**Title:** Alterations in the 3-dimensional scapular orientation in patients with nonspecific neck pain

**Authors:** Yildiz TI, Cools A, Duzgun I

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**Presented by:** Nipaporn Wannaprom, Student code 611155902, PhD. student in Biomedical Science.

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**Abstract**

**Background:** Alterations of scapular posture and movement have been demonstrated in patients with neck pain. However, there is still controversy and no clear information about the relationship between neck pain and scapular dysfunction.

**Objective:** To investigate the alterations in the 3-dimensional scapular orientation during multiplanar upper extremity movements on patients with chronic non-specific neck pain (CNNP).

**Methods:** Thirty-four patients with CNNP (age 29.1±5.0 years) and 29 healthy controls (age 28.2±3.3 years) were recruited. Flock of Birds electromagnetic device was used for collecting 3-dimensional scapular kinematics at 30°, 60°, 90°, 120° of humerothoracic elevations during raising and lowering phases in the sagittal, scapular, and frontal planes. Scapular kinematics was described in 3 rotation including internal/external rotation, upward/downward rotation and anterior/posterior tilt.

**Results:** Patients with CNNP demonstrated reduced scapular upward rotation on both the dominant and non-dominant sides in all three planes compared to healthy controls ($p < 0.05$). Patients with CNNP had increased scapular external rotation in the sagittal and frontal planes on the dominant side and increased scapular internal rotation in the frontal plane on the non-dominant side when compared to healthy controls ($p < 0.05$). There was no difference for scapular posterior tilt between groups.

**Conclusion:** Patients with CNNP demonstrated alterations in the 3-dimensional scapular orientation especially in the scapular upward rotation during elevation tasks. It suggested that scapula should be included to assessment and management on patients with neck pain.
Alterations in the 3-dimensional scapular orientation in patients with non-specific neck pain

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ABSTRACT

Background: Although it is thought that there is a relationship between neck pain and scapular dysfunction, there are controversial results and no clear information in the literature regarding this issue. This study aimed to investigate the alterations in the 3-dimensional scapular orientation on patients with non-specific neck pain.

Method: Thirty-four patients with chronic non-specific neck pain [age, 29.1 (5) years; height, 165.3 (6.1) centimeters; weight, 62.1 (9.6) kilogram] and 29 healthy controls [age, 28.2 (3.3) years; height, 166.8 (8.1) centimeters; weight, 60.9 (8.5) kilogram] were included in the study. 3-Dimensional scapular kinematics were obtained during arm elevation and lowering trials in the sagittal, scapular, and frontal planes.

Findings: Compared to healthy controls, the patients with neck pain demonstrated significantly reduced upward scapular rotation on both the dominant and non-dominant sides in all three planes. Patients with neck pain had increased internal rotation in the sagittal and frontal planes on the dominant side and increased external rotation in the frontal plane on the non-dominant side. No difference was observed between groups considering posterior scapular tilt.

Interpretation: There are alterations in the 3-Dimensional scapular orientations in patients with chronic non-specific neck pain compared to healthy controls. Therefore, the scapular control may also be examined in patients with neck pain and it can be included in the rehabilitation program if needed.

1. Introduction

Having a prevalence of between 30% and 50% in 12 months, neck pain is one of the most common and disabling musculoskeletal problems (Haldeman et al., 2010; Vos et al., 2012). In most of the patients, no specific pathology can be identified for the onset of the symptom; therefore, it is referred to as “non-specific neck pain (NNP)” (Childs et al., 2008). If the symptoms last longer than six months, the problem is called chronic non-specific neck pain (CNNP) (Helgadottir et al., 2010). Several potential mechanisms have been proposed as the underlying cause of the NNP; however, the exact mechanism is not clear yet. One of the important factors related to neck pain is muscle impairments on the cervical region (Cagnie et al., 2014).

