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Reliability and difference in neck extensor muscles strength measured by a portable dynamometer in individuals with and without chronic neck pain

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ABSTRACT

Objective: There are limited reports about the reliability of measuring neck extensor muscle strength using a portable dynamometer in neck pain patients. The aims of the current study were 1) to investigate intra- and inter-rater reliability of neck extensor isometric strength measurement using a portable dynamometer in patients with chronic nonspecific neck pain (CNSNP) and 2) to compare neck extensor isometric strength in participants with and without CNSNP.

Methods: Guidelines for Reporting Reliability and Agreement Studies (GRRAS) were followed. Two examiners received a 15-minute training before enrollment. Inter-rater reliability was assessed with a 10-minute interval between measurements, and intra-rater reliability was assessed with a 10-day interval. Three trials were assessed and examiners were blind to the strength values (in Newtons) from other sessions of 20 individuals with CNSNP (mean ±SD= 37.9 ± 9.8y; Neck Disability Index 29.2 ± 7.4%) and 20 individuals with other musculoskeletal disorders (mean ± SD = 32.8 ± 46.2y).

Results: Intra-rater reliability was excellent with intraclass correlation coefficient (ICC)(3,1) of 0.95 (CI:0.90–0.97) and inter-rater reliability was good to excellent with ICC(2,1) of 0.88 (CI:0.77–0.94) in CNSNP. No significant difference of neck extensor strength was found between CNSNP (93.27N±31.94) and Individuals without CNSNP (111.43N±40.11) ($p > 0.05$).

Conclusion: A portable dynamometer is a reliable tool for measuring maximal isometric neck extension strength in individuals with CNSNP. Slightly but no significant differences of neck extensor strength values between individuals with and without CNSNP. Future studies are needed to assess the generalizability of the findings in patients with other muscle deconditioning.

KEYWORDS
Cervical spine; neck muscle; reliability; dynamometer strength

1. Introduction

Neck pain is common in the general population, with a worldwide age standardized rate for point prevalence of 3.5% [1]. Studies have highlighted evidence of cervical muscle strength reduction in patients with chronic nonspecific neck pain (CNSNP) [2] or whiplash-associated neck pain [3,4]. Recent systematic reviews concluded that specific strengthening exercises of the neck, scapulothoracic and shoulder muscles were beneficial for patients with chronic neck pain [5] and for those having sustained a concussion [6]. Consequently, quantifying neck extensor muscle strength appears essential in order to identify impairment and to monitor changes in neck muscle performance during and after a strengthening program [7,8]. This requires a safe, reliable and validated tool to assess neck strength in clinical practice.

While many previous studies have described an excellent reliability for measuring neck muscle strength with isokinetic or other laboratory dynamometers [8–12], their high cost and complexity render them infeasible for clinical use. Portable dynamometers are more commonly used in clinical settings because of their ease of use, low cost, convenience and pragmatic approach for clinicians [13,14]. However, a recent systematic review concluded that there were a lack of research investigating the reliability of neck strength measurements in individuals with neck pain [15]. Because few studies have been conducted in participants with neck pain, it is not possible to draw a clear conclusion about how neck pain influences the reliability of cervical strength measurements [15]. For this reason, it is crucial to investigate the reliability of these measurements in

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participants with neck pain, which would provide more representative results for clinicians and improve the external validity [15].

The aims of the current study were 1) to investigate intra- and inter-rater reliability of neck extensor isometric strength measurement using a portable dynamometer in patients with CNSNP and 2) to compare neck extensor isometric strength in participants with and without CNSNP. We hypothesized that measuring cervical strength using a portable dynamometer with a standardized and controlled procedure would be reliable for clinical practice.

2. Methods

2. 1. Subjects

Participants aged 18–60 were recruited from a pool of patients in a physiotherapy clinic. Patients were included in the CNSNP group if they had a history of neck pain lasting three months or more, experienced a familiar neck pain provocation during neck muscle palpation or during neck movement, and had a neck disability index higher than 15%. Participants not suffering from CNSNP were recruited from patients attending physiotherapy for other musculoskeletal disorders (low-back or knee pain, lower limb surgery, etc.). Individuals were excluded if they had recent cranio-cervical trauma or surgery; joint inflammatory condition/arthritis; fibromyalgia; chronic dizziness; intense physical activity in the 24 hours before the experiment; cardiovascular, neurological or psychiatric pathologies; or were pregnant. Before enrollment, all participants provided written consent after being fully informed of the testing procedure. The current study followed Guidelines for Reporting Reliability and Agreement Studies (GRRAS) [16] and was approved by an ethics committee (Comité de protection des personnes sud est V, n°0.04.09.51157). A sample size of 20 participants per group was calculated using PASS 2020 (Power Analysis and Sample Size Software (2020). NCSS, LLC. Kaysville, Utah, USA, ncss.com/software/pass). Each participant was measured twice, producing a two-sided 95% confidence interval with a width of 0.1 when the estimated intraclass correlation is 0.9.

