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Original Article

Reliability of ultrasonography for the cervical multifidus muscle in asymptomatic and symptomatic subjects ☆

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Abstract

A test–retest and inter-tester study was designed to assess the reliability of ultrasonography to depict the size of the cervical multifidus muscle in asymptomatic and symptomatic subjects. Ten asymptomatic women (range 19–48 years) and 10 women with chronic whiplash associated disorder (WAD), grade II, (range 19–49 years), matched for height and weight participated. The women were imaged by ultrasonography on two separate occasions by two different testers. On each occasion the cross-sectional area (CSA), and the transverse versus the anterior–posterior dimensions (shape ratio) at the C4 level were measured. The repeated measurements of the CSA were plotted against their means to reveal the limit of agreement. Good agreement was found for the asymptomatic group measurements and the intra-tester agreement for the symptomatic group. The inter-tester agreement for the symptomatic group was questionable. The size of the multifidus muscle was significantly reduced in the symptomatic group ($P<0.05$). The results indicate that loss of clarity of the fascial layer between the semispinalis cervicis muscle and the cervical multifidus muscle may be a diagnostic sign of muscle atrophy. Ultrasonography can be used to precisely measure the size of the cervical multifidus muscle at the C4-level in asymptomatic young female subjects; it is also reliable for symptomatic subjects if the same tester performs the measurements. Additional criteria are recommended to improve the inter-tester agreement for symptomatic subjects.

Keywords: Ultrasonography; Cervical; Multifidus; Assessment; Whiplash; Atrophy

1. Introduction

Research has shown that ultrasonography can be used to precisely evaluate muscle dimensions both on the appendicular (Stokes and Young, 1986; Kelly and Stokes, 1993) and the axial skeleton (Rezasoltani et al., 1996, 1998; Emshoff et al., 1999). Among the imaging modalities it is the most cost-effective and feasible method for measurements of the muscular tissue. The muscles are visualized in real-time and measurements can be obtained in a relaxed state and in different states of contraction as well as during movements (Harcke et al., 1988; Rezasoltani et al., 2002). Ultrasonography has been used as a diagnostic tool for the lumbar multifidus (Hides et al., 1995) and is now also used as a biofeedback method for recruiting the deep muscles in the lumbo-pelvic region (Richardson et al., 1999). Due to the load differences between the cervical and lumbar spine, the cervical multifidus is a much smaller muscle than its counterpart in the lumbo-sacral region. It may therefore be more difficult to identify the cervical multifidus muscle.

Recent research into the passive integrity of the cervical spine has demonstrated that women with chronic whiplash associated disorders (WAD), grade II, have a different configuration of the cervical lordosis from asymptomatic women (Kristjansson and Jónsson, 2002). The relatively increased lordosis in the upper cervical spine and diminished lordosis in the lower cervical spine observed in this patient group are of great clinical importance (Kristjansson and Jónsson, 2002). Interestingly, the same pattern was found in the whole study sample of 100 young asymptomatic subjects when a heavy experimental load was imposed on the cervical spine (Ingelmark, 1942). The altered configuration of

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the cervical lordosis in this experimental study, conducted 60 years ago, strongly indicates that this pattern was due to increased muscle activity of the superficial torque-producing muscles and the incapability of the tonic deep segmental cervical muscles to maintain the cervical alignment under such great load conditions. One explanation for the altered configuration of the cervical lordosis in patients with WAD may therefore be muscle imbalance due to overactive superficial muscle and/or the diminished holding capacity of the deep cervical muscles.