Cervical and scapular regions are linked to each other via the axioscapular musculature. Therefore, alterations in the function of the axioscapular muscles are thought to induce abnormal mechanical stress on pain-sensitive cervical structures and may cause neck pain (Behrsin and Maguire, 1986; Falla et al., 2004; Jull et al., 2008a). There are number of studies aimed to investigate the activity patterns of axioscapular musculature on patients with neck pain. Most of the studies reported alterations in the activity behavior of the upper trapezius (UT) muscle during upper extremity movements (Falla et al., 2004; Johnston et al., 2008; Leonard et al., 2010; Nederhand et al., 2000; Zakharova-Luneva et al., 2012). Similarly, there can also be alterations in the function of the middle and lower trapezius (MT and LT) on patients with CNNP (Castelein et al., 2016; Zakharova-Luneva et al., 2012). In contrast to trapezius, serratus anterior (SA) muscle was found to have similar activity patterns on the healthy subjects and patients with CNNP (Castelein et al., 2016). However, it was also reported that SA has a delayed onset of activity and less duration of activation on patients with CNNP compared to healthy subjects (Helgadottir et al., 2011a). Moreover, studies also reported tightness in the levator scapula (LS) and UT muscles and decreased ability to relax in the UT after completion of a functional task on patients with CNNP (Behrsin and Maguire, 1986; Fredin et al., 1997; Jull et al., 2008b). Although there are some inconsistencies, generally neck pain is thought be in relation with the...
altered control of the axioskapular muscles.

Scapular orientation is primarily controlled by the axioskapular muscles. Therefore, alterations in the axioskapular musculature might cause abnormal scapular orientations on patients with CNNP. There are some studies investigated the relationship between scapular dysfunction and neck pain. Among the 2-dimensional motion analysis studies, two of them reported that scapular dysfunction can be observed on patients with neck pain (Özgünül Pekalyavş and n.d.; Szeto et al., 2002), while another study found no correlation between scapular dysfunction and neck pain (Castelain et al., 2016). Three studies investigated the alterations in the 3-dimensional scapular orientation on patients with CNNP. Scapula was found to be more downwardly rotated during the resting position on patients with CNNP compared to asymptomatic subjects (HelgadoTTir et al., 2011b). Likewise, Zabihihosseinian et al. also reported reduced scapular upward rotation (UR) on patients with neck pain compared to healthy subjects (Zabihihosseinian et al., 2017). However, another study revealed no differences in the 3-dimensional scapular orientation between with CNNP compared to healthy subjects (HelgadoTTir et al., 2010). There is still controversy and no clear information about the relationship between neck pain and scapular dysfunction.

In the literature, some studies investigated the effects of scapular correction strategies on neck pain due to the complex relationship between neck pain and scapular dysfunction. Immediate passive correction was found to help to regulate the activity of the trapezius and decrease the neck pain in some studies (Ha et al., 2011; Wegner et al., 2010). In contrast, Luch et al. (2014) found no effects of passive scapular correction on patients with neck pain. In addition, Yildiz et al. (2018) found no effects of 6 weeks of scapular stabilization exercise on patients with CNNP. There are also discrepancies in the literature about whether scapula should be included to the rehabilitation program on patients with neck pain. A clear understanding is needed about the relationship between the neck pain and scapular dysfunction to improve treatment methods. Yet, there is no clear information whether there is a relationship between neck pain and scapular dysfunction. Therefore, the aim of the study was to investigate the alterations in the 3-dimensional scapular orientation during multiplanar upper extremity movements on patients with CNNP.

2. Methods

2.1. General design

This was a cross-sectional study including patients with CNNP and asymptomatic-healthy control group. The differences in the scapular kinematics (scapular upward-downward rotation, internal-external rotation, and anterior-posterior tilt) between patients with CNNP and health subjects during upper extremity movements were investigated. Patients were initially recruited from the Hacettepe University Hospital, Ankara/Turkey between June 2017 and January 2018. Among the patients diagnosed with CNNP by an orthopedist the ones who met the inclusion criteria for all participants were: having a history of spinal injury or surgery, any known pathology or impairment in the shoulder joint and serious psychological condition. In total, 34 patients with CNNP (29 female and 5 male) and 29 healthy controls (23 female and 6 male) were included in the study. The Demographic information (age, weight, height and dominant side) of the participants was collected prior to the study. The dominant side was determined based on the hand dominance on both groups.

2.3. Instrumentation and experimental procedure

Scapular kinematic data were collected with Flock of Birds electromagnetic device (Ascension Technology Corporation, Shelburne, VT). The device consists of a transmitter and 6 sensors (1.9 × 3.3 × 3.5 cm) integrated with Motion Monitor software (Innovative Sports Training Inc., Chicago, USA).

