Abstract

Neck pain is the fourth leading cause of disability worldwide, and is a burden to both the affected individual and the society. Several studies have documented decreased neck strength in patients with chronic neck pain. However, there is a need for a practical and reliable device to measure neck strength in clinical practice. The main objective of this study was to determine the reliability of a handheld dynamometer in measuring maximal isometric neck strength in flexion, extension and lateral flexion. A second objective was to determine whether neck extension/flexion ratio was altered in patients with chronic neck pain, compared to healthy controls.

The reliability study included 50 healthy participants tested in flexion, extension and lateral flexion on three different occasions. To determine any differences in extension/flexion strength ratio, 19 patients with chronic neck pain were tested in flexion and extension. The intraclass correlation coefficient (ICC) indicated excellent reliability in all movement directions tested (mean ICC ranged from 0.89 to 0.96). Moreover, the results also indicated a reduction in within-subject variation between test days 2-3, compared to test days 1-2. The extension/flexion ratio was similar in both healthy controls and patients with chronic neck pain (1.59±0.5 vs 1.57±0.38), i.e., both patients and controls were approximately 60% stronger in extension than flexion. In conclusion, a handheld dynamometer is a reliable tool to measure maximal isometric neck strength in flexion, extension and lateral flexion in healthy subjects. There is no difference in the extension/flexion strength ratio in patients with chronic neck pain, compared to healthy controls.

Table of Contents

Introduction

According to the global burden of disease, neck pain is the fourth leading cause of disability worldwide (Vos et al., 2012). The one-year prevalence of neck pain is 30-50% (Hogg-Johnson et al., 2008), and the Norwegian HUNT study documented an increased prevalence of chronic neck pain in the period from 1995 to 2006 (23.6%-25.1%) among men and women (Hagen et al., 2011). Moreover, neck pain is the cause of 3.8% of all sick leave in Norway (Brage et al., 2010). Thus neck pain constitute a substantial burden to the society and the individual, due to workdays lost, costs in relation to sick leaves, disability pension, medication and treatment (Hansson and Hansson 2005).

Several factors influence the onset of chronic neck pain. People in all ages are affected, with the highest incidence in middle-aged women (Hogg-Johnson et al., 2008). Previous episodes of acute neck pain, chronic low back pain, headache, general poor health, sleep problems, obesity, high physical work demands, psychological problems and physical inactivity are associated risk factors. Mechanisms are unclear, but lower cervical strength leading to muscular fatigue and a dysfunction in the deep cervical flexor muscles have been reported as possible contributors to neck pain (Barton and Hayes 1996; Falla et al., 2004; Ylinen et al., 2004b).

A number of studies have investigated cervical strength in patients with neck pain, with varied results (Cagnie et al., 2007; Rezasoltani et al., 2010; Seng et al., 2002; Ylinen et al., 2004a). Seng et al., (2002) documented extensors and flexors as the strongest and weakest neck muscles, respectively, in healthy women. These results is supported by Cagnie et al., (2007), who in addition to lower strength also documented an altered extension/flexion ratio in women with chronic neck pain (ratio 1.39), compared to healthy controls (ratio 1.59). However, others have found lower strength in both flexion and extension and no alteration in the extension/flexion ratio (Rezasoltani et al., 2010). This is supported by Ylinen et al., (2004a) who found a general strength reduction of 23-29 % in both flexion, extension as well as rotation in patients with neck pain, compared to healthy controls.

Physical exercise has a positive effect on musculoskeletal disorders in general, and likewise on neck pain (Andersen et al., 2012; Andersen et al., 2013; Andersen et al., 2010). According to Andersen et al., (2008) strengthening exercise has a more pain-relieving and prolonged effect than general fitness training. In order to assess whether exercise interventions have been beneficial for improving neck strength, there is a need for measurement devices with high precision and reproducibility. Stationary dynamometers such as Biodex, Isobex and Myoforce have documented fair to excellent reliability in measurement of strength in the upper and lower body (Leggin et al., 1996; Meeteren et al., 2002; Milias et al., 2008; Pincivero et al., 1997; Tourville et al., 2013). Similar dynamometers have also been applied in measurements of neck strength (Cagnie et al., 2007; Chiu et al., 2002; Jordan et al., 1999). Stationary dynamometers make it possible to stabilize the subjects during the test, with concurrent measurement of angle and force. However, stationary dynamometers is expensive, the setup time required to test patients is long, and the size is inconvenient. This limits their use in clinical practice and other field settings (e.g., sports).

