

ORIGINAL RESEARCH ARTICLE

Open Access



Neck proprioception assessment with a laser beam device: reliability in participants without neck pain and differences between participants with and without neck pain

Nikolaos Ntenezakos¹, Michail Makrogkikas¹, Zacharias Dimitriadis² and George A. Koumantakis^{3*} 

Abstract

Background: Proprioception deficits have previously been reported in patients with non-specific chronic neck pain (NSCNP), with a comprehensive and valid battery of tests still required. This study aimed to investigate the test-retest and inter-rater reliability of cervical proprioception in participants without NSCNP and to examine differences in proprioception between participants with and without NSCNP. Twenty participants without NSCNP and 20 age- and sex-matched participants with NSCNP were recruited. Proprioception tests were sequentially performed in random order, in four head-to-neutral movement directions (starting positions at mid-flexion, mid-extension and mid-right/mid-left rotation head-neck positions and end position at neutral head-neck posture) and two head-to-target movement directions (starting position from neutral head-neck posture and end positions at right and left 45° rotation), with a laser beam device secured onto their forehead. Participants performed all tests in sitting at a 1-m distance from a whiteboard. The average deviations of the laser beam mark from set targets marked on the whiteboard represented proprioception deficits. The two-way random, absolute agreement model of the intraclass correlation coefficient (ICC), the standard error of the measurement (SEM) and the smallest detectable difference (SDD) were used as measures of reliability. Between-group differences were examined with the independent samples *t* test.

Results: The reliability of the laser beam device in participants without neck pain varied from poor to good. The following tests demonstrated good reliability: test-retest 'Head-to-neutral from flexion' (ICC: 0.77–0.78; SDD: 5.73–6.84 cm), inter-rater 'Head-to-neutral from flexion' (ICC: 0.80–0.82; SDD: 6.20–6.45 cm) and inter-rater 'Head-to-neutral from right/left rotation' (ICC: 0.80–0.84; SDD: 5.92–6.81 cm). Differences between participants with and without NSCNP were found only in head-to-neutral from flexion (4.10–4.70 cm); however, those were within the limits of the SDD values of the HtN from flexion test.

Conclusions: The laser beam device can be reliably used in clinical practice only in the aforementioned head-neck movement directions, based on the findings of the present study. The between-group differences noted involved only the head mid-flexion to neutral test, possibly denoting proprioception deficits only in this movement direction, for reasons that require further evaluation.

*Correspondence: g.koumantakis2@gmail.com

³ 401 General Army Hospital of Athens, Physiotherapy Department, Pan, Kanellopoulou 1, Athens, Greece

Full list of author information is available at the end of the article

Keywords: Cervical spine, Sensorimotor, Position sense, Proprioception, Neck pain, Disability

Background

Chronic neck pain is one of the most common musculoskeletal disorders, defined as the presence of symptoms in the cervical spine longer than or equal to three months, without any specific aetiology linked to symptoms. The usual causes of cervical pain may occur as a result of an injury, prolonged incorrect posture and/or movement of the cervical spine, nerve root pressure, muscle sprains and whiplash-associated disorders [1].

The symptoms associated with NSCNP include headache, migraine, vision disorders, severe pain, range of movement limitations, numbness along the shoulder and upper extremities, and a feeling of fatigue [2]. Proprioception deficits in the cervical spine have also been identified [3]. Proprioception is defined as the sense of movement (kinesthesia), sense of orientation in space (joint position sense) or sense of effort [3, 4]. Proprioception sensory input is provided primarily in the periphery and is integrated in the central nervous system, contributing to static control, stability, and other conscious senses [5].

It has been indicated in a recent systematic review that a number of different measurement tools and tests have been used to assess neck proprioception, commonly by assessing deviation from set targets, a method using joint position error (JPE) as an outcome [6]. A recent study that conducted a factor analysis of seven different sensorimotor control (SMC) tests concluded that JPE tests might be assessing a unique proprioception aspect, separate from other aspects that the other six tests examine [7]. Regarding the measuring instrument utilized to assess neck proprioception JPE, the laser beam device has been used in many studies [8–12]. However, further exploration of the methods of administration of cervical proprioception JPE tests is required, considering that previous reliability studies with the laser beam device presented non-uniform findings, with intra-rater reliability values ranging in participants without NSCNP from moderate to good [8, 9], or moderate to excellent [10]. Similarly, in participants with NSCNP reliability JPE values ranged from moderate to excellent [10], to moderate [11] and in mixed group of participants with and without NSCNP from moderate-poor [12]. In addition, a systematic review with meta-analysis that examined the known-groups validity of these tests between participants with and without neck pain has not been invariably demonstrated, with overlapping JPE test scores revealed in several test directions that were examined, resulting in non-significant differences between populations [6].

Therefore, the primary aim of this study was to investigate the reliability of a laser beam device to assess cervical proprioception in healthy participants. Furthermore, a secondary aim was to perform a comparison of cervical proprioception between two groups of age- and sex-matched participants with or without NSCNP, to assess the known-groups validity of the cervical proprioception assessment methods employed.

