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Musicians injuries: Upper quarter motor control deficits in musicians with prolonged symptoms - A case-control study

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Abstract

Study Design—Case-control study.

Background—A large number of student and professional musicians are affected by long term playing related musculoskeletal disorders (PRMSDs) during their career, with prevalence rates above 80%.

Objective—To investigate if there were differences between musicians with and without prolonged symptoms of upper quarter PRMSDs in the presence of: (1) scapular dyskinesis; (2) cervical motor control and endurance deficits.

Methods—Seventy-two musicians (24 males; 48 females) were matched based on sex, type of instrument and average hours played per week and assigned to one of two groups: A *symptomatic group* (mean age 23.3 ± 8.2 years) with history of prolonged PRMSDs (constant symptoms lasting more than one week) during the past year; and a *control group* (mean age 25 ± 10.5 years) with no history of PRMSDs lasting more than one week. Musicians completed a questionnaire and underwent clinical testing for the presence of scapular dyskinesis and cervical motor control and endurance deficits using the following tests: (1) cervical flexor endurance test; (2) scapular dyskinesis test; and (3) craniocervical flexion test. Assessor blinding as to group assignment was ensured.

Results—Participants in the symptomatic group presented with a statistically significant higher prevalence of positive scapular dyskinesis ($P < .0001$; OR = 7.8) and lower scores for the craniocervical flexion test ($P < .0001$).

Conclusion—Musicians with prolonged symptoms of PRMSDs presented with higher prevalence of scapular and cervical motor control deficits detected by standard clinical tests when compared to the control group.

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Financial disclosure and conflict of interest

I affirm that I have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

Level of Evidence—Therapy, level 4.

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Keywords

Instrumental musicians; Cervical pain; Shoulder pain; Upper quarter pain

1. Background

Music performance is a highly skilled task that requires intensive practice in order to develop proficiency (Chan and Ackermann, 2014). Student and professional musicians practice their instrument for thousands of hours a year, sometimes many hours a day, maintaining unfavourable postures and requiring a high level of neuromuscular activity, while placing a very significant load in their musculoskeletal system (Chan and Ackermann, 2014). Musical performance takes years to perfect and as instrument proficiency increases, the challenges increase as well, as musicians face more complex musical pieces. The long practice sessions, combined with other risk factors such as sex (Zaza and Farewell, 1997; Davies and Mangion, 2002), postures and other biomechanical stressors, lead to prevalence rates above 80% for playing related musculoskeletal disorders (PRMSDs) (Kaufman-Cohen and Ratzon, 2011; Ackermann et al., 2012).

Extensive research has evaluated the role of performance, sex and health related factors in the prevalence of PRMSDs in professional (Zaza and Farewell, 1997; Davies and Mangion, 2002; Ackermann et al., 2012; Mehrparvar et al., 2012) and student musicians (Ranelli et al., 2011, Steinmetz et al., 2012, Kok et al., 2013, 2015). Most commonly, occupational injuries in musicians affect the upper quarter region, with highest prevalence in the cervical-thoracic spine, shoulder, elbow, wrist and hand (Leaver et al., 2011, Paarup et al., 2011; Kok et al., 2013, 2016). These upper quarter injuries and consequential pain are frequently associated with neuromuscular changes often affecting the cervical spine and scapular stabilizers (Steinmetz et al., 2010; McCrary et al., 2016).

Although neck and shoulder pain has been associated with significant changes in cervical and scapular muscles performance (Barton and Hayes, 1996; Harris et al., 2005; O'Leary et al., 2011; Steinmetz et al., 2016; McCrary et al., 2016), limited data are currently available regarding cervical and scapular motor control alterations in the presence of prolonged pain among musicians. Due to the close neurophysiological relationship between the cervical spine and the shoulder, scapular dyskinesis has been associated with cervical dysfunctions (Cools et al., 2014) and shoulder pain has been associated with altered recruitment patterns of cervical muscles (Hidalgo-Lozano et al., 2012) in athletes and workers exposed to prolonged postures. Scapular dyskinesis can be caused by impairments of scapular muscle stabilizers and correlate positively with the presence of shoulder pain and pathology (Kibler and McMullen, 2003, Kibler and Sciascia, 2010, 2012).