Another recent study exploring sagittal plane segmental motion, conducted on the very same study sample as the above study on the configuration of the lordosis, (Kristjansson and Jónsson, 2002) found a subgroup of WAD patients who exhibited increased sagittal plane segmental motion of the mid-cervical segments (Kristjansson et al., 2003). The compromise on the passive integrity of the mid-cervical segments and kyphotic alignment at the C4-level in some WAD patients, grade II, indicates that the passive load-bearing capacity of the mid-cervical spine may be reduced (Kristjansson and Jónsson, 2002; Kristjansson et al., 2003). The relatively increased lordosis in the upper cervical spine in WAD patients, grades II, may therefore be a compensatory mechanism reflecting an attempt by the body to bear the weight of the head under these circumstances (Kristjansson and Jónsson, 2002). The compromises to the passive integrity of the cervical spine may be the primary source of dysfunction in these patients, and the aforementioned muscle imbalance in the cervical spine may develop secondarily to pain, further increasing the dysfunctional state of these patients.

Cumulative evidence suggests that the deeper muscles are better suited to producing fine graded reflex mediated muscle stiffness than the more superficial muscles (Sjölander et al., 2002). It has recently been suggested that scaling muscle spindle counts to a motor unit number may better represent the sensitivity of the γ muscle spindle system (Boyd-Clark et al., 2002). Moreover, the distribution of the spindles seems to be strategically arranged for a particular function. New evidence shows that the longus colli muscle has significantly greater spindle density than the multifidus in the same cervical region, but the multifidus comprises a greater proportion of Type I fibres. The muscle spindles of this muscle pair are also arranged differently (Boyd-Clark et al., 2001, 2002). This might reflect the different functional requirements of these muscles i.e. the longus colli may act more as a balancer of the cervical lordosis (Mayoux-Benhamou et al., 1994) while the cervical multifidus acts as a segmental adjuster (Conley et al., 1995).

A measure of cervical multifidus size is an important indicator for whether the muscle is capable of performing its important segmental stabilizing functions. The purpose of this study was to assess whether ultrasonography can be used to reliably depict the size of the cervical multifidus in asymptomatic and symptomatic subjects. The shape ratio was also measured to be able to, in future research, to compare the geometry of the multifidus muscle with the geometry obtained of the cervical multifidus muscle by other imaging modalities.

2. Methods

2.1. Subjects

The participants included 10 asymptomatic women and 10 women with chronic WAD, grade II, according to the Quebec task force classification of WAD (Spitzer et al., 1995). The women were matched according to age, weight and height to minimize the effect of these factors may have on actual muscle size in different individuals (Table 1). The asymptomatic women were a sample of convenience from university students who had no previous history of neck pain or injury. The women in the chronic WAD group were recruited from an outpatient physiotherapy research clinic and had to have had bilateral symptoms in the neck. Their average length of history of whiplash was 22.6 months $\pm$12.5. To be included the women had to be non-trainers so training effects would not confound the results. Subjects were not considered for either group if they suffered from diseases affecting the neck or throat, rheumatic or neurological disorders of any kind. All participants completed the Northwick Park Disability Index (Leak et al., 1994), and the whiplash subjects recorded their average pain level on a 100-mm visual analogue scale (VAS). All women gave their informed consent, and ethical clearance for the study was obtained from the Medical Ethics Committee at Landspitalinn University Hospital in Reykjavík, Iceland.

2.2. Ultrasonography protocol

A 7.5 MHz linear probe (Logiq 200, General Electrics, Milwaukee, WI) was used for the scanning. The subjects were positioned prone on an examination table with both arms lying along the sides of the body. A stable position for the head and neck was obtained by resting the face in the hole of the head section of the table. The whole forehead rested on the table requiring the tester to passively induce slight flexion movement of the occiput upon the atlas. A cushion supported the head in this position to prevent side bending and rotation. The head section of the table was maintained 20° below the horizontal plane to reduce the cervical lordosis. Effort was taken to ensure axial alignment of the spinous processes by inspection. The spinous process at the