Prior to the measurements, specific bony landmarks on the participants were marked with a board marker for the digitization process (Table 1) (HelgadoTTir et al., 2010). Later on, the sensors were placed. The first sensor was fixed to the spinous process of the first thoracic vertebrae, the second and the third sensors were fixed bilaterally to the flat surface of the acromion, and the fourth and the fifth sensors were attached to the participants with two-sided adhesive tapes and secured with straps. After the sensor placements, participants were instructed to stand in a relaxed posture in front of the transmitter while their backs turn to the transmitter and face to the positive ‘x’ axis (Fig. 1). The sixth sensor was used for digitization of the anatomic landmarks and a three-dimensional image of the participants was obtained. The coordinate system of the scapula, thorax, and humerus was defined using the digitization points. Sensor placements and digitization process were conducted according to the recommendation of International Society of Biomechanics (ISB) (Wu et al., 2005). The rotation center of glenohumeral joint was calculated with regression analysis (Meskers et al., 1997). The ‘y-x-z’ Euler angle sequence was used to describe scapular rotations relative to thorax (Wu et al., 2005). The system was set so that scapular internal-external rotation (IR-ER) occurs around ‘y’ axis, upward-downward rotation (UR-DR) occurs around ‘x’ axis and anterior-posterior tilt (AT-PT) occurs around ‘z’ axis.

The testing procedure was conducted on the same position that the digitization process was held. In front of the transmitter, a straight line

<table>
<thead>
<tr>
<th>Toraks</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8</td>
<td>Processus Spinous of the eighth thoracic vertebrae</td>
</tr>
<tr>
<td>C7</td>
<td>Processus Spinous</td>
</tr>
<tr>
<td>U</td>
<td>The deepest point of suprasternal notch</td>
</tr>
<tr>
<td>PX</td>
<td>Most caudal point of sternum (processus xiphoideus)</td>
</tr>
<tr>
<td>Scapula</td>
<td>Most caudal point of scapula (angulus inferior)</td>
</tr>
<tr>
<td>AA</td>
<td>Most latero-dorsal point of scapula (angulus acromialis)</td>
</tr>
<tr>
<td>TS</td>
<td>Midpoint of triangular surface on the medial border of the scapula in line with the scapular spine (trigonum spina scapula)</td>
</tr>
<tr>
<td>Humerus</td>
<td>Most caudal point of lateral epicondyle</td>
</tr>
<tr>
<td>LE</td>
<td>Most caudal point of medial epicondyle</td>
</tr>
</tbody>
</table>
was drawn on the ground and participants asked to stand while their
heels were on the line. During the testing procedure, participants
performed arm elevation trials in the sagittal, scapular and frontal planes.
The scapular plane (ScP) was defined as 40° of anterior to the frontal
plane (McClure et al., 2001). Two leader sticks were used to guide the
participants and maintain proper line of movement during arm eleva-
tion trials. In order to standardize the velocity of the movement, a
metronome was set at 60 beats per minute and participants performed
maximum arm elevation and lowering in a count of 6 beats (3 beats for
elevation and 3 beats for lowering) without stopping the movement.
Participants performed the arm elevation trials in their relaxed posture
so that we could assess the most natural movement patterns of the
scapula. To eliminate the effects of shoulder rotation on scapular ki-
nematics, all participants asked to keep their thumb upwardly during
the arm movements. Participants practiced 2 repetitions of arm eleva-
tion and lowering in all planes prior to the testing procedure for the
familiarization.

During the testing procedure, participants performed 3 arm elevation
trials in the sagittal (SP), ScP, and frontal (FP) planes while
maintaining the relaxed posture (Fig. 1). The order of planes was ran-
domized. The kinematic data was captured continuously for each arm
elevation trials. Scapular kinematics (IR-ER, UR-DR, and AT-PT) were
selectively chosen and recorded at 30°, 60°, 90°, 120° of humerothoracic
elevations during the elevation and the lowering phases of the move-
ment. The mean value of 3 arm elevation trials was recorded for sta-
tistical analysis.

2.4. Statistical analysis

2.4.1. Sample size calculation

Sample size was priori calculated with a significance level of 0.05
and a power of 0.80. It was aimed to detect a difference in scapular UR
of 5.9° with a standard deviation of 9.8° between the two groups during
the arm elevation in the ScP (Ogston and Ludewig, 2007). Based on
these criteria, at least 52 participants in total were required (26 par-
ticipants for each group). A total of 63 participants (34 in Group-1 and 29
in Group-2) were included in the study. Our total sample size provided
0.98 power in the post-hoc analyses.

