve these data. The data were averaged for the 2 repetitions of humeral elevation for each participant.

SPSS Version 18 (SPSS Inc, Chicago, IL) was used for statistical analysis. The age, weight, and height among the 3 groups were compared by analysis of variance (ANOVA). For each group, the mean and standard errors were calculated for the dependant variables of scapular orientation bilaterally. All data satisfied normality assumptions, and parametric tests were subsequently used in all analyses. To compare scapular orientation among the 3 groups, a mixed-model, 3-way ANOVA was used, with 1 between-individual factor (group [IONP, WAD, and controls]) and 2 within-individual factors (side [arm dominance] and angle [30°, 60°, 90°, and 120° of humeral elevation]). Full factorial model was used. In the presence of an interaction, differences were tested at each level of the interacting variable. The significance level for all tests was set at .05.

Pearson correlation between the dependant variables and the scores on the NDI and the VAS were also assessed. Based on the large number of correlations, a threshold of .5 was established as a meaningful correlation.

RESULTS

There was no significant difference in age, weight, and height among the 3 groups (**TABLE 1**). Summary kinematic group data are illustrated in **TABLE 3**, and **FIGURES 3**, **4**, and **5**. Based on visual inspection of the graphs, the general pattern in the 3 groups during arm elevation was for the clavicle to elevate and retract, and the scapula to upwardly rotate and posterior tilt. The scapula also internally rotated until the arm had been elevated up to 90°, then externally rotated until the arm reached 120°.

For clavicle elevation, there was a main effect of side ($F_{1,62} = 4.437$, $P<.05$) due to a 1.7° (SD, 0.8°) overall greater clavicle elevation of the nondominant side compared to the dominant side. There was also an angle-by-group interaction ($F_{3.357,104.07} = 3.708$, $P = .01$), and group differences were, therefore, assessed for each angle. Post hoc comparisons revealed a significantly greater clavicle elevation in the WAD group compared to the asymptomatic group at the

TABLE 3 Summary Data*

	Left Side			Right Side		
	Control	IONP	WAD	Control	IONP	WAD
Clavicle elevation (+)						
30°	12.3 (1.6)	11.2 (1.6)	15.0 (1.6)	10.9 (1.4)	11.3 (2.0)	11.8 (2.0)
60°	14.5 (1.2)	14.2 (1.7)	17.9 (1.7)	13.6 (1.6)	14.0 (2.3)	15.3 (2.2)
90°	17.1 (1.3)	17.9 (1.7)	21.4 (1.7)	15.7 (1.7)	16.8 (2.4)	18.4 (2.4)
120°	19.6 (1.2)	21.2 (1.7)	24.1 (1.6)	17.7 (1.7)	19.3 (2.4)	21.2 (2.3)
Clavicle retraction (+)						
30°	27.9 (1.4)	27.0 (2.0)	25.2 (1.9)	24.8 (1.4)	20.4 (1.9)	21.9 (1.9)
60°	29.6 (1.4)	28.3 (2.0)	26.6 (1.9)	26.8 (1.4)	22.4 (2.0)	23.3 (1.9)
90°	32.5 (1.4)	29.8 (1.9)	28.5 (1.9)	30.3 (1.5)	26.0 (2.1)	26.8 (2.1)
120°	37.3 (1.5)	33.6 (2.1)	32.4 (2.0)	35.9 (1.6)	31.7 (2.2)	32.8 (2.2)
Scapular posterior tilt (+)						
30°	–12.6 (1.7)	–11.2 (2.4)	–15.3 (2.4)	–11.3 (1.3)	–14.3 (1.8)	–11.6 (1.8)
60°	–10.8 (1.8)	–8.7 (2.5)	–13.2 (2.4)	–9.8 (1.4)	–11.6 (2.0)	–10.1 (1.9)
90°	–9.4 (1.8)	–6.2 (2.5)	–11.7 (2.4)	–7.4 (1.4)	–9.1 (2.0)	–8.3 (1.9)
120°	–4.2 (1.8)	–0.9 (2.5)	–6.8 (2.5)	–5.3 (1.7)	–5.4 (2.4)	–4.8 (2.3)
Scapular upward rotation (+)						
30°	0.0 (1.4)	–0.8 (1.9)	–0.7 (1.9)	–2.0 (1.6)	–2.6 (2.2)	–3.6 (2.1)
60°	6.5 (1.5)	5.3 (2.1)	5.8 (2.0)	5.6 (1.6)	3.4 (2.3)	2.9 (2.2)
90°	14.9 (1.5)	13.3 (2.2)	14.2 (2.1)	13.5 (1.6)	11.0 (2.2)	10.9 (2.2)
120°	24.6 (1.7)	23.3 (2.4)	24.1 (2.3)	21.9 (1.6)	19.2 (2.3)	20.1 (2.3)
Scapular internal rotation (+)						
30°	25.7 (1.4)	23.0 (2.0)	23.0 (1.9)	27.7 (1.3)	28.6 (1.8)	26.4 (1.8)
60°	27.2 (1.3)	24.5 (1.8)	25.8 (1.8)	29.1 (1.3)	30.4 (1.8)	28.6 (1.8)
90°	28.6 (1.3)	25.9 (1.8)	28.0 (1.8)	30.2 (1.4)	31.5 (1.9)	30.0 (1.9)
120°	25.4 (1.2)	23.1 (1.7)	25.1 (1.7)	26.7 (1.3)	28.1 (1.8)	26.8 (1.8)