Table 1
The characteristics of the asymptomatic group and the symptomatic group

Group	Mean ± SD				
	Age (years)	Height (m)	Weight (kg)	VAS (mm)	NPDI (%)
Asymptomatic ($n=10$)	31.5 ± 11.40 (19–48)	1.69 ± 5.48 (1.63–1.78)	67.1 ± 6.78 (54–78)		
Symptomatic ($n=10$)	32.5 ± 11.76 (19–49)	1.68 ± 4.95 (1.60–1.77)	70.3 ± 10.14 (60–86)	5.25 ± 1.62 (2–7)	45% ± 14% (25–71)

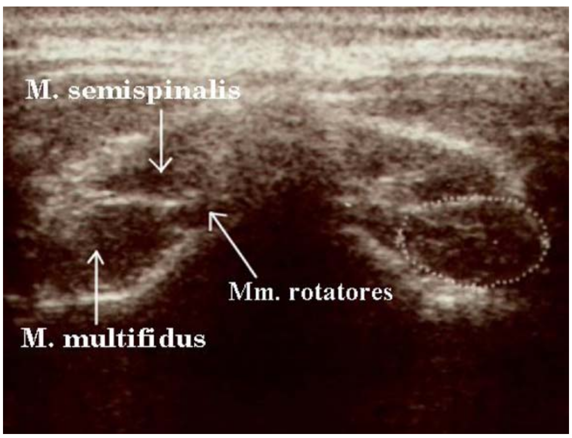

Fig. 1. Ultrasonogram of the multifidus muscle cross-sectional area at C4-level in an asymptomatic subject.

Table 2
Measurements of the cervical multifidus muscle at the C4-level

Variable	Mean ± SD (range)			
	Asymptomatic ($n=10$)		Symptomatic ($n=10$)	
	Left	Right	Left	Right
CSA* (cm^2)	1.25 ± 0.10 (1.14–1.48)	1.23 ± 0.09 (1.12–1.43)	1.06 ± 0.19 (0.77–1.31)	0.96 ± 0.19 (0.68–1.30)
Shape ratio (LD/APD)	1.58 ± 0.14 (1.35–1.88)	1.68 ± 0.19 (1.42–2.12)	1.68 ± 0.15 (1.35–2.04)	1.70 ± 0.32 (1.33–2.39)

* $P<0.05$ by the Mann–Whitney U-test.

C4-level was identified by palpation in the prone position and marked with a pen. This location was double checked by moving the probe from the C2 area down to C4, by following distinctive spinous processes. The configuration of the multifidus muscle was best revealed at this level. The intention was also to measure the multifidus muscle at the C7-level but this was not possible because the muscle was not visible on ultrasonography imaging at this level.

Axial images were obtained by placing the middle of the probe perpendicular to the long axis of the posterior neck at the C4-level. The left and right sides were imaged separately. The outlines of the cervical multifidus muscle were identified by the following landmarks: inferiorly by the echogenic vertebral lamina; medially by the echogenic spinous process, and superiorly laterally by the echogenic fascia layer dividing the semispinalis cervicis muscle and the cervical multifidus muscle. The CSA was measured by using on-screen calipers to follow the aforementioned contours of the multifidus muscle (Fig. 1), and the anterior–posterior dimension (APD) and lateral dimension (LD) were measured at right angles to each other as the greatest distance from border to border (Rezasoltani et al., 1996). Each subject was imaged and measured twice on day I by one tester; the same procedures were repeated on day II by a second tester. The within-day measurements were performed at a 30-min interval and required repositioning of the subjects. Two participating women were imaged in the 30-min interval between each subsequent test–retest trial to minimize the possibility of the testers remembering the measurements from the first test session. All measurements were performed in the afternoon in a darkened room. The testers were blind to the women's group.

2.3. Data management and analyses

Data analysis was performed with the procedures implemented by using SPSS 10.0. Data are presented as mean ± SD. The CSA (cm^2) and the shape ratio (LD/APD) were calculated and compared using the Mann–Whitney U- test to reveal any between group differences. The intra- and inter-tester agreement for the CSA measurements was assessed and presented by plotting the differences between repeated measurements against their means according to Bland and Altman (1986).