2.5. Data analysis

SPSS version of 22.0 (IBM Corp. SPSS Inc., Chicago, IL) was used for
statistical analyses. The demographic data and NDI scores between
groups were analyzed using independent sample t-test. A 2-by-8, 2-way
repeated measures of analysis of variance (ANOVA) was used to
compare the kinematic data between groups. The grouping variable
(CNNP and control) was determined as the between-subject factor to
identify the differences between the two groups for each arm elevation
degrees (30°, 60°, 90°, 120° of elevation and 120°, 90°, 60°, 30° of
lowering phases). Arm elevation on each plane was analyzed sepa-
ratey. A greenhouse-geisser correction was used when the sphericity
was not assumed. The significance level set at 0.05. When there was a
significant interaction between groups, pairwise comparisons between
groups evaluated at each angle.

The effect sizes of both significant and non-significant results be-
tween the two groups were calculated using Cohen-d coefficient score
for each arm elevation and lowering degrees (Cohen, 1988). An effect
size of lower than 0.2 was considered as small, around 0.5 was medium
and > 0.8 was large effect size (Cohen, 1988). All kinematic data was
reported with 95% confidence interval (CI).

3. Results

The kinematic data of the current study demonstrate excellent intra-
session reliability. The intercorrelation coefficient scores were ranging
from 0.95 to 0.99 on the dominant side and 0.81 to 0.98 on the ND side.
In addition, the standard error of our intra-session measurements was
between 0.81° and 1.41° on the dominant side and 0.8° and 3.4° on the
ND side. There were no differences between groups in terms of age,
hight and weight (p > 0.05) (Table 2). The mean score of NDI on
group-1 and group-2 was 29.4 and 5.1 points respectively. Group-1 had
significantly higher NDI score compared to group 2 (p < 0.001).

3.1. Scapular internal rotation

In the SP, there was a significant angle-by-group interaction (F113.1,
1.8, = 3.523, p = 0.03) on the dominant side. Pairwise comparisons
revealed a more internally rotated scapula on group-2 compared to
-group-1 at 30°, 60°, and 90° of humerothoracic elevations on both the
elevation and lowering phases. For the non-dominant (ND) side, there
was also a significant angle-by-group interaction (F156.8, 2.6 = 3.564,
p = 0.02). However, pairwise comparisons revealed no differences be-
tween groups during the arm elevation (p > 0.05). The significance
level was not due to group difference but the different scapular internal
rotation degrees at different arm elevation angles.

In the ScP, there were no angle-by-group interactions on both the
dominant (F105.1.7 = 0.768 p = 0.44) and ND sides (F138.6, 2.3 = 1.47
p = 0.2). Yet there were significant main effects of elevation on both the
dominant (F105, 1.7 = 11.978 p < 0.001) and the ND (F138.6,
2.3 = 5.467 p = 0.003) sides.

In the FP, significant angle-by-group interaction was observed be-
tween groups on both the dominant (F109, 1.7 = 5.909 p = 0.005) and
the ND sides (F131.2, 2.1 = 3.712 p = 0.02). Pairwise comparisons re-
vealed more internally rotated scapula on group-2 at 120° of humer-
othoracic elevation during the elevation and lowering phases of arm
elevation on the dominant side (p < 0.05). For the ND side, the scapula
was more internally rotated on group-1 compared to group-2 at 30° and
60° of humerothoracic elevations during the elevation and lowering
phases of the humerothoracic elevation (p < 0.05) (Table 3).

The Cohen-d score showed variable effect of pain on the scapular IR
(ranging from 0 to 0.94) during the elevation and lowering phases of
humerothoracic arm elevation (Table 3).

Table 2

<table>
<thead>
<tr>
<th>Age (SD) (years)</th>
<th>Height (SD) (cm)</th>
<th>Weight (SD) (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>29.1 (5)</td>
<td>165.3 (6.1)</td>
</tr>
<tr>
<td>Group 2</td>
<td>28.2 (3.3)</td>
<td>166.8 (8.1)</td>
</tr>
</tbody>
</table>

Abbreviations. SD: Standard deviation, cm: centimeter, kg: kilogram.
3.2. Scapular upward rotation

In the SP, there were significant angle-by-group interactions on both the dominant (F102.5, 1.6 = 5.219 p = 0.01) and ND sides (F134.2, 2.2 = 4.459 p = 0.01). Pairwise comparisons revealed a more upwardly rotated scapula on group-2 compared to group-1 at all humerothoracic elevation angles during arm elevation trials on both the dominant and ND sides (p < 0.05).