Two physiotherapists with 10 and 15 years of experience performed measurements. For intra-rater reliability, a first examiner assessed neck extensor muscle strength during 2 sessions separated by 10 days. For inter-rater reliability a second examiner also measured neck extensor muscle strength. Participants were assessed by both examiners in a randomized order to prevent familiarization bias and with a 10-minute interval between assessments. Maximal isometric strength of the neck extensor muscles was measured using a Microfet2 dynamometer (MicroFET2, Hoggan Health Industries, West Jordan, UT, USA). Each participant received explanations about the procedure including the importance of reaching their maximal isometric strength during the safe and painless test (Appendix A). Before recording measurements, the two examiners received a 15-minute instructional (Appendix A) training session with the device and performed the protocol themselves.

The test aimed to assess neck extension. To avoid neck retraction induced movement, the neck was passively placed in cranio-cervical flexion. To ensure a proper movement, participants were manually guided by the examiners to perform five active neck extensions. To avoid compensation movements, participants were firmly strapped onto a table at the edge of the spinous process of T4 or at the top of the thoracic kyphosis, depending on their morphology (Figure 1). The dynamometer was securely strapped onto the participants' occipital protuberance as previously described [8], maintaining a parallel position to the ground (Figure 1). Once the participant and equipment were correctly positioned, the participants completed a familiarization phase where they were asked to push against the dynamometer with a self-estimated submaximal contraction of 50% during 6 seconds. After 1 minute of rest, participants were instructed to progressively push back with their head against the pull strap with a maximal force, to achieve maximal strength at three seconds, and continue pushing as much as possible for another three seconds. To reduce fear-avoidance and kinesiophobia, participants received complete reassurance about the safety of the test. Then they were asked if they felt that had achieved their maximal contraction. The dynamometer was then zeroed, and participants performed three trials of maximal isometric voluntary contraction (MIVC) with one minute of rest between each trial. To ensure maximal strength measurements were obtained, participants were asked after each trial if they felt they had achieved their maximal contraction. The peak values of each trial calculated by the dynamometer were recorded. The maximal force from the three trials was calculated using the peak value from three trials (Peak MIVC), as well as the mean of the two peak values from

Figure 1. Fixed handheld dynamometer measuring neck extensor strength.

Table 1. Participant characteristics (n = 40).

	Without Chronic Neck Pain n = 20	Chronic Neck Pain n = 20	p-values
Women	15	16	p = 0.68
Age (years)	32.8 (6.2)	37.9 (9.8)	p = 0.10
Height (cm)	169.3 (6.8)	168.6 (10.9)	p = 0.71
BMI (kg.m^{-2})	22.7 (2.4)	21.9 (2.9)	p = 0.41
Pain (VAS)	3.25 (1.68)	4.05 (1.66)	p = 0.36
Neck symptoms duration (months)		37.6 (40.4)	–
Neck Disability Index (NDI) (%)	–	29.2 (7.4)	–

Values are presented as mean ± 1SD. BMI: body mass index; VAS:Visual analogic scale

three trials (Mean 2Max MIVC). The test lasted 10 minutes. The equipment was then removed, the examiner left the room and the participant rested in supine position for 10 minutes. The second examiner entered, repositioned the participants and equipment and followed the same procedure of assessment including the familiarization phase. Each examiner was blind to the MIVC strength value of the other examiner. Intra-rater reliability was assessed with a 10-day interval.