Abbreviations: IONP, insidious onset neck pain; NDI, Neck Disability Index; WAD, whiplash-associated disorder.

** Data are mean (SEM) degrees. Clavicle elevation was significantly greater in the WAD group (n = 23) compared to the asymptomatic (control) group (n = 20) at the 90° and 120° angle but only at the 120° angle compared to the IONP group (n = 21). Clavicle retraction was significantly lower in all groups on the dominant side compared to the nondominant side at the 30°, 60°, and 90° angle, but not the 120° angle. Scapular tilt was significantly different between the IONP and WAD group on the left side, where the WAD group demonstrated reduced posterior tilt and the IONP group increased posterior tilt.*

90° angle ($P<.05$) and compared to both the IONP group ($P<.05$) and the asymptomatic group ($P<.01$) at the 120° angle. No significant difference was observed at any angle between the IONP group and the asymptomatic group (**FIGURE 3**).

For clavicle retraction, there was a significant angle-by-side interaction, whereby the participants responded differently for sides ($F_{1.236,48.366}$ = 14.875, $P<.05$). Post hoc comparison revealed significant differences between the dominant and the nondominant side at 30° ($P<.01$), 60° ($P<.01$), and 90° ($P<.01$) angles, where a reduced clavicle retraction was observed on the dominant side compared with the nondominant side. However, there was no significant difference at 120° (P = .2). The main effects for groups were not significant ($F_{2,61}$ = 2.742, P = .07) (**FIGURE 4**).

For scapular tilt, the groups responded differently for sides ($F_{2,61}$ = 4.492, P = .01). Group differences, therefore, were assessed for each side. Post hoc comparisons revealed no significant differences between the symptomatic groups and the asymptomatic group on either side, but a significant overall difference was observed between the 2 symptomatic groups on the nondominant side ($P<.05$), where the WAD group demonstrated lesser scapular posterior tilt than the IONP group (**FIGURE 5**). Whereas the control group demonstrated no interlimb differences (P = .56), the IONP group demonstrated a 3.5° greater scapular posterior tilt on the nondominant side ($P<.01$). Conversely, the WAD group scapular posterior tilt was greater by 3.5° on the dominant side, although this did not reach statistical significance (P = .06).