A handheld dynamometer is an alternative to the stationary dynamometers, and gives an objective measure of maximal muscle strength (Shahidi et al., 2012). It is user- friendly, has a practical size and is relatively inexpensive. However, it has been speculated that the examiners strength may affect the reliability of the results (Krause et al., 2014; Thorborg et al., 2013; Wikholm and Bohannon 1991). Several studies have demonstrated valid and reliable results in measurement of isometric strength in the upper and lower parts of the body with a handheld dynamometer (Andersen et al., 2014; Arnold et al., 2010; Li et al., 2006; Lu et al., 2011). However, only a few studies have investigated the reliability of a handheld dynamometer on neck strength (Geary et al., 2013; Shahidi et al., 2012). Geary et al., (2013) tested the intra-rater reliability in flexion, extension, left and right lateral flexion, using a handheld dynamometer on 25 union hockey players. The subjects were testes on two occasions with two days between each test. All tests were performed in a sitting position, and the test leader applied a force in the opposite direction of the muscle contraction. Overall, the results in this study indicated that the handheld dynamometer has excellent reliability in measure of isometric neck strength in all movement directions tested.

With a reliable device to measure neck strength, it is possible to assess an asymmetry or weakness in specific muscles. Thus, in a rehabilitation setting, an intervention to strengthen the respective muscles could be applied.

The main objective of this study was therefore to assess the reliability using a handheld dynamometer to measure isometric neck strength in flexion, extension and lateral flexion. A second objective was to investigate if the extension/flexion ratio in patients with chronic neck pain differ from healthy controls.

Methods

Participants

The study included 50 healthy participants and 19 patients with severe chronic neck pain. The healthy controls constituted a convenience sample recruited among employees and students at NTNU. The patients were recruited from Department of Physical Medicine and Rehabilitation

(FYSMED) at St. Olav University Hospital. All participants gave their written consent to participate in the study and the regional ethics committee approved the study protocol.

Inclusion criteria for the healthy group were as follows: (a) men and women 20-60 years. Exclusion criteria were as follows: (a) neck pain the last three months, (b) migraine or tension headache. Inclusion criteria for the patient group were as follows: (a) men and women 20-60 years, (b) referred to Department of Physical Medicine and Rehabilitation for treatment of chronic neck pain.

Subject characteristics are presented in table 1. Data from one patient is missing.

Table 1. Characteristics of the healthy controls (n=50) and patients (n=18). Values are mean (SD) if not otherwise stated.

	Healthy controls	Patients
Males/females	20/30	6/13
Age (years)	27.3 (±7.6)	48.1 (±11.2)
Height (cm)	173.9 (±8.2)	167.9 (±10.6)
Weight (kg)	70.5 (±13.5)	78.6 (±17.8)
BMI	23.2 (±3.8)	27.8 (±5.5)
Worst neck pain last two weeks (0-10)	NA	6.2 (±1.8)

NA - not applicable
BMI, body mass index

Procedure

The procedure consisted of four strength tests to measure neck strength: flexion, extension, right and left lateral flexion. Each strength test consisted of three repetitions, with one-minute break between each repetition. The same tests were performed on three different days with minimum five days between each test. The duration of the tests were approximately 25 min on day one, and 20 min on the second and third test occasion. The test leader demonstrated the exercises before each test, and the participants had the opportunity to try each exercise one or two times without maximal force to make sure the execution was correct. The participants were instructed to build up maximal force within 3-5 sec by increasing the force against the dynamometer progressively. The test leader held against the pressure to provide isometric contraction. After each test, the participants ranked their effort on a scale from 0-10, where 10 was maximal effort.