Data analysis

Statistical analysis was carried out using SPSS (IBM SPSS 23.0; IBM Corp. Armonk, NY). Gender was described as frequency and proportion while continuous variables were computed as mean and standard deviation (SD). Depending on data normality, Student's t-tests or non-parametric Mann–Whitney tests were conducted to assess differences between groups (patients with and without CNSNP), examiners, and measurement times (T1 and T2), and for continuous variables (age, height, BMI, pain, neck strength). Fisher's exact test was used to compare categorical variables between groups. Normality was assessed using the Shapiro–Wilk test. Statistical significance was set at $p < 0.05$. Relative reliability was determined using Intraclass correlation coefficients (ICC) for intra- and inter-rater reliability with a confidence interval (CI) of 95% [17]. Two-way mixed-effects model, absolute agreement, and single rater/measurement was used to assess intra-rater reliability; a two-way random-effects model, absolute agreement, and single rater/measurement were used for inter-rater reliability, with a confidence interval (CI) of 95% [17]. The reliabilities were classified as poor (≤0.5), moderate (0.5–0.75), good (0.75–0.9), or excellent (≥0.90) [17]. Absolute reliability is the degree to which repeated measurements vary for individuals [18] and is expressed either in the units of the measurement or as a proportion of the measured values using the standard error of measurement, making it easier to interpret clinically in comparison with ICC [18]. Standard error of measurement (SEM) and minimal detectable change (MDC) (95%) were calculated using the following formula: $MDC = 1.96*SEM*\sqrt{2}$); $SEM = SD*\sqrt{(1\text{-}ICC)}$.

3. Results

Forty participants were enrolled in this study: 20 with CNSNP and 20 non-neck pain. Descriptive characteristics of the participants are summarized in Table 1. The control group was comprised of individuals with low back pain (n = 5), hip pain (n = 5), knee pain (n = 4), foot bone fracture (n = 2), ankle sprain n = 2, and Achilles' tendon tendinopathy (n = 1) and surgery (n = 1). We considered a clinically significant difference of 1.5 on the visual analogic scale (VAS) for pain between T1 and T2 for both groups of subjects.

Values of neck extensor isometric strength measurements are presented in Table 2. No significant differences were observed between examiners or groups ($p > 0.05$). For both intra- and inter-rater reliabilities, ICC values and lower bounds of CI, SEM and MDC95% were lower with the Maximal MIVC value from the three trials (Peak MIVC) and higher with the mean of two trial methods (Mean 2max MIVC; Table 3).

4. Discussion

This study aimed to investigate the intra- and inter-rater reliability of neck extensor isometric strength measurements in patients with and without CNSNP, using a portable dynamometer operated by examiners with a short-duration training (15 minutes) on the device and testing procedure. We reported excellent

Table 2. Maximal isometric neck extension strength recorded by examiners.

		Examiner 1 T1	Examiner 1 T2	Examiner 2 T1
Peak MIVC (N)	Neck pain	97.01 (32.56)	94.51 (27.91)	102.82 (34.14)
	Without neck pain	115.73 (41.01)	123.72 (45.35)	113.97 (40.61)
Mean 2Max MIVC (N)	Neck pain	93.27 (31.94)	98.10 (32.15)	91.46 (28.41)
	Without neck pain	111.43 (40.11)	108.18 (39.41)	119.71 (43.38)

Values are presented as mean ± 1SD. T1 = baseline; T2 = 10 days after baseline
Peak MIVC: Maximal MIVC value from the three trials; Mean 2Max MIVC: Mean of the two maximal MIVC values from the three trials

Table 3. Reliability for maximal isometric neck extension strength recorded by examiners.

		Intra-rater reliability					Inter-rater reliability		
		ICC (95%)	SEM	%SEM	MDC	%MDC		SEM	%SEM
Peak MIVC	Neck pain (n = 20)	0.93 (0.87–0.97)	9	8	24	25	0.87 (0.75–0.94)	12	12
	Without neck pain (n = 20)	0.95 (0.90–0.98)	9	11	25	22	0.96 (0.92–0.98)	8	7
	Total (n = 40)	0.94 (0.90–0.97)	9	9	25	24	0.92 (0.86–0.95)	10	10
Mean2Max MIVC	Neck pain (n = 20)	0.95 (0.90–0.97)	7	7	20	21	0.88 (0.77–0.94)	11	12
	Without neck pain (n = 20)	0.96 (0.91–0.99)	8	9	22	20	0.97 (0.93–0.99)	7	6
	Total (n = 40)	0.95 (0.90–0.97)	8	8	20	20	0.96 (0.92–0.98)	7	7

ICC = intraclass correlation coefficient; CI 95% = confidence interval; SEM = Standard error of measurement (in Newtons); MDC95% = minimal detectable change (in Newtons); %SEM = percentage of standard error of measurement with the mean of strength values; %MDC = percentage of minimal detectable change in comparison with the mean of strength values.Peak MIVC: Maximal MIVC value from the three trials; Mean 2Max MIVC: Mean of the two maximal MIVC values from the three trials.

intra- and inter-rater reliabilities for neck extensor strength measurements in both individuals with and without CNSNP.