Impairments of scapular and cervical stabilization systems in musicians have been suggested in the literature (Steinmetz et al., 2010) and exercise programs trying to address those impairments have been proposed (Chan et al., 2013, 2014a; b). However, no study to date

has investigated if there are differences in cervical and scapular motor control performance in musicians with versus without prolonged upper quarter symptoms of PRMSDs. Therefore, the purpose of this study was to investigate if musicians with and without prolonged symptoms of upper quarter PRMSDs displayed differences in motor control responses demonstrated by the results of three clinical tests targeting the cervical spine and shoulder girdle. These objective data could in turn assist in the development of motor control retraining approaches that could be further studied in clinical trials.

2. Methods

The study was designed as a single blind case-control study comparing results of motor control tests for the cervical spine and shoulder between musician with history of prolonged upper quarter PRMSDs symptoms and musicians with no history of prolonged upper quarter PRMSDs symptoms.

2.1. Power analysis

Power analysis for Chi Square for scapular dyskinesis was conducted using G-POWER to determine a sufficient sample size considering an alpha of 0.05, a power of 0.80, a large effect size (W = 0.5) (Tate et al., 2009; Steinmetz et al., 2010) with equal allocation of participants into each group. Based on the aforementioned assumptions, the desired sample size was 52 participants (a minimum of 26 matches). Power analysis for Mann-Whitney U was conducted for the craniocervical flexion test. Considering an alpha of 0.05, a power of 0.80 and a large effect size (d = 0.65) (Chiu et al., 2005), a desired sample size of 64 (a minimum of 32 matches) was necessary. Therefore, we recruited 81 musicians, with 36 matches included in the study.

2.2. Participants

2.2.1. Reliability—Prior to enrolling participants for the case-control study and after approval by the local University Institutional Review Board, a pilot study was performed to determine intrarater reliability for the cervical flexor endurance test, scapular dyskinesis test and craniocervical flexion test. One investigator (F.S.) practiced these three clinical tests daily for a period of three weeks, and then recruited a convenience sample of 20 asymptomatic participants not included in the case-control study to be evaluated over a two-day period. After consenting, F.S. performed the tests in two separate sessions with at least a 24-h interval between test days.

2.2.2. Case-control study—After acceptable intrarater reliability was achieved, participants' recruitment was initiated in April of 2015 and completed in March of 2016. Musicians were recruited by posts placed in the schools, musician's union boards, social media and word of mouth at Vanderbilt University Blair School of Music, Lipscomb University School of Music, Belmont University School of Music, Tennessee State University School of Music, Middle Tennessee State School of Music, the Nashville Symphony and the Nashville Musician's Union. After recruitment and prior to consenting to study participation, prospective participants completed a pre-screening questionnaire (Appendix A) that included information pertinent to inclusion/exclusion criteria, as well as

their pain history information to be used for group assignment in the matching process for the study.

Musicians commonly report musculoskeletal symptoms with very high prevalence rates (Paarup et al., 2011; Kok et al., 2013). Those symptoms may vary from intermittent to constant and are related to playing their instrument. To differentiate musicians with prolonged symptoms from others with minimal transient pain, participants were included in the *symptomatic group* if they reported a history of cervical or shoulder/upper extremity PRMSDs and pain during the past year with constant symptoms lasting more than one week and affecting musical performance. Conversely, the *control group* included individuals who reported no history of cervical, shoulder or upper extremity PRMSDs and pain during the past year with constant symptoms lasting more than one week and affecting musical performance. Additionally, participants were included in the study if they were student or professional musicians 18–65 years old playing an instrument at least 6 h per week (Roach et al., 1994; Morse et al., 2000).

Exclusion criteria for both groups consisted of (1) History of trauma or injury other than a playing related injury affecting their ability to play a musical instrument; (2) Pregnancy by self-report; (3) Neurological disorder affecting motor control to include, but not limited to Parkinson's disease, multiple sclerosis, amyotrophic lateral sclerosis, muscular dystrophy, myasthenia gravis and Guillain-Barre; (4) Rheumatoid arthritis or ankylosing spondylitis; (5) Any connective tissue disorder; (6) Cervical radiculopathy; and (7) History of recent (within the last year) cervical or shoulder surgery.