For the patient group the procedure only included tests of isometric strength in flexion and extension. The execution of the tests were the same as in the healthy participants, but the patients were only tested on one occasion. After each test, the participants ranked their effort and pain during the test on a scale from 0-10, where 10 was maximal effort/pain. A handheld dynamometer (Lafayette Manual Muscle Testing System, model 01165) was used to measure neck strength in all movement directions tested, and information about peak force was registered.

Flexion

The participants sat on a stool with their back and head against the wall, feet on the floor and hands in the lap (figure 1). The test was performed by bending the head forward, imagining the chin was led against the chest. The back was supported against the wall during the test, while the head moved 1-2 cm from the wall in the beginning of the test, until the test leader held against the pressure. The test leader stood in front of the stool and held the dynamometer with both hands. The dynamometers position during the test was just above the eyebrows.

Figure 1. Illustration of the neck flexion test.

Extension

The participants laid on the stomach on a training mat on the floor, with the forehead against the mat, arms placed along the body with extended feet (figure 2). The test was performed by lifting the head. The test leader was positioned with one foot on each side of the participants shoulders, and held the dynamometer with both hands. The test leader held against the pressure when the forehead was 1-2 cm above the mat. The position of the dynamometer was in the crossing point between an imaginary line from the spine to the top of the head, and from the left to the right ear. The shoulders and legs touched the mat during the whole test.

Figure 2. Illustration of the neck extension test.

Lateral flexion

The participants sat on a stool placed in the right/left side of a doorframe, with straight back and the shoulder leaning against the doorframe (figure 3). The test was performed by bending the head to the right/left, imagining the ear was lead against shoulder on the same side. The initial position of the head was a few degrees over the midline, bending against the doorframe. The test leader was positioned on the side of the stool with both hands on the dynamometer and the back leaning against the doorframe to accomplish stability. The dynamometer was positioned one cm above the ear.

Figure 3. Illustration of neck lateral flexion test.

Questionnaire

All participants answered a questionnaire about worst neck pain last two weeks. "Cross the number describing the worst pain you have felt the last two weeks" (0-10, where 0 is no pain and 10 is worst possible pain).

Statistical analyses

Analyses were performed by using Microsoft excel 2013. The results are expressed as means with SDs and with 95 % confidence intervals. The average of three trials for each test position were used for statistical analyses. Typical error was found by calculating the standard deviation in each subjects measurements between tests. Coefficient of variation (CV%) was calculated by expressing the typical error as a percent of the subjects mean score. Change in mean was calculated by subtracting the mean for test 1 from that in test 2, and from test 2 from that for test 3. Intraclass correlation coefficients (ICC 2.1) with absolute agreement were calculated to describe relative agreement between measurements. Correlation analyses were performed with Pearson correlation. Extension/flexion ratios were calculated by dividing the extension values by the flexion values. Only the values from day 1 were used in the calculations for the healthy controls.

Results

Mean strength

Table 2. Mean strength and standard deviation in healthy controls (n=50) and patients (n=19). Values are mean.

	Healthy controls	Patients
Flexion (N)	109.5 (±45.7)	89 (±45.7)
Extension (N)	164.9 (±56.4)	131.7 (±70.4)
Right lateral flexion (N)	135.6 (±43.8)	NA
Left lateral flexion (N)	143.2 (±47.9)	NA

NA- not applicable

Table 2 shows mean strength in the healthy controls and patients. Mean strength in flexion in the healthy controls were 109.5±45.7 N and range 43.8-207.8 N. Mean strength in extension were 164.9±56.4 N and range 94.4-310.6 N. Mean strength in right lateral flexion were 135.6±43.8 N, and range 58.3-251.7 N. Mean strength in left lateral flexion were 143.2±47.9 N and range 65.8-244.7 N. The correlation between peak force and effort in flexion was -0.14 in flexion, -0.20 in extension, -0.17 in right lateral flexion and -0.14 in left lateral flexion (p-value 0.183 to 0.349).

Mean strength in flexion in the patient group were 89±45.7 N and range 21.5-190.3. Mean strength in extension were 131.7±70.4 N and range 24.3-316.6. The correlation between peak force and effort in flexion was 0.23, and 0.21 in extension (p-value 0.349-0.398).

