

ORIGINAL RESEARCH

## Reliability of a laser beam device for the assessment of head repositioning accuracy in patients with chronic neck pain

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### Abstract

**Background:** Laser beam devices have been widely used for the assessment of cervical proprioception. However, their reliability for the assessment of repositioning accuracy in patients with chronic neck pain requires further examination. **Objective:** Examination of test-retest and inter-rater reliability of a laser beam device for the assessment of cervical proprioception in patients with chronic neck pain. **Methods:** Twenty patients with chronic neck pain were conveniently recruited. The patients performed a head-to-neutral test at four different movement directions (flexion, extension, left and right rotation) and a head-to-target test at two different movement directions (left and right rotation) by wearing on their head a laser beam device. Five trials were performed at each direction. The assessment was performed by two different raters for examining inter-rater reliability. One of the raters reassessed the patients after a one-hour resting period to examine test-retest reliability. **Results:** Test-retest reliability was found to be moderate to good (intraclass correlation coefficient [ICC] .56–.81, standard error of measurement [SEM] 2.09–5.01 cm, smallest detectable difference [SDD] 5.79–13.87 cm). Inter-rater reliability was found to be moderate to excellent (ICC .59–.92, SEM 1.75–3.27 cm, SDD 4.85–9.05 cm). **Conclusions:** A laser beam device presented moderate to excellent reproducibility, however relatively high measurement error for assessing cervical proprioception in patients with chronic neck pain.

**Keywords:** joint position sense, proprioception, light beam, spinal pain, validity

### Introduction

Chronic neck pain is one of the most common musculo-skeletal disorders and it is estimated that one-third of the population will suffer from this condition at least once in their lifetime (Côté et al., 2003; Ferrari & Russell, 2003). Patients with chronic neck pain may have a number of clinical manifestations including postural changes (Lau et al., 2009), reduction in the physiological range of motion (Mangone et al., 2018), a decline in cervical muscle strength and endurance (Chiu & Lo, 2002; Harris et al., 2005), psychological compromise (Dimitriadis et al., 2015), respiratory dysfunction (Dimitriadis et al., 2016) as well as changes in sensorimotor control (Cheng et al., 2010). The impaired proprioception of these patients may affect the informative input to the central nervous system and lead to alterations in movement control and recruitment timing and accuracy of motor commands affecting posture and contributing to neck pain (Arimi et al., 2018). Therefore its assessment seems to be of high importance for the management of patients with neck pain.

A number of measurement procedures and type of equipment have been proposed for the assessment of cervical proprioception. Laser beam devices gain more and more

acceptance for the assessment of cervical proprioception as they are affordable, easily applicable and non-invasive measurement tools for assessing cervical proprioception. Laser beam devices have been used in a number of different methods for the assessment of cervical proprioception including zig-zag (Ernst et al., 2019), figure of eight (Ernst et al., 2019; Gonçalves & Silva, 2019) and head repositioning tests (Revel et al., 1991). Head repositioning tests remain the most popular and can be divided into head-to-neutral tests where the patients are asked to reposition their head to neutral and head-to-target tests where the patients are asked to reposition their head in a predetermined non-neutral head position (Alahmari et al., 2017; Cheng et al., 2010). The deviation of head repositioning from the predetermined position represents the magnitude of the proprioceptive deficiency (Schmidt & Lee, 2005).

Literature suggests laser beam devices as reliable for assessing cervical repositioning in healthy people (Hatamvand et al., 2016). However, the evidence in patients with chronic neck pain is limited (Gonçalves & Silva, 2019; Jorgensen et al., 2014; Roren et al., 2009). This evidence becomes much more limited by considering that these studies have been focused only on specific aspects of reliability

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**Article history:** Received October 25 2020, Accepted April 9 2021, Published April 23 2021

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of the tests or specific movements. According to our knowledge, there is a lack of a study that examines both inter-rater and test-retest reliability for both head-to-neutral and head-to-target repositioning tests in patients with chronic neck pain. The findings from such a study could significantly add to our knowledge regarding the assessment of cervical proprioception.

Therefore, the aim of this study was to examine the test-retest and inter-rater reliability of a laser beam device for the assessment of cervical proprioception in patients with chronic neck pain by using both head-to-neutral and head-to-target tests.