There were no group main effects or interaction effects for scapular upward rotation and internal rotation. The correlation between scapular tilt on the nondominant side in the WAD group and the scores on the NDI and VAS were .36 and .49, respectively. The correlation between the other dependant variables and the scores on the NDI and VAS was below .30 in both symptomatic groups.

DISCUSSION

THE RESULTS OF THIS STUDY SUPPORT our hypothesis and suggest a different scapular orientation in patients with cervical disorders compared to asymptomatic people, during dynamic arm movement. The results further suggest that individuals with neck pain have an altered dynamic stability of the scapula, the presentation of which may, in part, relate to their diagnoses.

A significantly reduced clavicle retraction was demonstrated in the symptomatic groups and the asymptomatic group on the dominant side compared to the nondominant side at the 30°, 60°, and 90° angles but not at the 120° angle. The WAD group demonstrated increased elevation of the clavicle compared to the asymptomatic group and the IONP group. A different finding was demonstrated between the symptomatic groups in clavicle elevation and left scapular tilt, suggesting that a difference may exist between the nature of the impairments between

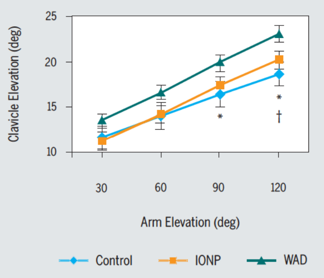

FIGURE 3. Mean (SEM) clavicle elevation during arm elevation. Abbreviations: IONP, insidious onset neck pain; WAD, whiplash-associated disorder. *Statistically significant difference between WAD and control (*P*<.05). †Statistically significant difference between WAD and IONP (*P*<.05).

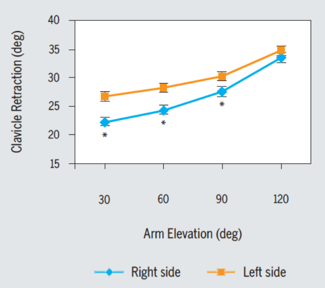

FIGURE 4. Mean (SEM) clavicle retraction during arm elevation for the right and left sides. *Significant interlimb difference (*P*<.01).

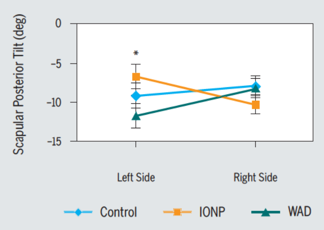

FIGURE 5. Mean (SEM) posterior tilt of the scapula through arm elevation for the left and right sides. Abbreviations: IONP, insidious onset neck pain; WAD, whiplash-associated disorder. *Statistically significant difference between WAD and IONP (*P*<.05).

these groups of patients. The impairments demonstrated in the WAD group are similar to those reported in patients with shoulder problems.[27,30,31,34]

For clavicle retraction, an interaction was demonstrated with side and angle (**FIGURE 4**). This finding corresponds to former studies in which clavicle retraction was typically reduced on the dominant side compared to the nondominant side.[43] This may be related to more use of the dominant arm compared to the nondominant arm and may reflect short overactive pectoral muscles and inefficiency in the trapezius muscle to retract the scapula and resist the activity of the serratus anterior. The middle trapezius is the main retractor, but the transverse-orientated fibers of upper and lower trapezius assist the action.[17,50] Reduced extensibility and overactivity in the pectoralis minor through attachment to the coracoid process, and the pectoralis major through attachment to the humerus, may influence the retraction of the clavicle.[41]