Methods

Participants

A total of 20 healthy participants were recruited, from the staff and students of Metropolitan College. The sampling method used was convenience sampling. Additionally, data from 20 participants with NSCNP in a previous study [13] were utilized. The participants were age- and sex-matched between the two groups, with the ‘individual matching’ method [14], to avoid confounding related to either of those anthropometric variables, previously shown to affect proprioception measures [15] or sex-related cervical muscles’ orientation [16].

The inclusion criteria for participants with NSCNP were age between 18 and 65 years and neck pain history of more than or equal to three months. All participants with non-specific chronic neck pain had previously consulted a medical practitioner (orthopaedic doctor) and had a diagnosis following a thorough clinical examination. They all had a history of either repeated or continuous episodes of pain limited to the neck area, with no radicular pain symptoms in the upper extremities, collectively exceeding a time-period of 3 months [1]. Participants with NSCNP with upper quadrant pathology or spinal dysfunctions other than neck pain were excluded. Admission criteria for healthy participants without NSCNP were as follows: age between 18–65 years and no history of neck pain. Exclusion criteria for all participants were clinical disorders that could affect proprioception, such as obesity, osteoporosis, spinal arthropathy, spinal disorders, spinal surgery, rheumatic diseases, cancer and pregnancy.

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Metropolitan College (approval number 208/2017). All procedures were performed in compliance with relevant laws and institutional guidelines and the rights of participants were protected at all times, according to the Declaration

of Helsinki. All participants signed an informed consent form prior to participation in this study.

Equipment and material

A laser beam device was constructed, by fixing a standard laser pointer to a commercially available head-mounted elastic band for action cameras. The laser pointer was secured with duct tape in the space available for mounting the action camera onto the strap. The laser pointer was positioned exactly in the centre of the participants' forehead and was parallel to the ground when the device was placed on the participants' head. In addition to the laser beam device, a blindfold was also used, to occlude the participants' vision, therefore eliminating all visual feedback during the proprioception experiment.

The participants with NSCNP were asked to report their usual daily life average pain intensity and their current pain intensity before the experimental proprioception testing procedure on a pain visual analogue scale (P-VAS). Participants with NSCNP were asked to mark their pain intensity level with a point on a 10-cm straight line extending between 0 (no pain) and 10 (maximum pain). The validity and reliability of the VAS for the evaluation of chronic musculoskeletal pain has been previously established [17]. The participants with NSCNP were also asked to fill in the Neck Disability Index (NDI), a functional impairment self-report subjective rating scale in relation to neck pain. Ten categories of questions are assessed, with six possible answers for each category and scores ranging from 0 (no disability) to 50 (maximum score). The score is then converted into a percentage score. The validity and reliability of this scale in evaluating cervical dysfunction in all categories of patients with cervical pain has been previously established [18]. The cross-culturally adapted version of the NDI scale in Greek was utilized [19].

Procedure

All participants completed a questionnaire with demographic characteristics. Participants with NSCNP additionally completed the NDI and P-VAS scales. Participants with NSCNP had also completed the test-retest and inter-rater reliability of the proprioception methods involved [13]. All questionnaires and consent forms were collected by one of the principal investigators (ZD), with assessors (ND and MM) remaining blinded to participants' grouping.

Each participant was then asked to sit on a stable chair at a set distance of 1 m away from a whiteboard to perform the proprioception tests. The measurement position was standardized for all participants by placing their knees and hips at 90°, their pelvis and low back resting firmly against the back of a chair and their hands resting

on their knees. All measurements were performed in a Physiotherapy Lab, where external auditory distractions were maintained at a minimum and temperature was kept constant, at 23 °C. The participants' vision was occluded throughout the experiment with a blindfold and the laser beam device was secured on their forehead (Fig. 1), following standard methodology [6, 7].

Two different types of JPE tests were performed in relation to their starting and end positions: four head to neutral (HtN) and two head to target (HtT) tests. Prior to the initiation of each test, the participants were asked to assume their relaxed, neutral head position (NHP) and memorize it. The examiner marked the exact point (point 0) where the laser beam was projected on the whiteboard with a black marker. When participants felt confident about memorizing this position, each test was initiated. Each test was administered in random order, to eliminate any order effects.

For the HtN tests, the examiner passively moved each participant's head in the following directions: right rotation, left rotation, flexion and extension, at approximately 45°. From each of these positions, participants were instructed to actively return their head to the NHP and the new point where the laser beam projected on the whiteboard was marked (point A). After the completion of this test, the examiner used a tape measure to record the distance between points 0 and A. This distance/deviation represented the proprioception deficit (JPE) of each participant for the examined movement. Five repetitions were performed for each movement direction and five