## Methods

### Sample

Twenty patients with chronic neck pain were conveniently recruited. Participants were recruited from students and staff of Metropolitan College as well as from the local community. Patients were included in the study if they: (a) were between 18–65 years old, (b) had neck pain for more than 3 months, (c) did not have conditions such as osteoporosis, rheumatic disease, neurological disease, cancer, pregnancy, spinal surgeries or any other conditions that could have affected the measurements, (d) their neck condition did not restrain them from participating in the testing procedure of the study. Before their participation, the patients had to sign an informed consent. All rights of participants were protected at all times, according to the Declaration of Helsinki. The study was approved by the Ethics committee of Metropolitan College.

### Equipment and materials

For the assessment of cervical proprioception, a laser beam device was used. The laser beam device included a strap that was placed on each patient's head so that the laser beam device was securely positioned on the forehead. A blindfold was also used in order to occlude participants' vision during the assessment.

A Visual Analog Scale (VAS) was used for recording patients' neck pain intensity. It consists of a 10 cm straight line with the end-points defining the extreme limits "no pain at all" and "worst possible pain". The patient was asked to mark the point of the line which best described his/her neck pain intensity (Kersten et al., 2014). VAS has been found to be valid and reliable for recording pain intensity (Price et al., 1983).

The Neck Disability Index (NDI) is a 10-item instrument for recording neck pain-induced disability. Each item includes a 6-point ordinal scale. The score of each item may range from 0 to 5. The total score of the scale may range from 0 to 50. The score can be converted to a percentage score. The higher the score the higher the level of disability. The instrument has been cross-culturally validated into the Greek language (Trouli et al., 2008).

### Procedure

Before the main measurements of cervical proprioception, participants had to complete a general health and

demographics questionnaire, VAS for recording their neck pain intensity and the NDI for recording their pain-induced disability.

For the assessment of cervical proprioception, the patients were sitting on a stable chair at an exactly 1-meter distance from a whiteboard. The chair was face-to-face to the whiteboard. The position of sitting was standardized for all the participants (flexed knees and hips at 90°, pelvis in touch with the back of chair, hands on knees). The room was quiet and the temperature was set at 23 °C. Patients were wearing a blindfold and a laser-beam device was strapped on their head (Figure 1).

Initially, head-to-neutral tests of cervical proprioception were performed. The participants were asked to find their natural head position (NHP) and memorize it until they felt confident to start the test. After the adjustment of the laser beam device, the examiner marked the point where the laser beam pointed on the whiteboard (point 0). Then, the examiner passively rotated the head to the right at 45°. From this position, the participants were instructed to return their head to the NHP and the new point where the laser beam pointed on the whiteboard was marked (point A). After the completion of this test, the examiner used a tape measure to record the distance between the point 0 and A. This distance/deviation represented the proprioceptive deficit of each patient for the examined movement. This test was repeated 5 times and therefore 5 scores of cervical proprioception for the left rotation were obtained. The same procedure was followed for the examination of cervical proprioceptive deficits for the cervical right rotation (return to NHP after an approximately 45° passive head rotation to the left), flexion (return to NHP after an approximately 45° passive head extension) and extension (return to NHP after an approximately 45° passive head flexion).

After the completion of these four tests, the chair was placed at a 45° angle to the whiteboard (initially rotated 45° to right and then rotated 45° to left) in order to perform head-to-target tests. From the same sitting position and conditions, the patients' head was passively rotated 45° to the left until the laser beam to be vertically orientated to the whiteboard. This was the target position of the head and it was marked on the whiteboard with the help of a laser beam (point 0). The patients were asked to memorize this position and their head was returned to its natural position. From this position, they were asked to rotate their head to the target position and the new position was marked again on the whiteboard with the help of the laser beam (point A). After the completion of this test, the examiner used a tape measure to record the distance between the point 0 and A. This distance/deviation represented the proprioceptive deficit of each patient for the examined movement. This test was repeated five times and 5 scores of cervical proprioception were obtained. The same procedure was repeated with the chair rotated 45° to the left to examine proprioceptive deficits during right head rotation.

The whole procedure was performed by examiner A. Five minutes after the completion of the procedure, it was repeated by examiner B. Then, participants were asked to leave and return after 60 minutes, for the same procedure

Figure 1 Setting of the study



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 blind to the measurements of each other. At the end of the procedure neck pain intensity of patients was assessed again.