Participants in the symptomatic and control groups were then matched according to (1) sex, (Leaver et al., 2011; Paarup et al., 2011; Ranelli et al., 2011; Wilke et al., 2011); (2) average hours of instrument playing per week (18 or more/less than 18) (Kaufman-Cohen and Ratzon, 2011); and (3) type of instrument played (string/other) (Davies and Mangion, 2002; Wilke et al., 2011).

A co-investigator (G.R.) reviewed the pre-screening questionnaire information in order to: (1) ensure that all criteria for inclusion in the study were met; (2) assure blinding of the investigator performing clinical testing; (3) determine group assignment; and (4) schedule the participants for testing. Following consent for study participation, the participants completed a second questionnaire containing relevant demographic, medical and surgical history information, PRMSD history, instrument playing habits, hobbies and activities outside work including exercise habits. Participants were then assigned a number and all identifying information was stored. Participants then proceeded to clinical testing with appropriate blinding of tester assured. A flow chart to the study is included (Fig. 1).

2.3. Testing

The three clinical tests performed were in the same sequence for all participants: (1) the cervical flexor endurance test; (2) scapular dyskinesis test; and (3) craniocervical flexion test.

The *cervical flexor endurance test* was performed following a protocol based on work of Harris et al. (2005), Olson et al. (2006) and Domenech et al. (2011). Participants lying supine with their neck and head in a neutral posture were asked to tuck their chin as far as possible and maintain the position. Next, the participants were asked to lift their head and neck approximately 2.5 cm from the table surface (Fig. 2). Time recording was initiated and ended as described by Domenech et al. (2011). The participants were tested twice, with a five-minute break between tests to allow for muscular rest. The scores were averaged between the tests.

Scapular dyskinesis was assessed using a protocol based on McClure et al. (2009) and Tate et al. (2009). Participants were asked to perform five repetitions of bilateral, active, weighted shoulder flexion in the sagittal plane and bilateral, active, weighted shoulder abduction in the frontal plane (Fig. 3a and b). The participants briefly practiced the motions prior to testing. Testing was performed while standing and started with arms by the side in a neutral position with the investigator standing behind the participants. They were asked to simultaneously elevate both arms overhead as far as possible to a three-second count using the ‘thumbs up” motion and then lower to a three-second count. Tests were performed with participants grasping dumbbells according to body weight, 1.4 kg (3 lb) for those weighing less than 68.1 kg (150 lb) and 2.3 kg (5 lb) for those weighing 68.1 kg or more (Fig. 3a and b). Participants’ movement quality was assessed and each test movement (flexion and abduction) was rated using the following protocol: (a) Normal motion: no evidence of abnormality (considered a negative test); (b) Subtle abnormality: mild or questionable evidence of abnormality, not consistently present (considered a negative test); and (c) Obvious abnormality: striking, clearly apparent abnormality, evident on at least 3/5 trials, which was considered a positive test (dysrhythmias or winging of 1 inch or greater displacement of scapula from thorax).

Final rating was based on combined flexion and abduction test movements (a) Negative: Both test motions were rated as normal or one/both motions were rated as normal or having subtle abnormality; and (b) Positive or obvious abnormality: Either flexion or abduction was rated as having obvious abnormality, which was considered a positive test.

The *craniocervical flexion test* was performed with participants in a supine hook lying position with their hands resting in the abdominal area and the neck in a neutral position (Jull et al., 2008). Stacked towels were used when needed in order to place the face in a horizontal position. An air-filled pressure sensor (Stabilizer TM, Chattanooga Group, Hickson, TN) was placed under the participant’s neck in the sub-occipital region and then inflated to 20 mmHg. The visual display of the sensor was mounted to a frame in front of the participant’s face so it could be easily viewed by both investigator and participant (Fig. 4). After proper positioning, participants were educated regarding test and allowed to briefly practice so to assure appropriate performance. After practice, they were asked to tuck their chin and perform an occipital slide in the cranial direction, increasing sensor pressure from 20 to 22 mm/Hg for 10 s before returning to a neutral position. The participants then rested for 10 s and then repeated the same process starting at 20 mmHg and elevating the reading incrementally to 24, 26, 28 and 30 mmHg. Failure to maintain proper pressure for 10 s at

any level or improper technique leading to failure (not maintaining the cranial direction occipital slide) during performance determined the level of performance and testing ended.