A different finding was revealed between the symptomatic groups in clavicle elevation and left scapular posterior tilt. The WAD group demonstrated an increased clavicle elevation and decreased left scapular posterior tilt compared to the IONP group. It has recently been suggested that clavicle elevation may be coupled with scapular anterior tilt where increased elevation of the clavicle is coupled with increased anterior tilting of the scapula.[47] This abnormality may reflect inefficiency in the action of the serratus anterior and lower trapezius, failing to generate normal posterior tilt and prevent excessive elevation of the scapula.[27,30,41] The contribution of the middle trapezius may also be important to reduce clavicle elevation, as it has been demonstrated that a voluntary reduction of the upper trapezius activity, when the arm is elevated, increases mainly the activity of the rhomboids, the middle trapezius, and the serratus anterior.[40] The reduced posterior tilt is considered to be associated with short overactive pectoralis minor.[41] However, increased activity in the levator scapulae and the rhomboid muscles[28] may explain the increased scapular posterior tilt observed in the IONP group (**FIGURE 5**).[41]

A difference in the activity of the upper trapezius has been found between patients with WAD and IONP, where patients with WAD had a tendency for higher and longer muscle activation patterns of the trapezius during upper limb tasks,[37] reduced ability to relax after tasks,[13] and significantly higher EMG amplitude in the muscle compared to patients with IONP.[10] However, reduced activity has been observed in the upper trapezius in patients with acute WAD (within 6 months from injury) during upper limb tasks. It has been suggested that the difference between patients with acute and chronic WAD may be explained by a greater level of pain and disability in the patients with chronic WAD.[38]

Interestingly, a different finding has been reported between patients with shoulder problems, in which patients with instability demonstrated less-elevated shoulders and patients with impingement syndrome more elevated shoulders on the symptomatic side compared to the asymptomatic side.[49] This difference in the scapular tilt between the symptomatic groups observed only on the nondominant side cannot be related to increased symptoms on that side, as the majority of the patients who participated had bilateral symptoms in the neck area. This finding may, however, be related to decreased proprioception around the shoulders, which has been reported in patients with WAD,[42] in association with less awareness and use of the nondominant arm compared to the dominant arm. Interestingly, EMG amplitude has been reported to increase in the left upper trapezius but decrease in the right trapezius during repetitive upper limb tasks in patients with cervical disorders compared to asymptomatic people.[10]

It has been argued that the presence of pain in the neck area may lead to altered activity in the scapular muscles, due to changes in the feed-forward response of the nervous system[9] or selective reflexive inhibition.[45] This altered activity may occur to minimize the activation of the painful muscles[38] or may reflect effort to compensate for inhibited muscles.[39] The increased clavicle elevation demonstrated in the WAD group may also be connected in some way to neural guarding, as the upper trapezius may contract to reduce compression on the brachial plexus.[6]

The results of this study suggest that altered dynamic stability of the scapula may be present in patients with cervical disorders and demonstrate a difference in the impairments between patients with IONP and WAD. The results suggest that similar impairments may be found in patients with WAD, as in patients with shoulder disorders,[30] but imply that patients with IONP may have different impairments than those previously reported.

Further studies are needed to provide information concerning the contribution of the scapular muscles in maintaining normal scapular orientation, with arms by the side and during arm elevation, in patients with cervical disorders. Information is needed to determine if the upper trapezius demonstrates proportionally reduced activity when the arms are by the side in patients with IONP, compared to asymptomatic people, and proportionally increased activity when the arm is elevated or if the activity is also low during arm elevation and the contribution of levator scapulae and the rhomboid muscles is increased. Fine-wire electrodes measuring the activity of the levator scapulae and the rhomboid muscles, with surface EMG to measure the activity of the trapezius and the serratus anterior, would provide further information about the contribution of each muscle.

The fact that the correlation between the dependant variables and the scores on the NDI and the VAS was not higher ($r<0.5$) suggests that pain or impairment in the neck area may partly be associated with dynamic stability of the scapula that is probably multifactorial in its genesis.