In the ScP, significant angle-by-group interaction was observed on both the dominant (F110.1, 1.8 = 7.085 p = 0.002) and ND sides (F140.8, 2.3 = 4.245 p = 0.012). Pairwise comparisons showed that the scapula was more upwardly rotated on group-2 compared to group-1 at all humerothoracic elevation angles during arm elevation trials on both the dominant and ND sides (p < 0.05).

In the FP, there were also significant angle-by-group interactions on both the dominant (F124.1, 2 = 5.889 p = 0.003) and ND sides (F128.8, 2.1 = 3.557 p = 0.02). Pairwise comparisons revealed greater upward rotation on group-2 compared to group-1 at all humerothoracic elevation angles during arm elevation trials on both the dominant and ND sides (p < 0.05) (Table 4).

The Cohen-d score indicated that neck pain has medium to large effect on the scapular UR rotation (ranging between 0.67 and 1.77) during the arm elevation and lowering (Table 4).

3.3. Scapular posterior tilt

In SP, there were no significant angle-by-group interactions on both the dominant (F115.2, 1.8 = 1.202 p = 0.3) and ND sides (F127.5, 2.1 = 2.018 p = 0.13). However, there was main effect of elevation on both the dominant (F115.2, 1.8 = 19.661 p < 0.001) and ND sides (F127.5, 2.1 = 25.120 p < 0.001).

In ScP, no significant angle-by-group interaction was observed either on dominant (F87.6, 1.4 = 0.131 p = 0.8) or on ND side (F94.7, 1.5 = 0.161 p = 0.8). The main effect of elevation was significant on ND side (F94.7, 1.5 = 20.894 p < 0.001).

In FP, there were no significant angle-by-group interactions on both the dominant (F104.1, 1.7 = 0.168 p = 0.8) and ND sides (F100.8, 1.6 = 0.461 p = 0.5). But elevation had significant main effect on both the dominant (F104.1, 1.7 = 8.735 p = 0.001) and ND sides (F100.8, 1.6 = 15.064 p < 0.001) (Table 5).

The Cohen-d score showed that pain has small to medium effect on the scapular PT (ranging between 0 and 0.46) during the arm elevation and lowering.

All scapular kinematics were summarized in Figs. 2, 3, and 4.

4. Discussion

Current study aimed to investigate the alterations in the 3-dimensional scapular orientation on patients with CNNP. The results of the study support the hypothesis that patients with CNNP have altered scapular orientation. Compared to healthy controls, patients with CNNP demonstrated reduced scapular UR on both the dominant and ND sides during humerothoracic elevation in all 3 planes.

Scapular UR is mainly coordinated by trapezius and SA muscles. Patients with CNNP were found to demonstrate reduced activity in the trapezius and SA (Cagnie et al., 2014; Helgadottir et al., 2011a). The decreased or inefficient activity in the behavior of the axioscapular muscles might have caused the reduced scapular UR (Huang et al., 2015). Moreover, the tightness and reduced extensibility in the LS on patients with CNNP may also induce reduced scapular UR (Behrisn and Maguire, 1986). In contrast to our results, Zabihhosseinian et al. (2017) found increased scapular UR on patients with neck pain compared to healthy subjects. However, they collected the kinematic data during seated and upright position, while we collected the kinematics data during standing in a relaxed posture. The scapular kinematics are highly dependent on the posture (Kebaetse et al., 1999). Therefore, the difference in the participants’ posture during testing procedure might cause the discrepancies between the results of the studies. Moreover, the upright posture of the shoulder and the cervical spine may enhance the SA muscle activity and the length-tension relationship of the upper trapezius and SA (Cagnie et al., 2014; Helgadottir et al., 2011a).
Trapezius (Thigpen et al., 2010; Weon et al., 2010). This may also explain the differences between the two studies.

The interesting results of this study were that the scapula was more externally rotated on the dominant side, while it was more internally rotated on the ND side compared to healthy controls. Significantly increased scapular ER was observed on patients with NNP on the dominant side on SP and FP (Fig. 2). The increased activity in the MT (Wegner et al., 2010) and rhomboid muscles (Ludewig et al., 1996), and tightness in the rhomboids (Sahrmann, 2002) might be the reason for the increased scapular ER on the dominant side of patients with CNNP.