2.4. Statistical analyses

Excel and SPSS version 24 for Windows were used for descriptive and inferential statistical analysis. Descriptive statistics were compiled for age, height, weight, BMI, number of years played, main instrument played (string or other), other instruments played (string or other), average number of hours per week playing their instrument, taking breaks during performance (yes/no), length of breaks in minutes per hour and location of symptoms in the upper quarter (cervical, shoulder, elbow, wrist and hand). Additionally, a prior medical history in upper quarter (yes/no), history of pain in the upper quarter in the previous 12 months (yes/no) and fitness activities participation frequency (more than 2 h/2 h or less per week), length in minutes/week and type of fitness activities were recorded. To answer the research questions, we analysed the scores of the cervical flexor endurance test, craniocervical flexion test and the presence of scapular dyskinesis (yes/no).

Intraclass correlation (ICC) and standard error of the measurements (SEM) statistics were used to determine reliability and measurements' precision for the cervical flexor endurance test (ICC 3,2) and cranio-cervical flexion test (ICC 3,2). Cohen's Kappa was used for establishing reliability for the scapular dyskinesis test.

Pearson's Chi-square test was used to determine statistically significant differences for positive scapular dyskinesis [yes/no]. *Independent t-tests* were used to test the cervical flexor endurance test scores. Due to the craniocervical flexion test scores not being normally distributed (Shapiro Wilk: $p < 0.001$), *Mann-Whitney U test* was used to test the scores of craniocervical flexion test.

3. Results

3.1. Reliability testing

Intrarater reliability for the cervical flexor endurance test using ICC (3,2) was 0.98, 95% CI (0.96, 0.99); SEM = 2.65 s, craniocervical flexion test using ICC (3,1) was 0.84, 95% CI (0.6, 0.94); SEM = 0.32 mmHg, and scapular dyskinesis test using Kappa was 0.9, 95% CI (0.46, 1.00).

3.2. Case-control study

Of the 81 participants recruited for the study, seven were excluded due to lack of matches, one was excluded due to cervical spine surgery history and one was excluded due to volunteering information prior to testing that interfered with investigator blinding. The remaining 72 participants entered the study, with 36 individuals matched in each group. Descriptive data for all participants, frequency distribution, group means and standard deviations are presented in Table 1. Using *independent t-tests*, no significant differences were found between the symptomatic and control groups for age ($p = .43$), height ($p = .28$), weight ($p = .55$), BMI ($p = .83$), number of years playing their instrument ($p = .77$), average hours playing per week ($p = .88$), time spent exercising per week ($p = .65$) and frequency/

week exercising ($p = .85$). At the time of testing, twenty-nine participants (80.6%) reported pain in the symptomatic group and 11 (30.6%) reported occasional intermittent upper quarter pain in the control group.

Pearson's Chi-square test showed a higher number of participants in the symptomatic group with positive *scapular dyskinesis* test (26/36 or 72.2%) as compared to the control group (9/36 or 25%) ($p < .0001$) OR = 7.8, 95%CI (2.73–22.27) (Table 2). *Mann-Whitney U test* showed that participants in the symptomatic group presented with statistically significant lower scores for the craniocervical flexion test (Mean = 26.2 ± 2.3 s) as compared to the control group (Mean = 28.4 ± 1.7 s) ($p < .0001$). *Independent t-test* showed no significant difference between groups for the cervical flexor endurance test performance scores (Table 3).

4. Discussion

This is the first study to investigate and compare motor control pattern deficits in the cervical spine and shoulder girdle in musicians with and without prolonged pain from upper quarter PRMSDs. The most significant finding was that musicians in the symptomatic group displayed lower performance in clinical tests for both cervical and scapular motor control tests.

Cervical motor control alterations are frequently observed in the presence of pain. Previous research using EMG showed that violinists with pain used greater amplitude of sternocleidomastoid muscle activation during the craniocervical flexion test than pain free violinists, suggesting lower activation of the deep neck flexors (Steinmetz et al., 2016). Similar altered cervical motor control patterns were reported in subjects with chronic cervical pain who presented lower performance on the *craniocervical flexion test* as compared to asymptomatic subjects (Chiu et al., 2005). The scores of the symptomatic and control groups in our study were similar to the scores obtained by Chiu et al. (2005).