Intra-rater reliability

Intra-rater reliability was excellent in groups with and without CNSNP, with an ICC of 0.96 (CI: 0.91–0.99) and 0.95 (0.90–0.97), respectively, based on the mean of the two highest from the three trials. To our knowledge, no previous study has assessed intra-rater reliability of neck extensor strength in patients suffering from chronic neck pain. A recent systematic review concluded a lack of studies investigating the reliability of neck strength measurement in individuals with neck pain, providing less external validity [15]. This is the first study reporting excellent intra-rater reliability for maximal isometric neck extensor strength in CNSNP. Many studies have assessed intra-rater reliability of neck extensor strength in individuals without neck pain [19–24] and reported lower reliability with an ICC between 0.63 [23] and 0.93 [20] in seated position, and ICC ranging between 0.76 and 0.94 in lying position [21, 23, 24], but with lage CI and lower bound of CI ranging from 0.21 to 0.89 [20, 21, 23, 24], meaning poor to good reliability in healthy participants. Tudini et al. reported an excellent reliability of 0.97 (0.94–98) in asymptomatic individuals [22].

Despite the efforts made by the above-mentioned authors to describe a reliable clinical test for neck extensor strength measurements with a portable dynamometer, it appears that insufficient details about the level of examiner training [20, 21, 23], a lack of details patient instructions [21, 23, 24], and a lack of information during the procedure. In some studies, the position of the device was not well described and participants were not securely strapped to avoid variations due to compensation movements [20-24]. These differences may explain the higher reliability and lower strength values obtained in our study. Performing a strength measurement with a non-fixed dynamometer could lead to errors in measurement due to the strength difference of the examiner and therefore provide less reliability [21, 24]. Our testing procedure in prone position was similar to that of two previous studies [21,24]. However, Vannebo et al. [21] did not securely strap participants and obtained lower intra-reliability; Carnevalli et al. [24] used the same position, securely strapped the participants but did not secure the dynamometer, and they found lower reliability. In the current study, we obtained strength values similar to Carnevalli et al. [24], and lower than Vannebo et al. [21]. Our procedure was described to the examiner in detail, the dynamometer was fixed to the participant, and participants were strapped to avoid compensations during the test. These differences may lead to less dispersion and explain the higher reliability observed in our study.

Inter-rater reliability

We found good to excellent inter-rater reliability with an ICC of 0.88 (CI: 0.77–0.94) for CNSNP patients and excellent for individuals without CNSNP with an ICC of 0.97 (CI: 0.93–0.99). Three previously published studies assessed inter-rater reliability of neck extensor strength with a portable dynamometer in individuals without neck pain [20, 24, 28]. They with a portable dynamometer in individuals without neck pain [20, 24, 25]. They reported lower inter-rater reliability with ICC ranging from 0.78 [24] to 0.88 [20, 25] and very large CI, ranging from 0.53 to 0.97 and 0.51 to 0.90 in healthy populations and from 0.61 to 0.93 in neck pain [25]. They also reported low inter-rater reliability (poor to good reliability) in migraine patients, with an ICC of 0.69 (CI: 0.41–0.85)[24].

Calculation Methods

In the literature there seems to be little variation in the methods of determining maximal isometric neck strength. Researchers have used a portable dynamometer during the first trial [28]; the peak value from two [22] or three trials [24], the mean of two [23] or three trials [20, 21, 24]. Determining the best method to estimate strength would help guide the clinician in carrying out the measurement. In our study the ICC and CI values were similar when using Peak MIVC or Mean 2Max MIVC methods in patients with CNSNP (0.93 [0.87–0.97] and 0.95 [0.90–0.97], respectively) and without (0.95 [0.90–0.98] and 0.96 [0.91–0.99], respectively). One previous study compared the peak value from three trials and the mean of three trials for neck strength reliability measurements with a portable dynamometer [24]. They reported similar results: lower ICC and CI with using the peak value (ICC = 0.69; CI:0.41–0.85) compared with the mean of three trials (ICC = 0.76, CI:0.54–0.89), suggesting that averaging trials leads to reducing errors and improves ICC and CI. The slight differences of ICC and CI between the peak and the mean of the two peak values from three trials methods in our study may be explained by the reliability of our procedure–regardless of the method.