Within-subject variation

Table 3 shows within subject variation in peak force during flexion, extension, right and left lateral flexion. Overall, the results indicate that the typical error of measurements decreased from test 2 to test 3, compared to from test 1 to test 2 in all movement directions tested. Likewise, change in mean was considerable smaller between tests 2-3 than 1-2. The mean typical error was lowest in flexion with 10.1 N, and highest in right lateral flexion 15.6 N. The mean coefficient of variation (CV %) was about 9% for flexion and extension, and 11-14% for lateral flexion.

Table 3. Typical error, coefficient of variation (CV %) and change in peak force during isometric neck flexion, neck extension and lateral neck flexion.

	Test 1-2 (95%CI)	Test 2-3 (95% CI)	Mean (95% CI)
Flexion			
Typical error (N)	10.6 (8.9-13.2)	9.6 (8.0-11.9)	10.1(8.8-12.1)
CV (%)	8.5 (7.0-10.7)	8.7 (7.2-10.9)	8.6 (7.4-10.3)
Change in mean (N)	9.3 (5.0-13.6)	1.5 (-2.4-5.3)	
Extension			
Typical error (N)	16.2 (13.5-20.1)	10.8 (9.0-13.5)	13.8 (11.9-16.4)
CV (%)	11.0 (9.1-13.9)	6.8 (5.7-8.6)	9.2 (7.9-11.0)
Change in mean (N)	7.8 (1.3-14.3)	0.3 (-4.1-4.6)	
R. Lat. Flexion			
Typical error (N)	16.9 (14.1-21.1)	14.3 (11.9-17.8)	15.6 (13.5-18.7)
CV (%)	15.3 (12.7-19.5)	11.8 (9.8-14.9)	13.7 (11.7-16.5)
Change in mean (N)	2.5 (-4.3-9.3)	1.7 (-4.1-7.4)	
L. Lat. Flexion			
Typical error (N)	14.6 (12.2-18.2)	12.7 (10.6-15.8)	13.7 (11.8-16.3)
CV (%)	12.3 (10.2-15.6)	9.0 (7.4-11.3)	10.7 (9.2-12.9)
Change in mean (N)	6.4 (0.6-12.3)	-2.2 (-7.3-2.9)	

Figure 4 shows Bland-Altman plots of test 1-2 (A) and test 2-3 (B) during neck flexion, test 1-2 (C) and test 2-3 (D) during neck extension, test 1-2 (E) and test 2-3 (F) during right lateral flexion and test 1-2 (G) and test 2-3 (H) during left lateral flexion. The limit of agreement was slightly narrower between test 2 and test 3 in both flexion, extension, right lateral flexion and left lateral flexion compared to test 1 and test 2.