The between-group difference in craniocervical flexion test mean scores (26 mm/hg in the symptomatic versus 28 mm/hg in the control group) that was found in our study is clinically noteworthy. Falla et al. (2012) in a study of participants with prolonged neck pain, found that improvements in deep neck flexor activity after training were associated with pain reduction. The study indicated that upturns in deep cervical flexor activation across the final 2 stages of the craniocervical flexion test (28 and 30 mm Hg) correlated with a greater reduction in average neck pain intensity. The same was not observed for activation below that threshold. Future studies investigating prospectively musicians with upper quarter PRMSDs would be valuable to determine if cervical motor control improvements would translate in better outcomes in pain and disability for musicians.

In contrast to the differences found in the craniocervical flexion test results, *cervical flexor endurance test* scores were not statistically different between groups. Overall, mean scores for both groups were significantly lower than previously published normative data adjusted by age (Domenech et al., 2011). Our results were similar to subjects with neck pain in a study by Harris et al. (2005) (mean = 24.1 ± 12.8) and considerably lower than

asymptomatic subjects, suggesting that musicians in general display decreased cervical flexor muscle group endurance. This finding may be of relevance and suggest that cervical flexor motor control may play a more important role in posture and management of PRMSDs than endurance. To help determine the impact, it would be positive to investigate prospectively if neck flexor motor control deficits would result in greater incidence of upper quarter PRMSDs and if rehabilitation programs targeting the deep neck flexor muscles could prevent the development of upper quarter PRMSDs in musicians.

Previous research has observed that altered cervical spine motor control patterns were characterized by a preponderance of the superficial neck and head flexor muscles suggesting deep neck flexor muscle activation alteration in musicians (Steinmetz et al., 2012, 2016). Cervical flexor endurance alterations in asymptomatic participants could be explained by the fact that musicians frequently maintain prolonged static postures with forward head position and raised or rounded shoulders (Blanco-Piñeiro et al., 2015). Some musicians are more affected by posture than others, depending on instrument and technique (Eijsden Besseling et al., 1993). Prior studies performed in non-musician populations have shown that exercises aimed at improving deep neck flexor strength, endurance and motor control assist with cervical symptoms' improvement (Jull et al., 2009; Falla et al., 2012). Additionally, rehabilitation programs can mitigate the effects of forward head posture and decrease cervical spine and upper quarter pain and disability (Gupta et al., 2013; Kang, 2015).

Previous EMG studies have shown differences in neuromuscular activity for scapular and shoulder muscles between symptomatic and asymptomatic musicians (violinists) with shoulder pain (McCrary et al., 2016). Our study found that musicians in the symptomatic group were significantly more likely to present with *scapular dyskinesis* as compared to the control group. The 72% prevalence of scapular dyskinesis in the symptomatic group is similar to previous data reporting 85% scapular stabilization impairments prevalence in musicians with PRMSDs (Steinmetz et al., 2012). Such motor control alterations could contribute to prolonged presence of PRMSDs in the upper quarter. Scapular motor control impairments are found in association with many types of shoulder and cervical pathologies (Kibler and Sciascia, 2013; Kibler et al., 2013; Amorim et al., 2014; Andersen et al., 2014). A systematic assessment of scapular dyskinesis in musicians with upper quarter PRMSDs would be valuable. Therapeutic programs addressing altered motor control pattern in the shoulder girdle could be implemented in musicians as they have shown benefits in the management of shoulder and neck conditions (De Mey et al., 2012; Holmgren et al., 2012).

Future studies addressing cervical and scapular motor control deficits in musicians using specific exercise protocols are warranted to evaluate if motor control improvements translate into improvements of upper quarter PRMSDs and if such programs could be used to prevent prolonged PRMSDs in musicians.

5. Limitations

There were limitations to the study that require consideration. First, we included in our study musicians that played a variety of instruments. We used a broad classification (string or other) due to recruitment needs. In order to improve generalisability, it may be more relevant

in the future to classify groups according to specific instruments due to their unique requirements. Secondly, there were several musicians in both groups that had intermittent symptoms. This is a common occurrence due to the very high prevalence rates of pain in musicians. Finally, the study used a single tester. This may affect interrater reliability and generalization of results.