Table 4
Summary of the scapular upward rotation data (+).

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Non-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain mean (SD)</td>
<td>Healthy control mean (SD)</td>
</tr>
<tr>
<td>Sagittal plane</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3.4(6.5)</td>
</tr>
<tr>
<td>60</td>
<td>10.2(8.2)</td>
</tr>
<tr>
<td>90</td>
<td>17.6(9.5)</td>
</tr>
<tr>
<td>120</td>
<td>23.8(11.8)</td>
</tr>
<tr>
<td>120</td>
<td>23.4(12.3)</td>
</tr>
<tr>
<td>90</td>
<td>17(10.8)</td>
</tr>
<tr>
<td>60</td>
<td>9.9(9.5)</td>
</tr>
<tr>
<td>30</td>
<td>2.6(8.3)</td>
</tr>
</tbody>
</table>

Scapular plane

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Non-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain mean (SD)</td>
<td>Healthy control mean (SD)</td>
</tr>
<tr>
<td>30</td>
<td>7.8(7)</td>
</tr>
<tr>
<td>60</td>
<td>14.6(8.4)</td>
</tr>
<tr>
<td>90</td>
<td>21.8(11)</td>
</tr>
<tr>
<td>120</td>
<td>20.9(13.3)</td>
</tr>
<tr>
<td>60</td>
<td>5.6(8.8)</td>
</tr>
<tr>
<td>30</td>
<td>1(2.75)</td>
</tr>
</tbody>
</table>

Abbreviations. SD: Standard deviation.

Table 5
Summary of the scapular posterior tilt data (+).

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Non-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain mean (SD)</td>
<td>Healthy control mean (SD)</td>
</tr>
<tr>
<td>Sagittal plane</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>−0.5(6.6)</td>
</tr>
<tr>
<td>60</td>
<td>8(7.8)</td>
</tr>
<tr>
<td>90</td>
<td>15.3(9.8)</td>
</tr>
<tr>
<td>120</td>
<td>22.2(11.8)</td>
</tr>
<tr>
<td>120</td>
<td>20.7(12.1)</td>
</tr>
<tr>
<td>90</td>
<td>13.9(9.9)</td>
</tr>
<tr>
<td>60</td>
<td>6.5(8.8)</td>
</tr>
<tr>
<td>30</td>
<td>−1.2(7.5)</td>
</tr>
</tbody>
</table>

Scapular plane

<table>
<thead>
<tr>
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<th>Non-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain mean (SD)</td>
<td>Healthy control mean (SD)</td>
</tr>
<tr>
<td>30</td>
<td>−11.9(5)</td>
</tr>
<tr>
<td>60</td>
<td>−12.4(7.2)</td>
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<tr>
<td>90</td>
<td>−12.6(8.1)</td>
</tr>
<tr>
<td>120</td>
<td>−8.8(7.8)</td>
</tr>
<tr>
<td>120</td>
<td>−9.2(7.9)</td>
</tr>
<tr>
<td>90</td>
<td>−13(7.9)</td>
</tr>
<tr>
<td>60</td>
<td>−13.6(7.4)</td>
</tr>
<tr>
<td>30</td>
<td>−10.9(6.1)</td>
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</table>

Scapular plane

<table>
<thead>
<tr>
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<th>Non-dominant</th>
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<tbody>
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<td>90</td>
<td>−12.6(8.1)</td>
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<tr>
<td>120</td>
<td>−8.8(7.8)</td>
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<tr>
<td>120</td>
<td>−9.2(7.9)</td>
</tr>
<tr>
<td>90</td>
<td>−13(7.9)</td>
</tr>
<tr>
<td>60</td>
<td>−13.6(7.4)</td>
</tr>
<tr>
<td>30</td>
<td>−10.9(6.1)</td>
</tr>
</tbody>
</table>