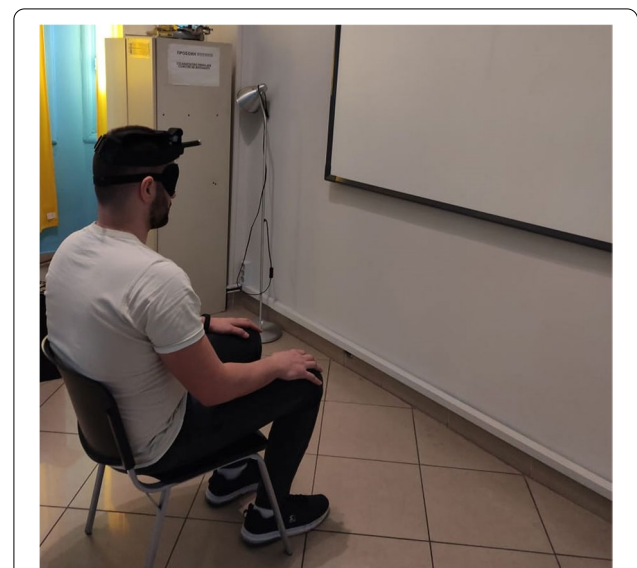


Fig. 1 Experimental set-up for neck proprioception testing, with the laser beam device placed on the participant's head and vision occluded with a blindfold

scores of cervical proprioception JPE were obtained for each movement direction.

For the two HtT tests, the chair was placed at a 45° angle to the whiteboard (rotated either at 45° to the right or to the left). Maintaining the same conditions, the participants' heads were passively rotated at 45°. This was the target position and was marked on the whiteboard with a black marker (point 0). Participants were asked to memorize this position and their heads were returned to their neutral positions. Immediately after, they were asked to rotate their head to the target position and the new laser beam position was marked again on the whiteboard (point A). Again, five repetitions were performed for each movement direction and five scores of JPE were recorded for each HtT test movement direction. For all tests performed the average deviation from the set target of the first three repetitions and all five repetitions represented the overall proprioception deficit (JPE) per movement direction [20].

The whole procedure was performed by examiner A and after a 5-min break, it was repeated by examiner B. Then, participants were asked to leave and return after 45–60 min, for the same procedure to be repeated by examiner A. During this period, patients were asked not to smoke, eat or participate in any activities that could affect their neck condition. The examiners were blinded to each other's measurements.

Statistical analysis

The distribution of all variables was checked using the Kolmogorov-Smirnov test. Test-retest and inter-rater reliability was examined using the second model of intraclass correlation coefficient (ICC) (two-way random, absolute agreement). The averages of the first three and all five trials per test were used for the reliability and between-group differences analyses. ICC values of <0.50, between 0.50 and 0.75, between 0.75 and 0.90 and >0.90 are considered to indicate poor, moderate, good and excellent reliability, respectively [21]. The associated standard error of measurement (SEM), ($SEM = SD\sqrt{1-ICC}$) and smallest detectable difference (SDD), ($SDD = 1.96\sqrt{2SEM}$) were calculated for each ICC [22]. The smallest detectable difference (SDD) represents the minimum amount of change that can be considered a real change, beyond the error of the measurement [22].

Independent samples t-tests were performed to test for differences between the two groups. An a priori power calculation was performed in the G*Power 3.1.9.7 for Windows program [23] to establish the required sample size for the known-groups validity part of this study. It was calculated that to detect a between-group mean difference of 4 cm with a common standard deviation of 4.5 cm, a-level (2-sided) of 0.05 and 0.80 power level, the

required sample would be $n=20$ per group. Additionally, an a priori power calculation was performed in an online web-based sample size calculator for reliability studies and for an expected ICC=0.85, measurements taken at two occasions, a lowest acceptable ICC=0.55, a-level (2-sided) of 0.05 and 0.80 power level, the required sample would be $n=21$ (https://wnarifin.github.io/ssc_web.html). The significance level was set at $p=0.05$ for all comparisons. The Statistical Package for Social Sciences (SPSS, version 26.0) was used for all data analyses.

Results

The demographic characteristics and all proprioception variables for each of the groups of participants, and the symptoms variables of participants with NSCNP conformed to a normal distribution ($p>0.05$), according to the Kolmogorov-Smirnov test.

Demographics of the two groups examined and the symptoms of participants with NSCNP are presented in Table 1. No significant differences were identified in the between-group comparisons of the demographic characteristics of participants, using the independent samples t-test.

Reliability in healthy participants was calculated from the average of the first three, as well as of the five repetitions for each movement direction, to examine whether higher reliability levels could be achieved with either of those averaging methods.