The limitation of the study was that surface sensors may be distorted by skin motion, which is, however, considered minimal within the first 120° of arm elevation.[22] Secondly, while the results only present mean values for each group, a great variability was observed within each group. Therefore, these findings should not be generalized to all patients with neck pain. Thirdly, evaluating for restriction in extensibility in the pectoral muscles might have provided information about the relationship of a restriction to alteration in scapular orientation.[3]

CONCLUSION

A SIGNIFICANTLY REDUCED CLAVICLE retraction was demonstrated in the symptomatic groups and the asymptomatic group, on the dominant side compared to the nondominant side, at the 30°, 60°, and 90° angles but not the 120° angle. The WAD group demonstrated an increased elevation of the clavicle, compared to the asymptomatic group and the IONP group, and reduced scapular posterior tilt on the nondominant side compared to the IONP group. This finding suggests that a difference may exist between the nature of the impairments between these groups of patients. The altered scapular orientation observed in this study suggests that an altered dynamic stability of the scapula may be an important mechanism for maintenance, recurrence, or exacerbation of symptoms in these patients. ◉

KEY POINTS

FINDINGS: In arm elevation, a reduced retraction of the clavicle is observed on the dominant side compared to the nondominant side in individuals with neck pain and asymptomatic individuals. Individuals with neck pain following a motor vehicle accident have increased clavicle elevation compared to people with no pain and people with neck pain and no history of a motor vehicle accident. They also have reduced scapular posterior tilt on the nondominant side compared to people with neck pain and no history of motor vehicle accident.

IMPLICATION: People with whiplash-associated disorder have impairments similar to those with shoulder pain. People with neck pain and no history of a motor vehicle accident demonstrate different impairments.

CAUTION: A high level of variability is observed among individuals. Therefore, these findings may not be generalized to all patients with neck pain.

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REFERENCES

1. Behrsin J, Maguire K. Levator scapulae action during shoulder movement: a possible mechanism for shoulder pain of cervical origin. *Aust J Physiother*. 1986;32:101-106.
2. Biryukova EV, Roby-Brami A, Frolov AA, Mokhtari M. Kinematics of human arm reconstructed from spatial tracking system recordings. *J Biomech*. 2000;33:985-995.
3. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther*. 2005;35:227-238.
4. Braun BL. Postural differences between asymptomatic men and women and craniofacial pain patients. *Arch Phys Med Rehabil*. 1991;72:653-656.
5. Comerford M, MOttram S. *Diagnosis of Uncontrolled Movement, Subgroup Classification and Motor Control Retraining of the Shoulder Girdle*. Ludlow, UK: KC International; 2010.
6. Coppieters MW, Stappaerts KH, Staes FF, Everaert DG. Shoulder girdle elevation during neurodynamic testing: an assessable sign? *Man Ther*. 2001;6:88-96. http://dx.doi.org/10.1054/math.2000.0375
7. Crosbie J, Kilbreath SL, Hollmann L, York S. Scapulohumeral rhythm and associated spinal motion. *Clin Biomech (Bristol, Avon)*. 2008;23:184-192. http://dx.doi.org/10.1016/j.clinbiomech.2007.09.012
8. Elliott J, Sterling M, Noteboom JT, Darnell R, Galloway G, Jull G. Fatty infiltrate in the cervical extensor muscles is not a feature of chronic, insidious-onset neck pain. *Clin Radiol*. 2008;63:681-687. http://dx.doi.org/10.1016/j.crad.2007.11.011
9. Falla D. Unraveling the complexity of muscle impairment in chronic neck pain. *Man Ther*. 2004;9:125-133. http://dx.doi.org/10.1016/j.math.2004.05.003
10. Falla D, Bilenkij G, Jull G. Patients with chronic neck pain demonstrate altered patterns of