SEM and MDC

SEM and MDC provide information about the relative magnitude of an error associated with a test and enable clinicians to distinguish real change that occurs as a result of an intervention. Previous studies regarding neck extension strength have reported a range of SEM from 8% to 9.6% in asymptomatic individuals [20, 21, 24] to 17% in migraine patients [24], compared to 7% in CNSNP patients in our study. Tudini et al. [22] and Kubas et al. [20] reported a MDC of 21% [22] and 23% [20] in asymptomatic individuals in comparison with 21% in CNSNP in the current study. Based on our results, a change of at least 21% (19.8 N) in neck extensor strength is required to obtain a confidence level of 95% that a change has occurred rather than a measurement error. This test is sufficiently sensitive and precise to monitor change in CNSNP patients.

Position/procedure

In the two studies that assessed inter-rater reliability of neck extensor strength in asymptomatic individuals [20] and migraine patients [24], the position of the dynamometer on the patient's head was not reported [20,24], therefore reducing replication possibilities for research and clinical practice. It should also be noted that most previous studies assessed neck extensor strength from neck retraction [22] or combined neck retraction and extension movements [21, 23, 24]. Kubas et al. [20] asked participants 'to think about looking up towards the ceiling', which may induce more cranio-cervical extension than global neck extension. Consequently, these previous studies did not strictly evaluate cervicothoracic extension strength. Neck retraction movement is a linear movement including upper cervical flexion and neck extension, while neck extension movement is an angular movement with a global cervical spine extension [29]. We proposed in the current study to differentiate the neck retraction movement from pure neck extension movement to strictly assess muscle strength of neck extensors.

CNSNP versus non neck pain patients

We found higher ICC values for intra-rater reliability compared to two previous studies (Cagnie et al. 0.94 (0.85 -0.98) and Scheuer et al 0.76 (no CI reported)) [26] and similar ICC values to Chiu et al. 0.95 (0.90 -0.99); Ylinen et al. 0.98 (0.94 -0.99); and Salmon et al. 2017 0.97 (0.93 -0.99)) [9, 11, 12] who explored neck extensor strength in laboratory settings. Most clinical studies investigating neck muscle strength in patients with neck pain in comparison with healthy individuals found significant lower neck extensor strength in neck pain patients [8 -12]. and by using istructions which ensure reassurance avoid fear [27] and force perception in people with neck pain the current study we assessed non-healthy patients without neck pain (but experienced lower back pain, hip pain, knee pain). Our results showed no significant differences of neck extensor strength values between individuals with CNSNP (93.27 N) and without (111.43 N). Ghamkhar et al. [27] found lower strength in trunk and hip muscles in neck pain patients compared with healthy individuals. Considering the excellent reliability of our measure, we may postulate that non-healthy patients without CNSNP could have general muscle deconditioning including neck muscles. Further studies are required to investigate the neck strength in CNSNP in comparison by using istructions which ensure reassurance [28] and force perception in people with neck pain [29] to avoid a "reduction of strength".

Study limitations

Our study has potential limitations such as the number of examiners, which limits the external validity of the findings. Having two reviewers could lead to an over or underestimation of the reliability. Some patients with neck pain could not tolerate the prone position or could not tolerate to perform maximum voluntary contraction of the neck extensors. Further studies are necessary to determine the reliability with several examiners and the validity compared to a laboratory machine in a large sample of asymptomatic individuals and patients with neck pain [30].

6. Conclusion

This study found excellent intra-rater and good to excellent inter-rater reliabilities for neck extension isometric strength measurements using a portable dynamometer in patients with and without CNSNP. The protocol we describe allows an examiner with minimal training to reliably assess neck extensor strength and should therefore be considered as a dependable and applicable tool in clinical settings to quantify neck extensor muscle strength and to monitor strength changes during and after a strengthening program in individuals with chronic neck pain.

We found no significant differences in neck extensor strength between patients CNSNP and non-healthy patients without CNSNP. This might be explained by general muscle deconditioning, including neck muscles, in non-neck pain individuals.

Disclosure statement

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