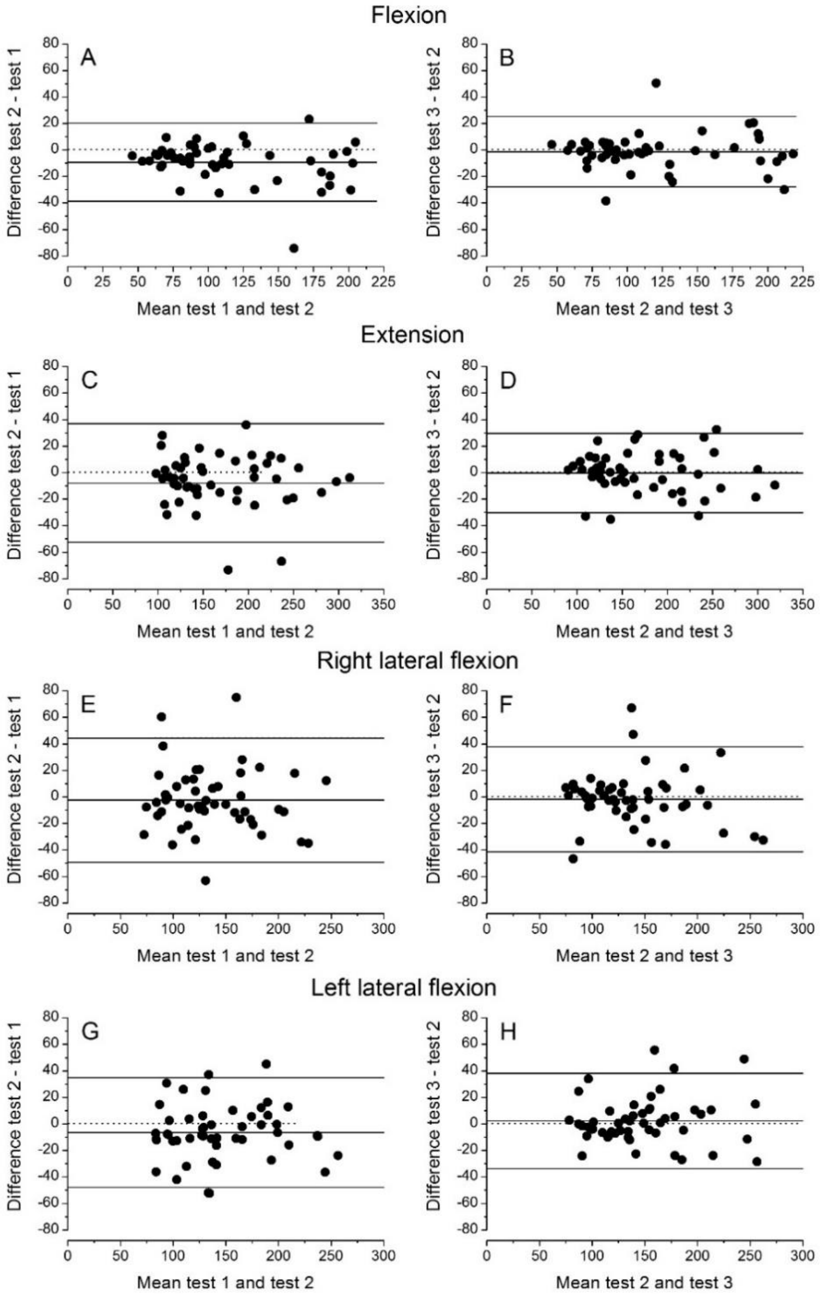

Figure 4. Bland-Altman plots illustrating agreement between peak force during neck flexion in test 1-2 (A) and test 2-3 (B), neck extension in test 1-2 (C) and test 2-3 (D), right lateral flexion in test 1-2 (E) and test 2-3 (F), and left lateral flexion in test 1-2 (G) and test 2-3(H). Agreement between the two tests is plotted as mean values against differences between the two tests. The dotted horizontal line indicate zero while the solid lines indicate mean difference and limits of agreement (mean difference ±1.96 SD).

Retest correlation

Table 4 shows ICC with 95% CI. Overall, ICC was high for all movement directions and slightly higher between test 2 and 3, compared to test 1 and 2. Moreover, ICC was slightly higher for neck flexion and extension compared to lateral flexion.

Table 4. Intraclass correlation

ICC	Test 1-2 (95 % CI)	Test 2-3 (95 % CI)	Mean (95 % CI)
Flexion	0.95 (0.92-0.97)	0.96 (0.94-0.98)	0.96 (0.93-0.97)
Extension	0.92 (0.87-0.96)	0.97 (0.94-0.98)	0.95 (0.91-0.97)
R. Lateral flexion	0.86 (0.77-0.92)	0.91 (0.85-0.95)	0.89 (0.82-0.93)
L. Lateral flexion	0.91 (0.85-0.95)	0.93 (0.88-0.96)	0.92 (0.87-0.95)