The test-retest reliability level in participants without NSCNP varied from low to good (Table 2). Specifically, the test-retest reliability of HtN from flexion (ICC: 0.77–0.78; SEM: 2.07–2.47 cm; SDD: 5.73–6.84 cm) was good, with either of the two methods of averaging repetitions. In addition, the test-retest reliability of HtT at 45o right

Table 1 Demographic characteristics of all participants and symptoms characteristics of participants with NSCNP

Characteristic	Healthy Mean (SD)	NSCNP Mean (SD)
Sample (-)	20	20
Gender (female/male)	10/10	10/10
Age (years)	32.3 (16.2)	32.8 (14.8)
Height (cm)	171.4 (8.3)	173.6 (7.6)
Body mass (kg)	72.4 (14.4)	71.8 (12.3)
Pain duration (months)	-	14.4 (10.7)
Pain frequency (times/week)	-	3.9 (1.3)
NDI	-	17.8 (8.73)
VAS usual Pain (cm)	-	5.4 (2.3)
VAS current Pain (cm)	-	3.6 (1.7)

NSCNP non-specific chronic neck pain, NDI Neck Disability Index, VAS visual analogue scale, SD standard deviation

Table 2 Test-retest reliability of the laser beam device in healthy participants

TEST	Average repetitions	ICC	95% CI	SEM (cm)	SDD (cm)
HtN from R rotation	1st–3rd	0.40	– 0.16, 0.6	3.71	10.27
	All	0.44	– 0.15, 0.63	2.99	8.28
HtN from L rotation	1st–3rd	0.32	0.29, 0.58	3.84	10.63
	All	0.46	– 0.13, 0.64	3.3	9.14
HtN from flexion	1st–3rd	0.78	0.3, 0.04	2.47	6.84
	All	0.77	0.27, 0.83	2.07	5.73
HtN from extension	1st–3rd	– 0.07	– 0.47, 0.4	4.06	11.24
	All	0.36	– 0.24, 0.6	3.43	9.5
HtT to 45° R rotation	1st–3rd	0.31	– 0.24, 0.56	4.52	12.52
	All	0.56	– 0.03, 0.7	2.8	7.75
HtT to 45° L rotation	1st–3rd	0.43	– 0.19, 0.64	3.12	8.64
	All	0.73	0.31, 0.89	2.21	6.12

HtN head-to-neutral, HtT head-to-target, ICC intraclass correlation coefficient, CI confidence intervals, SEM standard error of measurement, SDD smallest detectable difference, R/L right/left

and at 45° left rotation was moderate (ICC: 0.56–0.73; SEM: 2.08–2.21 cm; SDD: 6.12–7.75 cm), when the average score of all five repetitions was considered. For those three tests, the SEM was the lowest (2.07–2.8 cms). For the remaining test directions, the test-retest reliability was low.

The inter-rater reliability level in participants without NSCNP also varied from low to good (Table 3). The inter-rater reliability in three out of six tests (HtN from right rotation, left rotation and flexion) was good (ICC: 0.80–0.84; SEM: 2.14–2.46; SDD: 5.92–6.81 cm), with either of the two methods of averaging repetitions. Also, inter-rater reliability of HtN from extension (ICC: 0.66; SEM: 3.35 cm; SDD: 9.27 cm) and HtT at 45° left rotation (ICC: 0.59; SEM: 2.27 cm; SDD: 6.28 cm) were moderate,

when the average score of all 5 repetitions was considered. However, the inter-rater reliability in the HtT at 45° right rotation test was low with either method of averaging repetitions.

Differences in proprioception JPE values between participants with and without NSCNP were not significantly different (Table 4), except for the HtN from the flexion test ($p < 0.05$). However, the between-group differences for this test were between 4.10 and 4.70 cm, within the limits of the SDD values of the HtN from the flexion test.

Discussion

This study assessed the within-day reliability (test-retest and inter-rater) of a laser beam device with a battery of six repositioning accuracy tests (HtN and HtT) in

Table 3 Inter-rater reliability of the laser beam device in healthy participants.

TEST	Average repetitions	ICC	95% CI	SEM (cm)	SDD (cm)
HtN from R rotation	1st–3rd	0.84	0.42, 0.88	2.46	6.81
	All	0.84	0.44, 0.88	2.18	6.03
HtN from L rotation	1st–3rd	0.82	0.37, 0.86	2.14	5.92
	All	0.80	0.32, 0.85	2.46	6.81
HtN from flexion	1st–3rd	0.82	0.39, 0.87	2.24	6.20
	All	0.80	0.33, 0.85	2.33	6.45
HtN from extension	1st–3rd	0.45	– 0.16, 0.64	4.79	13.26
	All	0.66	0.08, 0.76	3.35	9.27
HtT to 45° R rotation	1st–3rd	0.30	– 0.2, 0.54	4.38	12.13
	All	0.40	– 0.25, 0.57	3.28	9.08
HtT to 45° L rotation	1st–3rd	0.48	– 0.15, 0.66	3.38	9.36
	All	0.59	0.00, 0.72	2.27	6.28

HtN head-to-neutral, HtT head-to-target, ICC intraclass correlation coefficient, CI confidence intervals, SEM standard error of measurement, SDD smallest detectable difference, R/L right/left

Table 4 Proprioception deficit differences (in cm) between healthy and NSCNP participants