Abbreviations. SD: Standard deviation.
Fig. 2. Scapular internal rotation degrees. (*): significant differences between groups.
Fig. 3. Scapular upward rotation degrees, (*): significant differences between groups.
Fig. 4. Scapular posterior tilt degrees.
However, the dominant and ND sides demonstrate different kinematics adaptations. The scapula was more externally rotated on the dominant side on SP and FP, while it was more internally rotated on the ND side on FP. The differences between the dominant and ND sides might be due to complex adaptation strategies occurred due to the neck pain (Hodges and Tucker, 2011). It was revealed that every muscle develops unique adaptation strategies to the pain and this adaptation differs between the individuals and the functional tasks (Hodges and Tucker, 2011). Therefore, it may be thought that the dominant and ND sides may respond differently to the neck pain. In addition, participants were asked to stand in a relaxed and comfortable posture during the measurements. It is possible that the participants alter their posture to compensate for the neck pain and stand in a pain-free position during the arm elevation tasks. This compensation might also lead to differences between the dominant and ND sides. The effect size of the neck pain on scapular IR was also variable (Table 2). Therefore, it is difficult to interpret whether there is a strong/weak relationship between the neck pain and abnormal scapular IR.

Similar scapular PT in both the dominant and ND sides was observed in both groups. Our results are in agreement with Helgadottir et al. (2010) and Zabbihosseini et al. (2017), who also reported no difference in scapular PT between patients with neck pain and healthy subjects. The PT of the scapula is mainly coordinated by LT and SA muscles (Ebaugh et al., 2005). It can be concluded that even if there is a decreased duration in the activation of SA (Helgadottir et al., 2011a), the LT can have a normal activation pattern (Castelein et al., 2015) and can compensate for the inefficiency in the SA. The current study also revealed the relatively small effect of neck pain on scapular PT. We conclude that there is a weak relationship between the neck pain and scapular PT.

The axiscapular muscles are primarily responsible from the scapular rotations (UR, ER and PT). However, there were differences in the scapular UR and IR between patients with CNNP and healthy subjects, while both groups have similar PT. In addition, the dominant and ND sides developed different kinematic adaptations considering scapular ER on patients with CNNP. These discrepancies might best be explained by “pain adaptation theory” (Hodges and Tucker, 2011). According to this theory, multiple levels of the central nervous system (CNS) are recruited, and the CNS reorganizes and protects the painful parts of the body from further damage (Hodges and Tucker, 2011; Tsao et al., 2008). This reorganization enables the redistribution of activity between muscles and alters the movement patterns and the mechanical behaviors of muscles (Hodges and Tucker, 2011; Lamoth et al., 2002; Lamoth et al., 2004). The redistribution of the muscle activity patterns and alterations in the movement kinematics are unique processes for each muscle and functional task, and thus, a muscle might act differently between two tasks (Hodges et al., 2003; Hodges and Tucker, 2011; Lamoth et al., 2002; Lamoth et al., 2004; Sterling et al., 2001). Therefore, the differences across the scapular rotations and between the dominant and ND sides might be due to the different adaptation strategies. This theory may also explain the distinctive results between the studies in the literature.

Scapular dysfunction has been studied especially on patients with shoulder problems. Although there are conflicting results, it is generally thought that there is a relationship between scapular dysfunction and shoulder problems (Kibler et al., 2013; Timmons et al., 2012). Moreover, it was revealed that scapular dyskinesis increases the risk of shoulder problems nearly 50% on the asymptomatic athletes (Hickey et al., 2018). Therefore, although the relationship between neck pain and scapular dyskinesis is relatively a new study topic and researchers do not have certain results, current study revealed that there are abnormalities in the 3-dimensional scapular orientation on patients with CNNP. Hence, scapular control may also be included to the management of the CNNP.

There were some limitations to this study. First, we asked participants to stand in relaxed posture during measurements. This can be interpreted as both a strength and weakness of our study. Standing in a relaxed posture enables us to eliminate the interference during measurements and helps to collect the natural positioning of the scapula. However, the 3-dimensional scapular orientation is highly correlated with posture. Therefore, there can be substantial variability in scapular kinematics considering the different posture of the participants. Second, the dominant side was determined based on the hand dominance to have clear results. However, the painful side may also be determined as the dominant side on patients with CNNP to investigate the effects of dominance by pain. Third, although all of the patients have CNNP > 6 months, the exact time for how long they have been suffering from the pain is unclear. As the duration of the pain is one of the factors for the compensative kinematic changes to occur, this is another limitation for our study.

5. Conclusion

Patients with CNNP demonstrate alterations in the 3-dimensional scapular orientation especially in the scapular UR. Although these alterations may have short-term beneficial effects, they may cause further damage in the long-term (Hodges and Tucker, 2011). Therefore, the scapular dysfunction also needs to be considered during the management of the CNNP.

Declaration of competing interest

We have no conflict of interest in this study and no financial support was received.

References


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