6. Conclusion

Musicians with prolonged upper quarter playing related pain presented with higher prevalence of scapular dyskinesis and lower craniocervical flexion test performance when compared to musicians with no history of prolonged upper quarter playing related pain. Cervical flexor endurance test performance did not differ significantly between groups. These findings may assist with future studies evaluating programs geared at preventing and managing prolonged PRMSDs in musicians.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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This study protocol was approved by the Institutional Review Board at Vanderbilt University. IRB Number: 141569.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.msksp.2018.04.006.

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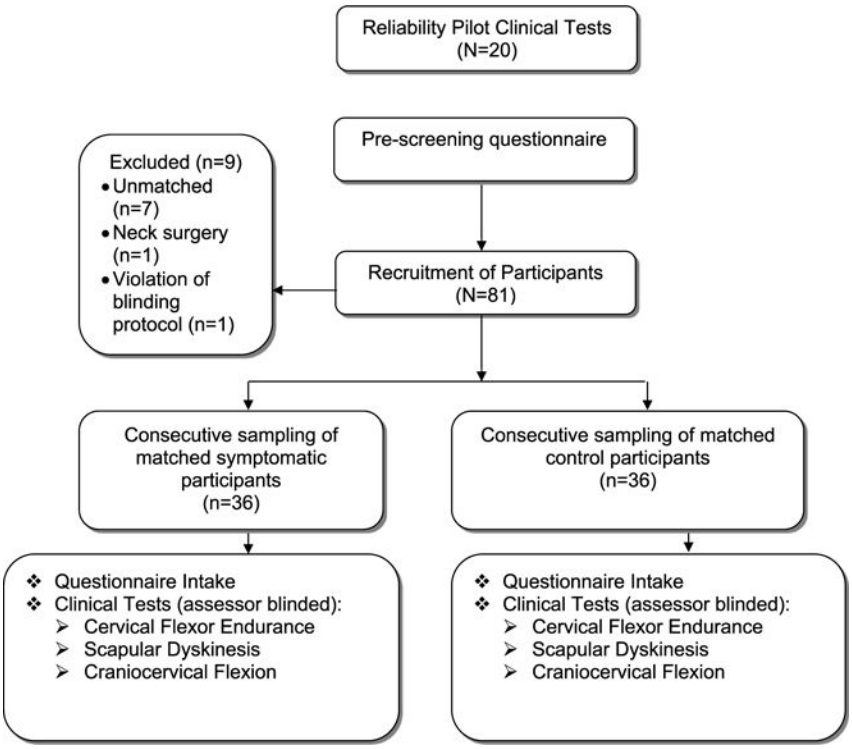

Fig. 1.
Flow Chart for the study.

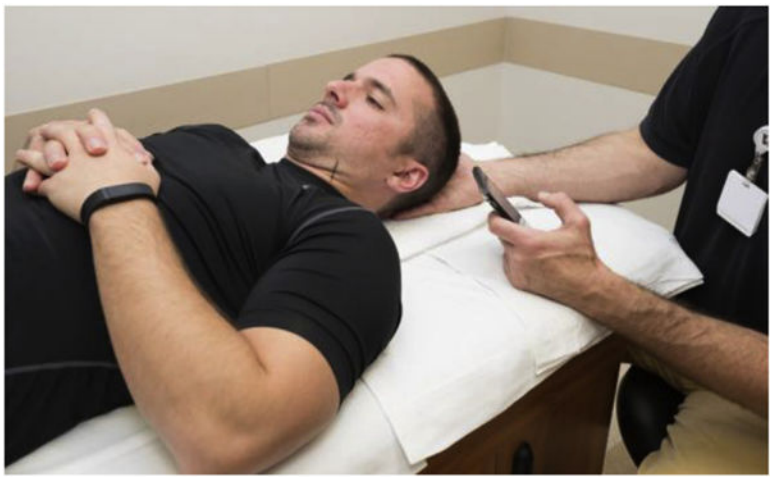

Fig. 2.

Test performance for cervical flexor endurance test. Participant is positioned for test with examiners hand placement to detect changes in craniocervical flexion.

Fig. 3.

a–b. Posterior (a) and lateral (b) views for scapular dyskinesis test. Participant is holding a 2.3 kg weight according to protocol.