TEST	Average repetitions	Healthy Mean (SD)	NSCNP Mean (SD)	p
HtN from R rotation	1st–3rd	9.0 (5.3)	8.98 (3.55)	0.98
	All	8.36 (4.18)	9.04 (2.85)	0.55
HtN from L rotation	1st–3rd	8.68 (3.9)	9.95(4.75)	0.36
	All	9.08 (4.68)	10.14(5.17)	0.49
HtN from flexion	1st–3rd	8.95 (4.43)	13.11 (8.31)	0.05*
	All	9.10 (3.94)	13.81 (9.01)	0.03*
HtN from extension	1st–3rd	9.25 (4.82)	10.91 (6.02)	0.34
	All	9.16 (4.54)	10.88 (4.96)	0.26
HtT to 45° R rotation	1st–3rd	11.67 (5.78)	12.01 (4.93)	0.84
	All	9.88 (4.05)	11.39 (3.59)	0.22
HtT to 45° L rotation	1st–3rd	9.24 (4.25)	9.87 (3.46)	0.60
	All	8.77 (3.44)	9.61 (2.62)	0.39

HtN head-to-neutral, HtT head-to-target, NSCNP non-specific chronic neck pain, SD standard deviation, R/L right/left, *p<0.05

participants without NSCNP. This device is low-cost and tests performed with this evaluation tool are not time-consuming compared to other tools that evaluate cervical proprioception. The methodology used for assessing cervical proprioception in participants without NSCNP demonstrated adequate test-retest reliability in three out of six tests (HtN from mid-flexion, HtT at 45° right and at 45° left rotation) and adequate inter-rater reliability in five out of six tests (all, apart from the HtT at 45° right rotation). The average of five repetitions over three repetitions towards each test direction is recommended, based on our test-retest and inter-rater reliability data, as ICC values tended to increase and SEM and SDD values tended to decrease when more repetitions were used. For the participants with NSCNP included in the current study, following the same experimental procedure, moderate to good same-day test-retest (ICC: 0.56–0.81, SEM: 2.09–5.01 cm, SDD: 5.79–13.87 cm) and moderate to excellent inter-rater reliability (ICC: 0.59–0.92, SEM: 1.75–3.27 cm, SDD 4.85–9.05 cm) were also reported [13].

The test-retest reliability level in previous cervical proprioception studies utilizing the laser beam as a measuring instrument was variable, ranging from moderate to good [8, 9] or moderate to excellent [10] in participants without NSCNP. Specifically, in a recent study examining test-retest reliability ($n=24$, same day-12h interval) of 4 HtN tests and calculating JPE by averaging 5 repetitions per test, the reliability values of HtN from flexion (ICC:0.75, SEM: 0.49 cm), extension (ICC: 0.81, SEM: 0.64 cm), and right and left rotation (ICC: 0.64, SEM: 0.63 cm) [8]. In another similar previous study that examined the effect of 10 different averaging methods on reliability ($n=40$, same day-1h interval), it was reported

that when the HtN from rotation test was executed in its original form (10 trials for each test), the reliability level was moderate to good (horizontal plane ICC: 0.80, SEM: 0.9o; vertical plane ICC: 0.52, SEM: 0.7 o) [9]. In a more recent study examining test-retest reliability ($n=33$, same day), 4 different tests were administered bilaterally (HtN rotation tests, trunk to target rotation tests, HtT rotation tests and figure of eight tests), calculating JPE by averaging 6 repetitions per test [10]. Reliability values for the healthy participants were good to excellent for the within-session intra-rater reliability (ICC: 0.75–0.93, SEM: 0.5–1.2°); however, for the between-session intra-rater reliability, they were moderate to good (ICC: 0.55–0.83, SEM: 0.7–1.1°) [10]. Although the SEM values were in general of low magnitude, the authors of that study remained sceptical about the clinical utility of the tests, since error was masking the JPE differences identified between participants with and without NSCNP [10]. In another study, the intra-rater reliability values in 41 participants with NSCNP (same examiner repeating the procedure after 1 h, HtN from maximal cervical rotation test) was moderate (ICC=0.68) [11]; however, no SEM values were reported in parallel. Under a different methodology set-up, with the laser beam positioned 1 m behind the participant, and the laser beam projected to a cm ruler attached to a cap worn by the participants, 2 different studies reported from poor to good (ICC: 0.48–0.80) [24] to poor-moderate (ICC: 0.02–0.66) results for three different HtN tests (from rotation, flexion, and extension) [12].

In all the above studies the HtN tests were conducted by a return to neutral from an end of range movement in each test direction. The methodology we employed was slightly different, as participants were requested to

match the neutral position upon return from a mid-range respective movement direction, to provide less end-of-range feedback to participants; however, this variation in test performance did not provide substantially different reliability estimates. Possible reasons for increased reliability may have been the larger samples ($n=33-41$) recruited in some of the previous studies [9, 10]. Additionally, it was observed that when proprioception JPE was calculated from tests that included at least 5 repetitions, ICC and error values improved [9], whereas moderate-low reliability was reported in studies that only three repetitions per test were performed [9, 12].