Extension- flexion ratio

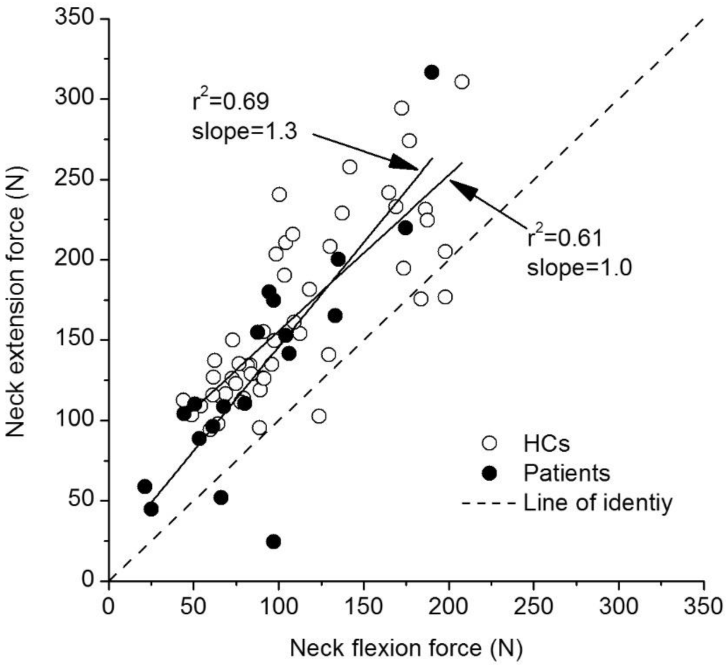

Figure 5. Scatter plot illustrating neck extension force and neck flexion force in patients and healthy controls.

Figure 5 shows a scatter plot of peak neck extension force and peak neck flexion force in patients and healthy controls. The correlation between peak force in neck extension and neck flexion was relatively high in both patients and healthy controls, and the slope did not differ significantly (p=0.96). The extension/flexion ratio was 1.59±0.5 in the healthy controls and 1.57±0.4 in the patient group.

Discussion

The main objective of the present study was to assess the reliability of a handheld dynamometer in measuring neck strength. A second objective was to investigate if the neck extension/flexion ratio differed between healthy controls and patients with neck pain. The results showed a reduction in within-subject variation between tests 2-3, compared to tests 1-2. The ICC indicated good to excellent reliability in all movement directions tested. Based on these results, the handheld dynamometer should be considered as a highly reliable tool in measurement of neck strength. There was no evidence of a difference in neck extension/flexion strength ratio between healthy controls and patients.

Mean strength

The present study found a lower neck strength in both flexion and extension in patients with chronic neck pain, compared to healthy controls. This is in line with Rezasoltani et al., (2010) and Ylinen et al., (2004a) who also documented decreased strength in flexors and extensors in patients with neck pain. However, the results are not comparable, due to the age difference between the patients and the healthy controls in the present study. The mean age in the patient group was 48.1±11.2, compared to 27.3±7.6 in the healthy controls. It is documented that muscle strength decrease with age, and that this decrease takes place around the age of 40-50 (Vandervoort 2002). The lower strength in the patient group may thus reflect a decrease in strength due to a higher age, and not necessary due to neck pain.

Within subject variation

Overall, the within subject variation in the present study showed a reduction in variation between tests 2-3, compared to tests 1-2. According to Hopkins (2000) variation in typical error is often due to biological sources such as motivation and physical state. It is possible that the test subjects were more motivated on the second and third test occasion, because they were familiar with the procedure and in addition wanted to improve their results. There was a small but systematic change in the mean in all directions tested between test 1 and test 2, except for right lateral flexion. This systematic change was not present between test 2 and test 3. The general reduction in variation between tests 2-3, compared to tests 1-2, may be explained by learning effects (Hopkins 2000). It is also likely that the subjects had learned the exercises from the first test occasion and thus improved their technique, which lead to higher force production and more stable results on test 2 and 3. The present study have thus a sufficient number with test occasions to characterize the learning effect. A study by Ylinen et al., (2004a) investigated neck flexion, extension and rotation strength in women with chronic neck pain on two different test occasions. The results also indicated better results on the second test occasion compared to the first, and are in line with the results in the current study. Another study by Ylinen et al., (1999) tested neck flexion, extension and rotation strength in healthy subjects, and found an increase in strength of approximately 2-8% between two different measurements within the same day. These results shows that small improvements in neck strength may be due to a learning effect, and not a result of an actual increase in strength capacity. However, in the present study the subjects were tested on three different occasions, and it is therefore possible that the first test session induced a training effect, i.e., an increase in strength (Hopkins 2000). It is documented that a small amount of stimuli is sufficient to increase strength in untrained muscles (Akima et al., 1999). Thus, based on the current results as well as other previous findings it is recommended that intervention studies include two baseline sessions.