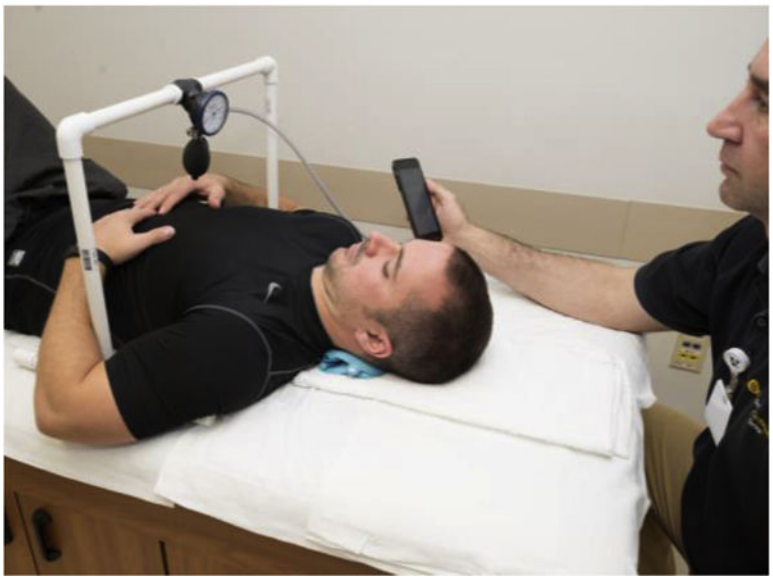

Fig. 4.
Starting position for the craniocervical flexion test. Note cervical alignment corrected with towel and pressure sensor (Stabilizer TM, Chattanooga Group, Hickson, TN) properly positioned below the occiput.

Table 1

Demographic data for participants in the symptomatic and control groups.

Demographic Variables	Symptomatic	Control	P value
Number of Participants	36	36	1
Males/Females	12/24	12/24	1
Age years (Mean ± SD)	23.28 ± 8.21	25.03 ± 10.50	.433
Height meters (Mean ± SD)	1.68 ± 0.11	1.71 ± 0.10	.279
Weight Kg (Mean ± SD)	69.59 ± 20.39	72.17 ± 15.34	.546
Body Mass Index (Mean ± SD)	24.44 ± 6.0	24.71 ± 4.57	.835
Years of Instrument practice (Mean ± SD)	15.33 ± 8.35	14.69 ± 9.95	.774
Exercise times per week (Mean ± SD)	3.17 ± 2.08	3.08 ± 1.57	.848
Exercises minutes per week (Mean ± SD)	158.32 ± 133.32	171.53 ± 110.43	.648
Professional Musicians (%)	8 (22.2%)	9 (25%)	.782
Student Musicians (%)	28 (77.8%)	27 (75%)	.782
Hours played per week (< 18/≥18)	26/10	26/10	1
Type of instrument (string/other[a])	12/24	12/24	1
History of pain in the last year (%)	36 (100%)	17 (47.2%)	< .001*
Pain not lasting more than a week for the asymptomatic group			
Neck (%)	20 (55.6%)	9 (25%)	.008*
Shoulder (%)	24 (66.7%)	8 (22.2%)	< .001*
Elbow/Hand (%)	27 (75%)	11 (30.5%)	.002*
History of Pain Prior to Last Year (%)	17 (47.2%)	8 (28.6%)	.025*

*Indicates Statistical Significance (P < .05).

[a]String instruments included violin, viola, cello, guitar, bass; other referred to piano and percussion instruments as well as woodwind and brass instruments. Subjects were matched to same instruments.

Table 2

Chi square test for evaluation of presence of scapular dyskinesis.

Variables	Symptomatic N = 36	Control N = 36	Chi-Square *P* Value	Partial eta squared	Power
(+) Scapular Dyskinesis Test	26	9	< .001 *	.223	.968

* Indicates Statistical Significance (P < .05).

Table 3

Independent *t*-test[1] and Mann-Whitney *U* test[2] for evaluation of Differences between Groups for the Craniocervical Flexion Test and Cervical flexor Endurance Test.

Variables	Symptomatic N = 36	Control N = 36	*P* Value	Partial eta squared	Power
Craniocervical Flexion Test[2] (Median/Interquartile range)	26/24–28	28/28–30	< .001 *	.253	0.998
Cervical Flexor Endurance Test (Mean ± SD)	22.8 ± 11.9	22.8 ± 9.9	.989	< .001	.030

* Indicates Statistical Significance (P < .05).