Additionally, the known-groups validity of the proprioception assessment methods used requires rigorous assessment. To this end, the present study further examined the differences in JPE between two age- and sex-matched populations of participants with and without NSCNP. Statistically significant between-group differences were observed only in the HtN from the flexion test. However, these differences were within the SDD values for this particular test direction; therefore, they cannot be considered clinically significant. The results of this study coincide with those of three previous studies that included patients with NSCNP and healthy participants, where statistically significant between-group JPE differences were reported only in HtN from flexion [25–27]. In contrast, other studies [10, 11, 28, 29] have reported that healthy participants have significantly less JPE compared to participants with NSCNP for HtN from rotation tests, also.

Considering the between-group differences in JPE identified in this study (in HtN from flexion) it seems that JPE was primarily affected in sagittal plane movements in participants with NSCNP. However, forward head posture or motor control between-group differences were not examined in this study. Therefore, as a hypothesis to be tested in future studies, it is proposed that alterations in neck posture, such as forward head posture [30], may sequentially lead to proprioception acuity diminution related to this particular plane of movement [31, 32] in conjunction with pain presence. Motor control exercises that are effective in reducing symptoms in patients with NSCNP [33] may also be re-training the proprioception acuity of the cervical spine [34], possibly contributing in parallel to the therapeutic effect.

As a limitation to this study, no separate familiarization session was included, which could have improved the reliability level of the tests employed, and is proposed to be included in the future. Furthermore, the vertebral level of pain in participants with NSCNP recruited was not examined, as in NSCNP the distribution of pain is widespread. However, the region of cervical pain may affect JPE values, especially if located in the upper cervical spine [35]. Future

studies may need to classify participants with NSCNP according to their primary area of symptoms, if possible. In addition, the participants recruited for this study constituted a sample of convenience. Future investigations could recruit a larger sample of participants with NSCNP, following certain neck pain categorization criteria [36], to provide more population-specific results. Finally, psychosocial characteristics of patients with NSCNP (anxiety and fear) reported to correlate with disability levels [37, 38] and JPE values [10], require further study.

Conclusions

In a group of healthy participants without NSCNP, the laser beam device JPE tests demonstrated variable test-retest and inter-rater reliability. Therefore, these can be used with confidence in clinical practice only in particular testing directions with the least measurement error. The between-group differences between participants with and without NSCNP involved only one of the six movement directions examined. Future diagnostic and therapeutic studies are required to confirm these findings in a larger sample of participants and subgroups of neck pain patients with a range of pain, disability, and psychological characteristics.

Abbreviations

CI: Confidence intervals; HtN: Head-to-neutral; HtT: Head-to-target; ICC: Intraclass correlation coefficient; JPE: Joint position error; NHP: Neutral head position; NDI: Neck Disability index; NSCNP: Non-specific chronic neck pain; P-VAS: Pain visual analogue scale; R/L: Right/left; SEM: Standard error of measurement; SDD: Smallest detectable difference; SMC: Sensorimotor control; SD: Standard deviation.

Acknowledgements

The authors wish to thank all participants for their valuable contribution to this study.

Authors' contributions

All authors made equal contributions to the conception and design of the work; ND and MM performed all the acquisition of data; ZD and GAK performed the data analysis; all authors performed the interpretation of data; all authors have drafted the work or substantively revised it and have approved the submitted version; all authors have agreed both to be personally accountable for the author's own contributions and to ensure that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and the resolution documented in the literature.

Funding

None.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics committee of Metropolitan College (approval number 208/2017). All procedures were performed in compliance with relevant laws and institutional guidelines and the rights of participants

were protected at all times, according to the Declaration of Helsinki. Prior to participation to this study, all subjects had to sign an informed consent form. A written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Author details

¹MSc Physiotherapy Programme, Metropolitan College, Health Sciences Faculty, Department of Physiotherapy, Affiliated Institution with University of East London, London, UK. ²Physiotherapy Department, University General Hospital 'Attikon', Rimini 1, Athens, Greece. ³401 General Army Hospital of Athens, Physiotherapy Department, Pan, Kanelloupolou 1, Athens, Greece.