3. Results

The subjects' characteristics are presented in Table 1. The descriptive results of the measurements of the cervical multifidus muscle at the C4-level are summarized in Table 2. The mean difference between groups

Table 3
Limit of intra-tester and intertester agreement for CSA measurements at the C4-level

Group	Mean difference ± 2SD (cm^2)		
	Intra-tester		Inter-tester
	Tester 1	Tester 2	Tester 1 vs. Tester 2
Asymptomatic ($n = 10$)	0.0 ± 0.2	0.02 ± 0.10	0.02 ± 0.18
Symptomatic ($n = 10$)	−0.02 ± 0.16	−0.01 ± 0.12	0.07 ± 0.30

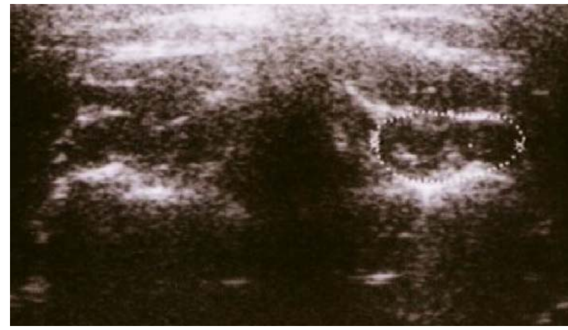

Fig. 2. Ultrasonogram of the multifidus muscle cross-sectional area at the C4-level in a symptomatic subject.

was 0.23 cm^2 (95% confidence interval, 0.13 – 0.33). The Mann–Whitney U-test revealed that this difference was significant ($P = 0.03$). The shape ratio was similar between groups and sides (Table 2). The plots of the CSA trials performed within days and between the left and the right sides showed the same pattern as plotting the averaged values of these trials. This confirmed the appropriateness of using averaged values to plot the intra-tester and the inter-tester agreement. The limit of intra- and inter-tester agreement is shown in Table 3. The mean difference of these trials was not significantly different from zero.

4. Discussion

The results of this study indicate that the ultrasonography protocol used in this study is reliable in detecting the size of the cervical multifidus muscle at the C4-level in asymptomatic subjects (Table 3). For the symptomatic group, the intra-tester agreement was acceptable (Table 3) but the inter-tester agreement was questionable (Table 3). This is apparent when the limit of agreement (Table 3) is compared to the standard deviations of the measurements (Table 2) and the 95% confidence interval (0.13 – 0.33) for the mean difference between the asymptomatic and the symptomatic groups. As noted, the broader limit of inter-tester agreement for the symptomatic group (0.07 ± 0.30) is partly outside the above-mentioned 95% confidence interval. The lack of inter-tester agreement for the symptomatic group (Table 3) makes it therefore more difficult to monitor the changes in the size of the cervical multifidus muscle when comparing results between two or more testers.

The wider limit of agreement for the symptomatic group was due to the fact that the outline of the fascia layer dividing the semispinalis cervicis muscle and the cervical multifidus muscle superiorly-laterally was not readily visible in seven out of 10 symptomatic subjects. This can be visualized by comparing Figs. 1 and 2, which show an asymptomatic subject and a symptomatic subject, respectively. This is probably a diagnostic sign indicating muscle atrophy of the deep cervical muscles and a consequent shrinkage of the fascia layer obscuring its outlines. It has been pointed out in earlier ultrasonography imaging of the semispinalis capitis muscle that the fascia and aponeurotic intersections are clearer in athletes than in non-athletes (Rezasoltani et al., 1999), indicating greater thickness and tensioning of the fascia layers due to muscle hypertrophy in athletes. The ultrasonography imaging in this study supports this. Three symptomatic subjects in this study had similar CSA of the multifidus muscle to the asymptomatic subjects, and the fascia layer in these subjects was also clearly visible. It seems therefore that the measurements of the CSA in the symptomatic group are not reliable until the muscle has reached a certain size. However, the present results also suggest that the multifidus muscle can be ranked as dysfunctional until its fascia layer becomes clearly visible. Different interpretation of the presence of the small rotatores muscles (Figs. 1 and 2) may also have compromised the inter-tester reliability in this study. To enhance objectivity in future research, it is possible to detect the relative brightness of the fascia layer by computer technology. For clinicians it is important to note that the reliability of the CSA measurements seem to be acceptable in clinical settings when one tester is involved in the measurements. The shape ratio, an unitless index, can be used in future studies to compare the geometry of multifidus muscle between different imaging modalities to reveal the validity of the ultrasonography measurements.