### Statistical analysis

Data normality was confirmed by using Q-Q plots. For descriptive statistics, Means and Standard Deviations were used as measures of central tendency and dispersion respectively. Test-retest and inter-rater reliability were examined with the second model of intraclass correlation coefficient (ICC; two-way random, absolute agreement). The average of the five trials was used for the analysis. For each ICC, its associated standard error of measurement (*SEM*) and smallest detectable difference (*SDD*) were calculated (Portney & Watkins, 2009). ICC values of < .50, .50–.75, .75–.90 and > .90 are considered to indicate poor, moderate, good and excellent reliability, respectively (Koo & Li, 2016). A dependent *t*-test was used for assessing whether the pain intensity of participants changed after the assessment procedure. The significance level was set at  $p = .05$ . IBM SPSS Statistics (Version 20.0; IBM, Armonk, NY, USA) was used for all data analyses.

## Results

Patient demographics are presented in Table 1. Descriptives of patients' proprioception (deviation) are presented in Table 2.

**Table 1** Demographics of patients with chronic neck pain ( $N = 20$ )

| Demographic                        | <i>M</i> ( <i>SD</i> ) |
|------------------------------------|------------------------|
| Gender (men/women)                 | 10/10                  |
| Age (years)                        | 32.8 (14.8)            |
| Height (cm)                        | 173.6 (7.59)           |
| Weight (kg)                        | 71.8 (12.28)           |
| Pain chronicity (months)           | 14.4 (10.68)           |
| Pain frequency (days/week)         | 3.95 (1.27)            |
| Neck Disability Index              | 17.8 (8.7)             |
| VAS usual pain intensity (cm)      | 5.37 (2.26)            |
| VAS current pain intensity (cm)    | 3.65 (1.75)            |
| VAS pain after the assessment (cm) | 3.45 (1.76)            |

Note. VAS = visual analog scale.

**Table 2** Descriptives of cervical proprioception in patients with chronic neck pain

| Test                       | Deviation as <i>M</i> ( <i>SD</i> ) |
|----------------------------|-------------------------------------|
| HNP left rotation (cm)     | 9.04 (2.85)                         |
| HNP right rotation (cm)    | 10.14 (5.17)                        |
| HNP flexion (cm)           | 10.88 (4.96)                        |
| HNP extension (cm)         | 13.80 (9.00)                        |
| HTP45° right rotation (cm) | 11.39 (3.59)                        |
| HTP45° left rotation (cm)  | 9.61 (2.62)                         |

Note. HNP = head-to-neutral position; HTP45° = head-to-target position with 45° head rotation.

Test-retest reliability was found to be moderate to good (ICC .56–.81, *SEM* 2.09–5.01 cm, *SDD* 5.79–13.87 cm). Inter-rater reliability was also found to be moderate to excellent (ICC .59–.92, *SEM* 1.75–3.27 cm, *SDD* 4.85–9.05 cm). The results about the test-retest and inter-rater reliability of laser beam device for assessing cervical proprioception are analytically presented in Tables 3 and 4, respectively. Figure 2 presents the difference in recordings between the two raters for each test.

Current neck pain intensity did not significantly change after the end of the measurements ( $p > .05$ ).

## Discussion

The results of the study revealed that the test-retest reliability of a laser-beam device for the assessment of cervical proprioception is moderate to good. The findings are in agreement with Roren et al. (2009). However, Roren et al. (2009) examined only head-to-neutral repositioning tests with rotatory movements and therefore the current study provides a more complete picture of the test-retest reliability of the procedure. The studies by Jorgensen et al. (2014) and Gonçalves and Silva (2019) examined rather intra-rater