muscle activation during performance of a functional upper limb task. *Spine (Phila Pa 1976)*. 2004;29:1436-1440.
11. Falla D, Farina D, Graven-Nielsen T. Experimental muscle pain results in reorganization of coordination among trapezius muscle subdivisions during repetitive shoulder flexion. *Exp Brain Res*. 2007;178:385-393. http://dx.doi.org/10.1007/s00221-006-0746-6
12. Finley MA, Lee RY. Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. *Arch Phys Med Rehabil*. 2003;84:563-568. http://dx.doi.org/10.1053/apmr.2003.50087
13. Fredin Y, Elert J, Britschgi N, Nyberg V, Vaher A, Gerdle B. A decreased ability to relax between repetitive muscle contractions in patients with chronic symptoms after whiplash trauma of the neck. *Journal of Musculoskeletal Pain*. 1997;5:55-70.
14. Harryman DT, 2nd, Sidles JA, Clark JM, McQuade KJ, Gibb TD, Matsen FA, 3rd. Translation of the humeral head on the glenoid with passive glenohumeral motion. *J Bone Joint Surg Am*. 1990;72:1334-1343.
15. Hartling L, Brison RJ, Ardern C, Pickett W. Prognostic value of the Quebec Classification of Whiplash-Associated Disorders. *Spine (Phila Pa 1976)*. 2001;26:36-41.
16. Janda V. Muscles and motor control in cervicogenic disorders: assessment and management. In: Grant R, ed. *Physical Therapy of the Cervical and Thoracic Spine*. New York, NY: Churchill Livingstone; 1994:195-216.
17. Johnson G, Bogduk N, Nowitzke A, House D. Anatomy and action of trapezius muscle. *Clin Biomech*. 1994;9:44-50.
18. Jull G. Management of cervical headache. *Man Ther*. 1997;2:182-190. http://dx.doi.org/10.1054/math.1997.0298
19. Jull G, Falla D, Treleaven J, Sterling M, O'Leary S. A therapeutic exercise approach for cervical disorders. In: Boyling J, Jull G, eds. *Grieve's Modern Manual Therapy: The Vertebral Column*. Edinburgh, UK: Churchill Livingstone; 2004:451-470.
20. Jull G, Sterling M, Falla D, Treleaven J, O'Leary S. *Whiplash Headache and Neck Pain: Research-based Directions for Physical Therapies*. Edinburgh, UK: Churchill Livingstone; 2008.
21. Karduna AR, McClure PW, Michener LA. Scapular kinematics: effects of altering the Euler angle sequence of rotations. *J Biomech*. 2000;33:1063-1068.
22. Karduna AR, McClure PW, Michener LA, Sennett B. Dynamic measurements of three-dimensional scapular kinematics: a validation study. *J Biomech Eng*. 2001;123:184-190.
23. 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.
24. Kibler WB, Ludewig PM, McClure P, Uhl TL, Sciascia A. Scapular Summit 2009: introduction. July 16, 2009, Lexington, Kentucky. *J Orthop Sports Phys Ther*. 2009;39:A1-A13. http://dx.doi.org/10.2519/jospt.2009.0303
25. Kibler WB, McMullen J. Scapular dyskinesis and its relation to shoulder pain. *J Am Acad Orthop Surg*. 2003;11:142-151.
26. Kristjansson E, Jonsson H, Jr. Is the sagittal configuration of the cervical spine changed in women with chronic whiplash syndrome? A comparative computer-assisted radiographic assessment. *J Manipulative Physiol Ther*. 2002;25:550-555. http://dx.doi.org/10.1067/mmt.2002.128371
27. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther*. 2000;80:276-291.
28. Ludewig PM, Cook TM, Nawoczenski DA. Three-dimensional scapular orientation and muscle activity at selected positions of humeral elevation. *J Orthop Sports Phys Ther*. 1996;24:57-65.
29. Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, LaPrade RF. Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Joint Surg Am*. 2009;91:378-389. http://dx.doi.org/10.2106/JBJS.G.01483
30. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther*. 2009;39:90-104. http://dx.doi.org/10.2519/jospt.2009.2808
31. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther*. 1999;29:574-583; discussion 584-576.
32. MacDermid JC, Walton DM, Avery S, et al. Measurement properties of the neck disability index: a systematic review. *J Orthop Sports Phys Ther*. 2009;39:400-417. http://dx.doi.org/10.2519/jospt.2009.2930
33. Magee D. *Orthopedic Physical Assessment*. Philadelphia, PA: WB Saunders Company; 1987.
34. McClure PW, Michener LA, Karduna AR. Shoulder function and 3-dimensional scapular kinematics in people with and without shoulder impingement syndrome. *Phys Ther*. 2006;86:1075-1090.
35. Mottram SL. Dynamic stability of the scapula. *Man Ther*. 1997;2:123-131. http://dx.doi.org/10.1054/math.1997.0292
36. Mottram SL, Woledge RC, Morrissey D. Motion analysis study of a scapular orientation exercise and subjects' ability to learn the exercise. *Man Ther*. 2009;14:13-18. http://dx.doi.org/10.1016/j.math.2007.07.008
37. Nederhand MJ, Hermens HJ, MJ IJ, Turk DC, Zilvold G. Cervical muscle dysfunction in chronic whiplash-associated disorder grade 2: the relevance of the trauma. *Spine (Phila Pa 1976)*. 2002;27:1056-1061.
38. Nederhand MJ, Hermens HJ, MJ IJ, Turk DC, Zilvold G. Chronic neck pain disability due to an acute whiplash injury. *Pain*. 2003;102:63-71.
39. O'Leary S, Falla D, Elliott JM, Jull G. Muscle dysfunction in cervical spine pain: implications for assessment and management. *J Orthop Sports Phys Ther*. 2009;39:324-333. http://dx.doi.org/10.2519/jospt.2009.2872
40. Palmerud G, Sporrong H, Herberts P, Kadefors R. Consequences of trapezius relaxation on the distribution of shoulder muscle forces: an electromyographic study. *J Electromyogr Kinesiol*. 1998;8:185-193.
41. Sahrmann S. *Diagnosis and Treatment of Movement Impairment Syndromes*. St Louis, MO: Mosby; 2002.
42. Sandlund J, Djupsjobacka M, Ryhed B, Hamberg J, Bjorklund M. Predictive and discriminative value of shoulder proprioception tests for patients with whiplash-associated disorders. *J Rehabil Med*. 2006;38:44-49.
43. Sobush DC, Simoneau GG, Dietz KE, Levene JA, Grossman RE, Smith WB. The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *J Orthop Sports Phys Ther.* 1996;23:39-50.
44. Spitzer WO, Skovron ML, Salmi LR, et al. Scientific monograph of the Quebec Task Force on Whiplash-Associated Disorders: redefining "whiplash" and its management. *Spine (Phila Pa 1976)*. 1995;20:1S-73S.
45. Sterling M, Jull G, Wright A. The effect of musculoskeletal pain on motor activity and control. *J Pain*. 2001;2:135-145. http://dx.doi.org/10.1054/jpai.2001.19951
46. Szeto GP, Straker L, Raine S. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Appl Ergon*. 2002;33:75-84.
47. Teece RM, Lunden JB, Lloyd AS, Kaiser AP, Cieminski CJ, Ludewig PM. Three-dimensional acromioclavicular joint motions during elevation of the arm. *J Orthop Sports Phys Ther*. 2008;38:181-190. http://dx.doi.org/10.2519/jospt.2008.2386
48. Thigpen CA, Gross MT, Karas SG, Garrett WE, Yu B. The repeatability of scapular rotations across three planes of humeral elevation. *Res Sports Med*. 2005;13:181-198.
49. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using Moire topographic analysis. *Clin Orthop Relat Res*. 1992;191-199.
50. Wickham J, Pizzari T, Stansfeld K, Burnside A, Watson L. Quantifying 'normal' shoulder muscle activity during abduction. *J Electromyography Kinesiol*. 2010;20:212-222.
51. Williams P. *Gray's Anatomy*. 36th ed. London, UK: Churchill Livingstone; 1980.
52. Wu G, van der Helm FC, Veeger HE, et al. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder, elbow, wrist and hand. *J Biomech*. 2005;38:981-992.

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