Prior ultrasonography studies of the splenius (Rezasoltani et al., 1996) and semispinalis capitis (Rezasoltani et al., 1998) muscles, as well as of the lumbar multifidus (Hides et al., 1995), used different statistical methods to assess the reliability of repeated measurements. Plotting the differences against their mean, as in this study, was considered more appropriate as data on repeated measures may show a fairly high correlation coefficient in spite of poor agreement (Bland and Altman, 1986). Ultrasonography depends on a strict measurement protocol as slight angulations of the probe and the probe pressure exerted on the underlying muscle greatly influence the image produced. The investigator must also have a thorough knowledge of cross-sectional anatomy as the resolution of the image is not as good as on a CT and MRI. Marking the boundaries of the muscle with the cursor is dependent on the investigator's level of training, and as shown in this present study, on whether the muscle is enclosed in a readily identifiable fascia (Harcke et al., 1988). In order to minimize the error inherent in any measurement, it is necessary to standardize ultrasonography measurements for each muscle or muscle group.

Upon inspecting several images taken by computerised tomography (CT) of the same subjects it became clear that the cervical multifidus muscle is a very small muscle at the C7-level. The reason is probably that the C7-level has very tight ligamentous connections, which make this cervical level a very rigid one. Some clinicians even refer to the C7-level as the ''sacrum'' of the cervical spine. Despite this, clinical experience indicates that the C7-level may exhibit kyphotic alignment in some chronic neck pain patients which was hypothesized might indicate gapping of the zygapohysial joints due to inadequate support from the deep segmental muscles. The C4-level was chosen for imaging in this study for two reasons. Firstly, the passive integrity of the mid-cervical spine, as already mentioned in the introductory section, seems to be compromised in a subgroup of patients with chronic WAD. Secondly, the configuration of the multifidus muscle was best revealed at the C4-level in asymptomatic subjects.

Future studies should correlate the size of the multifidus muscle at different cervical levels to cervical pain and dysfunction. It has been shown that in the lumbar spine the multifidus muscle may become inhibited and atrophied unilaterally at a painful segmental level (Hides et al., 1994; Danneels et al., 2000). The segmental innervation of the multifidus muscle explains this (Macintosh et al., 1986). However, new research indicates that the nerve supply to the zygapophysial joints may control activation of the deep paraspinal muscles (Indahl et al., 1997). As each zygapophysial joint is innervated from the medial branch of the posterior primary rami of three cervical segments (Bogduk, 1982) it is possible that the multifidus muscle at the C4-level may also become inhibited from stimuli one segment above and below. Ultrasonography can be used as a biofeedback at the initial stage of training for the cervical multifidus muscle using a similar procedure to the one established for the lumbar multifidus (Richardson et al., 1999). Physiotherapists are encouraged to conduct more research into this field which will help them to relate observed changes in the size of the cervical multifidus muscle to dysfunctional states and help them to better direct successful treatment interventions.

5. Conclusion

Therapists can use ultrasonography to depict the size of the cervical multifidus muscle at the C4-level by following a strict measurement protocol. The lack of agreement for the symptomatic group in this study was due to loss of clarity of the fascial layer between the semispinalis cervicis and the multifidus muscles. This is probably a diagnostic sign of muscle atrophy that can be used as an indicator of whether treatment interventions are successful in building up the size of the cervical multifidus muscle.

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