**Table 3** Test-retest reliability of laser beam for the assessment of cervical proprioception in patients with chronic neck pain

| Test                       | GM    | ICC  | 95% CI       | SEM (%GM)    | SDD (%GM)      |
|----------------------------|-------|------|--------------|--------------|----------------|
| HNP left rotation (cm)     | 8.84  | 0.64 | [0.09, 0.86] | 2.09 (23.6%) | 5.79 (65.5%)   |
| HNP right rotation (cm)    | 9.56  | 0.57 | [0, 0.83]    | 3.26 (34.1%) | 9.04 (94.5%)   |
| HNP flexion (cm)           | 10.93 | 0.81 | [0.52, 0.93] | 2.59 (23.7%) | 7.18 (65.7%)   |
| HNP extension (cm)         | 12.40 | 0.66 | [0.18, 0.86] | 5.01 (40.4%) | 13.87 (111.9%) |
| HTP45° right rotation (cm) | 10.50 | 0.56 | [0, 0.82]    | 2.47 (23.5%) | 6.85 (65.2%)   |
| HTP45° left rotation (cm)  | 10.10 | 0.65 | [0.14, 0.86] | 2.22 (22.0%) | 6.15 (60.9%)   |

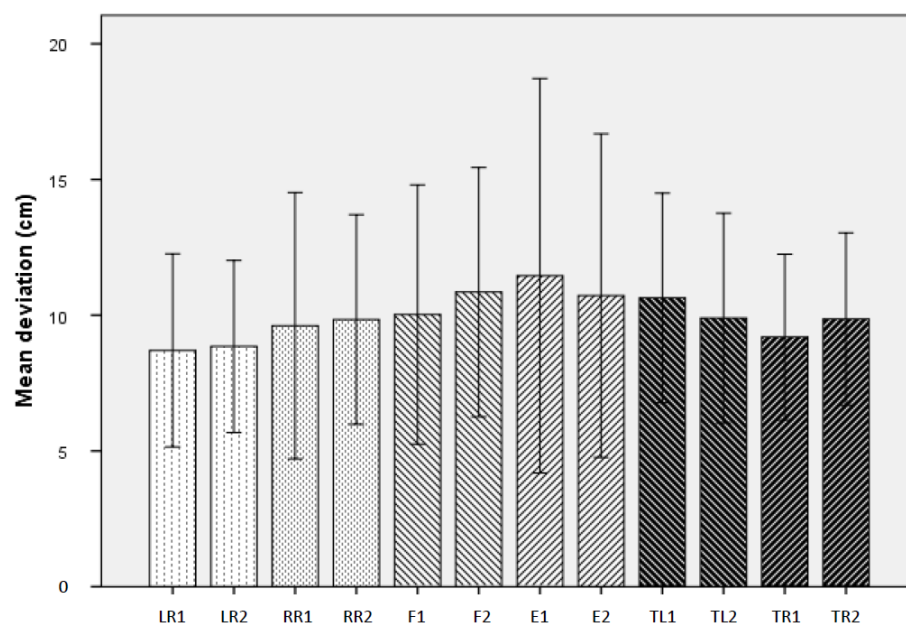
Note. GM = grand mean; ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement; SDD = smallest detectable difference; HNP = head-to-neutral position; HTP45° = head-to-target position with 45° head rotation.

**Table 4** Inter-rater reliability of laser beam for the assessment of cervical proprioception in patients with chronic neck pain

| Test                       | GM    | ICC  | 95% CI       | SEM (%GM)    | SDD (%GM)    |
|----------------------------|-------|------|--------------|--------------|--------------|
| HNP left rotation (cm)     | 9.10  | 0.64 | [0.06, 0.86] | 1.75 (19.2%) | 4.85 (53.3%) |
| HNP right rotation (cm)    | 10.47 | 0.85 | [0.61, 0.94] | 2.39 (22.8%) | 6.62 (63.2%) |
| HNP flexion (cm)           | 11.36 | 0.66 | [0.15, 0.87] | 3.27 (28.8%) | 9.05 (79.7%) |
| HNP extension (cm)         | 13.33 | 0.92 | [0.79, 0.97] | 3.14 (23.6%) | 8.70 (65.3%) |
| HTP45° right rotation (cm) | 11.17 | 0.73 | [0.32, 0.89] | 2.59 (23.2%) | 7.18 (64.3%) |
| HTP45° left rotation (cm)  | 9.90  | 0.59 | [0, 0.84]    | 2.49 (25.2%) | 6.90 (69.7%) |

Note. GM = grand mean; ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement; SDD = smallest detectable difference; HNP = head-to-neutral position; HTP45° = head-to-target position with 45° head rotation.