Received: 8 June 2021 Accepted: 13 October 2021

Published online: 28 November 2021

References

- Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. *BMJ*. 2017;358:j3221 [PMID: 28807894. <https://doi.org/10.1136/bmj.j3221>].
- Sterling M, de Zoete RMJ, Coppieters I, Farrell SF. Best evidence rehabilitation for chronic pain part 4: neck pain. *J Clin Med*. 2019;8(8):1219 [PMID: 31443149. <https://doi.org/10.3390/jcm8081219>].
- Treleaven J, Takasaki H, Grip H. Altered trunk head co-ordination in those with persistent neck pain. *Musculoskelet Sci Pract*. 2019;39:45–50 [PMID: 30476827. <https://doi.org/10.1016/j.msksp.2018.11.010>].
- Li DE, David KEB, O'Leary S, Treleaven J. Higher variability in cervical force perception in people with neck pain. *Musculoskelet Sci Pract*. 2019;42:6–12 [PMID: 30981102. <https://doi.org/10.1016/j.msksp.2019.04.001>].
- Roijezon U, Clark NC, Treleaven J. Proprioception in musculoskeletal rehabilitation. Part 1: basic science and principles of assessment and clinical interventions. *Man Ther*. 2015;20(3):368–77 [PMID: 25703454].
- de Zoete RMJ, Osmotherly PG, Rivett DA, Farrell SF, Snodgrass SJ. Sensorimotor control in individuals with idiopathic neck pain and healthy individuals: a systematic review and meta-analysis. *Arch Phys Med Rehabil*. 2017;98(6):1257–71 [PMID: 27771360. <https://doi.org/10.1016/j.apmr.2016.09.121>].
- de Zoete RMJ, Osmotherly PG, Rivett DA, Snodgrass SJ. Seven cervical sensorimotor control tests measure different skills in individuals with chronic idiopathic neck pain. *Braz J Phys Ther*. 2020;24(1):69–78 [PMID: 30446237 PMCID: Pmc6994390. <https://doi.org/10.1016/j.bjpt.2018.10.013>].
- Hatamvand S, Ghiassi F, Asgari Ashtiani AR, Akbari A, Hossienifar M. Intra-rater reliability of cervical sensory motor function and cervical reconstruction test in healthy subjects. *Int J Med Res Health Sci*. 2016;5(7S):598–603.
- Pinsault N, Fleury A, Virone G, Bouvier B, Vaillant J, Vuillerme N. Test-retest reliability of cervicocephalic relocation test to neutral head position. *Physiother Theory Pract*. 2008;24(5):380–91 [PMID: 18821444. <https://doi.org/10.1080/09593980701884824>].
- Gonçalves C, Silva AG. Reliability, measurement error and construct validity of four proprioceptive tests in patients with chronic idiopathic neck pain. *Musculoskelet Sci Pract*. 2019;43:103–9 [PMID: 31376618. <https://doi.org/10.1016/j.msksp.2019.07.010>].
- Roren A, Mayoux-Benhamou MA, Fayad F, Poiraudeau S, Lantz D, Revel M. Comparison of visual and ultrasound based techniques to measure head repositioning in healthy and neck-pain subjects. *Man Ther*. 2009;14(3):270–7 [PMID: 18514016. <https://doi.org/10.1016/j.math.2008.03.002>].
- Jorgensen R, Ris I, Falla D, Juul-Kristensen B. Reliability, construct and discriminative validity of clinical testing in subjects with and without chronic neck pain. *BMC Musculoskelet Disord*. 2014;15:408 [PMID: 25477032 PMCID: Pmc4325947. <https://doi.org/10.1186/1471-2474-15-408>].
- Makrogikas M, Ntenezakos N, Koumantakis GA, Dimitriadis Z. Reliability of a laser beam device for the assessment of head repositioning accuracy in patients with chronic neck pain. *Acta Gymnica*. 2021;51:e2021.2010. <https://doi.org/10.5507/ag.2021.010>.
- Setia MS. methodology series module 2: case-control studies. *Indian J Dermatol*. 2016; 61(2): 146–151 [PMID: 27057012 PMCID: Pmc4817437 DOI: <https://doi.org/10.4103/0019-5154.177773>].
- Artz NJ, Adams MA, Dolan P. Sensorimotor function of the cervical spine in healthy volunteers. *Clin Biomech*. 2015;30(3):260–8 [PMID: 25686675 PMCID: Pmc4372261. <https://doi.org/10.1016/j.clinbiomech.2015.01.005>].
- Keidan L, Barash A, Lenzner Z, Pick CG, Been E. Sexual dimorphism of the posterior cervical spine muscle attachments. *J Anat*. 2021;239(3):589–601 [PMID: 33876427. <https://doi.org/10.1111/joa.13448>].
- Boonstra AM, Schiphorst Preuper HR, Reneman MF, Posthumus JB, Stewart RE. Reliability and validity of the visual analogue scale for disability in patients with chronic musculoskeletal pain. *Int J Rehabil Res*. 2008;31(2):165–9 [PMID: 18467932. <https://doi.org/10.1097/MRR.0b013e3282fc0f93>].
- Vernon H, Mior S. The neck disability index: a study of reliability and validity. *J Manip Physiol Ther*. 1991;14(7):409–15 [PMID: 1834753].
- Trouliti MN, Vernon HT, Kakavelakis KN, Antonopoulou MD, Paganas AN, Lionis CD. Translation of the neck disability index and validation of the Greek version in a sample of neck pain patients. *BMC Musculoskelet Disord*. 2008;9:106 [PMID: 18647393 PMCID: Pmc2492862. <https://doi.org/10.1186/1471-2474-9-106>].
- Schmidt RA. Methodology for studying motor performance. In: Schmidt RA, Lee TD, Winstein CJ, Wulf G, Zelaznik HN, editors. *Motor control and learning: a behavioral emphasis*. 6th ed. Champaign, IL: Human Kinetics; 2019. p. 23–56.
- Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med*. 2016;15(2):155–63 [PMID: 27330520 PMCID: Pmc4913118. <https://doi.org/10.1016/j.jcm.2016.02.012>].
- Portney LG, Watkins MP. *Foundations of clinical research: applications to practice*. 3rd. International Edn. Ed. Harlow, Essex: Pearson Education Ltd.; 2014.
- Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175–91 [PMID: 17695343. <https://doi.org/10.3758/bf03193146>].
- Juul T, Langberg H, Enoch F, Søgaard K. The intra- and inter-rater reliability of five clinical muscle performance tests in patients with and without neck pain. *BMC Musculoskelet Disord*. 2013;14:339 [PMID: 24299621 PMCID: Pmc4219589. <https://doi.org/10.1186/1471-2474-14-339>].
- Rix GD, Bagust J. Cervicocephalic kinesthetic sensibility in patients with chronic, nontraumatic cervical spine pain. *Arch Phys Med Rehabil*. 2001;82(7):911–9 [PMID: 11441377. <https://doi.org/10.1053/apmr.2001.23300>].
- Palmgren PJ, Andreasson D, Eriksson M, Hägglund A. Cervicocephalic kinesthetic sensibility and postural balance in patients with nontraumatic chronic neck pain—a pilot study. *Chiropr Osteopat*. 2009;17:6 [PMID: 19566929 PMCID: Pmc2715410. <https://doi.org/10.1186/1746-1340-17-6>].
- Portelli A, Reid SA. Cervical proprioception in a young population who spend long periods on mobile devices: a 2-group comparative observational study. *J Manipulative Physiol Ther*. 2018;41(2):123–8 [PMID: 29338884. <https://doi.org/10.1016/j.jmpt.2017.10.004>].
- Revel M, Andre-Deshays C, Minguet M. Cervicocephalic kinesthetic sensibility in patients with cervical pain. *Arch Phys Med Rehabil*. 1991;72(5):288–91. 2009044.
- Dugaillly PM, De Santis R, Tits M, Sobczak S, Vigne A, Feipel V. Head repositioning accuracy in patients with neck pain and asymptomatic subjects: concurrent validity, influence of motion speed, motion direction and target distance. *Eur Spine J*. 2015;24(12):2885–91 [PMID: 26438174. <https://doi.org/10.1007/s00586-015-4263-9>].
- Mahmoud NF, Hassan KA, Abdelmajeed SF, Moustafa IM, Silva AG, et al. *Curr Rev Musculoskelet Med*. 2019;12(4):562–77 [PMID: 31773477 PMCID: Pmc6942109. <https://doi.org/10.1007/s12178-019-09594-y>].
- Ha SY, Sung YH. A temporary forward head posture decreases function of cervical proprioception. *J Exerc Rehabil*. 2020;16(2):168–74 [PMID: 32509702. <https://doi.org/10.12965/jer.2040106.053>].
- Alghadir A, Zafar H, Iqbal Z, Al-Eisa E. Effect of sitting postures and shoulder position on the cervicocephalic kinesthesia in healthy young males.