Retest correlation

The ICC in the present study indicated high correlation using a handheld dynamometer in measurement of isometric neck strength. The ICC ranged from 0.89-0.96, which indicates good to excellent correlation in all movement directions tested. There was a tendency towards slightly higher values between tests 2-3, compared to tests 1-2. Moreover, these results supports Hopkins (2000) theory about learning and training effect, as mentioned above. The correlation was slightly higher in flexion and extension, probably because this is more familiar movements than lateral flexion. The results are comparable to a study by Cagnie et al., (2007) who tested intrarater reliability in neck extension and neck flexion in healthy men and women with a stationary dynamometer (i.e., Biodex). As in the present study, the subjects were tested on three occasions, and the results indicated excellent reliability with ICC ranging between 0.94-0.96. However, there was only 12 participant tested. Seng et al., (2002) also tested the reliability of a Biodex in measurement of isometric neck flexion, extension and lateral flexion. Ten healthy men were tested on three different occasions. The two first occasions were on the same day with three hours apart, the third was one week later. The results indicated an inter-day ICC between 0.82-0.93. Both Cagnie et al., (2007) and Seng et al., (2002) reported high ICC in measurement of neck strength in a Biodex which is comparable to the results of the current study, using a handheld dynamometer.

Extension- flexion ratio

In the present study the extension/flexion ratio was 1.57±0.4 in patients and 1.59±0.5 in the healthy controls, indicating that both groups are approximately 60 % stronger in neck extension, compared to neck flexion. These results are in line with a study by Ylinen et al., (2004a) who also documented no difference in the neck strength ratio between chronic neck patients and healthy controls. The present results do not comply with Cagnie et al., (2007), who found lower extension/flexion ratio in patients with chronic neck pain (1.39) compared to healthy controls (1.59). In this protocol, the subjects were tested in a lying supine position in extension and in a lying prone position in flexion, in contrast to a lying prone position in extension and a sitting position in flexion in the present study. Rezasoltani et al., (2010) also documented a reduced neck flexion/extension strength ratio in the patient group compared to the healthy controls tested in a sitting position. There might be a variation in the force production in the different positions, and this may have affected the extension/flexion ratios in the mentioned studies. A study by Ylinen et al., (2004b) shows that neck pain affects force production, and the results of a maximal force production test may depend on the patient's pain threshold. Thus, whether patients with neck pain possess a muscle imbalance in neck muscles remain an unresolved issue.

Strengths and limitations

A strength of the current study is the relatively large sample size and three repeated testing on three different days, which is recommended in estimation of reliability (Hopkins 2000). There was a minimum of five days between each test, meaning there was minimum muscle soreness in the neck muscles on the three test occasions. Moreover, to reduce learning effects, practice trials were performed each test day, and the same test leader performed all tests.

The time between test occasions varied considerable between subjects (5-34 days). Some subjects may therefore have forgotten the study protocol, and had to learn the exercises again. The age of the majority of the healthy participants were between 20-30 years old. This makes it difficult to use the results as reference values for other age groups.

Even though the protocol was standardized, there may have been a slight variation in the position of the head during the exercises, and this may have affected the force production. The strength of the test leader may also have an impact. It has been documented that strength of the test leader affect the magnitude and reliability of maximal strength measures with a handheld dynamometer (Wikholm and Bohannon 1991). Thus, it cannot be ruled out that the reliability will improve with stronger test leaders.

In conclusion, this study showed excellent reliability in isometric measurement of maximal neck strength in healthy subjects using a handheld dynamometer. This makes a handheld dynamometer a convenient measurement tool in both intervention studies and in clinical settings, where clinicians with training in the specific techniques can use the handheld dynamometer. In addition, the present study documented no difference in extension/flexion ratio between healthy subjects and subjects with chronic neck pain.

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