**Figure 2** Difference in recordings between raters for each one of the six tests



Note. Error bars show standard deviation. LR = left rotation; RR = right rotation; F = flexion; E = extension; TL = torso left; TR = torso right; 1 = rater A; 2 = rater B.

than test-retest reliability, focusing more on the reproducibility between trials rather than between sessions. *SEM* and *SDD* scores were found to be rather high. Unfortunately, Roren et al. (2009) did not provide *SEM* and *SDD* values to directly compare to our results.

The inter-rater reliability of the laser beam device was found to be moderate to excellent. Inter-rater reliability in patients with neck pain was also examined by Jorgensen et al. (2014). Similarly to the current study, Jorgensen et al. (2014) examined the reliability of head-to-neutral repositioning in all four movements (flexion, extension, right and left rotation). The reliability was found to be lower than the reliability of the procedure used in the current study, with poorer ICC values in that previous study. The lower number of trials as well as differences in the adoption of NHP before each trial and the laser-beam placement might have been factors that contributed to this difference. In that same study, although both *SEM* and *SDD* values were calculated, only *SDD* values have been reported. These values are similar to the values in the current study confirming its rather high measurement error.

In contrast to the studies by Roren et al. (2009) and Jorgensen et al. (2014), the current study additionally examined the reliability of a laser beam device for assessing cervical proprioception by using a head-to-target test. In contrast to head-to-neutral tests, head-to-target tests are believed to be less dependent on memory and provide more focus on proprioception testing since the NHP is a head position that is predominantly adopted in daily life (Kristjansson et al., 2003). The test-retest and inter-rater reliability of the head-to-target tests was found to be moderate. The reliability of the head-to-target tests in patients with neck pain was also examined by Gonçalves and Silva (2019). Although a different magnitude of rotation was selected (30° vs. 45°), the findings were similar revealing moderate reliability of the tests. However, Gonçalves and Silva (2019) examined intra-rater and not test-retest or inter-rater reliability and the results of the two studies can be considered complementary of each other.

The results suggest that a laser beam device has satisfactory reproducibility and can be used for the assessment of cervical proprioception in patients with chronic neck pain. The results suggest that the assessment of head repositioning in the sagittal plane (flexion/extension) provides better reliability estimates and might be preferable to the examination of head repositioning at the transverse plane (rotations). Furthermore, the differences between the reliability estimates of head-to-neutral and head-to-target tests were not of considerable importance. Therefore, both types of tests could be used although, as suggested by Kristjansson et al. (2003), head-to-target tests may have better face validity due to their lower dependence on memory. The tests seem to have relatively increased measurement error something which should be considered by researchers and clinicians before their use. Clinicians are additionally provided with *SDD* values which can be adopted for easily understanding whether a change observed after an intervention can be considered as a real change.

A debatable limitation of the study could be the selection of a short interval between the two sessions. The interval between the first and the second session was selected to be an hour. The same interval was also selected in the other one test-retest reliability study by Roren et al. (2009). A close interval may have led to some testing effects such as pain change, fatigue, or learning effects that might remain through the trials or during the second session. We believe these problems were reduced to some extent, by giving resting periods between the trials, by keeping the execution of the tests in the same order and by examining changes in neck pain intensity before and after the completion of the tests. However, the selection of this short interval was based on some advantages as it can lead to easier patient recruitment, it has a considerably reduced risk for drop-outs and it offers a better control about the patients' activities that should be avoided between the sessions.

Future studies should focus on how different parameters of the tests could affect the reliability estimates. The number of trials, the magnitude of the range of movement for each examined movement and the distance of the laser beam device from the target could be some important test parameters that should be examined. The understanding of the most appropriate and reliable parameters could provide proprioception tests of high validity that could improve the understanding of the effectiveness of neck pain interventions and in consequence the management of their clinical condition.

## Conclusions

The laser beam device used in the current study was found to provide reproducible estimates of cervical proprioception. However, the tests were found to be accompanied by a considerable measurement error. Future studies are advised to be additionally conducted with the selection of different target angles, different distances of the laser beam device from the target and at a variable number of repetitions. The estimation of the most reliable parameters for the investigation of cervical proprioception may significantly impact the assessment of patients with neck pain, simultaneously leading to improved clinical reasoning.

## Conflict of interest

The authors report no conflict of interest.

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