[RESEARCH REPORT]

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

• **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*

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

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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.

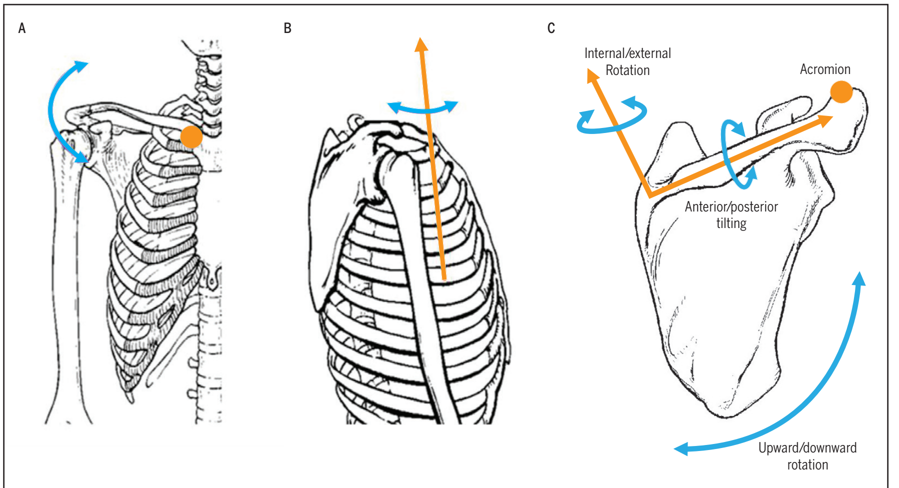

FIGURE 1. Clavicle elevation/depression (A), clavicle protraction/retraction (B), scapular anterior/posterior tilt, scapular upward/downward rotation, and scapular internal/external rotation (C).

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

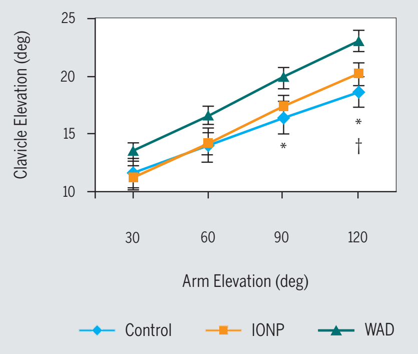

FIGURE 3. Mean (SEM) clavicle elevation during arm elevation. Abbreviations: IONP, insidious onset neck pain; WAD, whiplash-associated disorder. *Statistically significant difference between WAD and control (*P*<.05). †Statistically significant difference between WAD and IONP (*P*<.05).

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

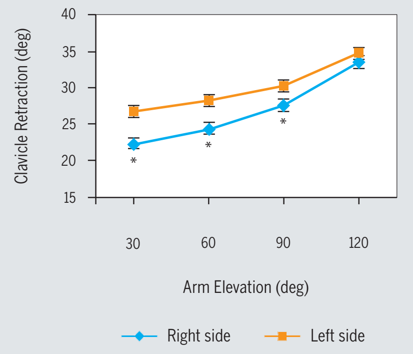

FIGURE 4. Mean (SEM) clavicle retraction during arm elevation for the right and left sides. *Significant interlimb difference (*P*<.01).

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

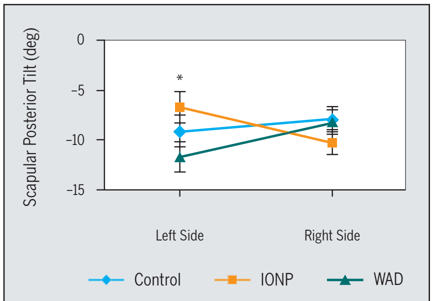

FIGURE 5. Mean (SEM) posterior tilt of the scapula through arm elevation for the left and right sides. Abbreviations: IONP, insidious onset neck pain; WAD, whiplash-associated disorder. *Statistically significant difference between WAD and IONP (*P*<.05).

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.