- Somatosens Mot Res. 2016;33(2):93–8 [PMID: 27255483. <https://doi.org/10.1080/08990220.2016.1189895>].
33. Price J, Rushton A, Tyros I, Tyros V, Heneghan NR. Effectiveness and optimal dosage of exercise training for chronic non-specific neck pain: A systematic review with a narrative synthesis. *PLoS One*. 2020;15(6):e0234511 [PMID: 32520970. <https://doi.org/10.1371/journal.pone.0234511>].
 34. Jull G, Falla D, Treleaven J, Hodges P, Vicenzino B. Retraining cervical joint position sense: the effect of two exercise regimes. *J Orthop Res*. 2007;25(3):404–12 [PMID: 17143898. <https://doi.org/10.1002/jor.20220>].
 35. Treleaven J, Clamaron-Cheers C, Jull G. Does the region of pain influence the presence of sensorimotor disturbances in neck pain disorders? *Man Ther*. 2011;16(6):636–40 [PMID: 21890397. <https://doi.org/10.1016/j.math.2011.07.008>].
 36. Guzman J, Hurwitz EL, Carroll LJ, Haldeman S, Côté P, Carragee EJ, et al. A new conceptual model of neck pain: linking onset, course, and care: the bone and joint decade 2000–2010 task force on neck pain and its associated disorders. *J Manipulative Physiol Ther*. 2009;32(2 Suppl):S17–28 [PMID: 19251062. <https://doi.org/10.1016/j.jmpt.2008.11.007>].
 37. Sá S, Silva AG. Repositioning error, pressure pain threshold, catastrophizing and anxiety in adolescents with chronic idiopathic neck pain. *Musculoskelet Sci Pract*. 2017;30:18–24 [PMID: 28494262. <https://doi.org/10.1016/j.msksp.2017.04.011>].
 38. Dimitriadis Z, Kapreli E, Strimpakos N, Oldham J. Do psychological states associate with pain and disability in chronic neck pain patients? *J Back Musculoskelet Rehabil*. 2015;28(4):797–802 [PMID: 25736955. <https://doi.org/10.3233/bmr-150587>].

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen[®] journal and benefit from:

- Convenient online submission
- Rigorous peer review
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at ► [springeropen.com](https://www.springeropen.com)
