A Web Based Version of the Cervical Joint Position Error Test: Reliability of Measurements from Face Tracking Software

Angelo Basteris[1(✉)], Luke Hickey[2], Ebony Burgess-Gallop[2], Ashley Pedler[2], and Michele Sterling[2]

[1] School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, Singapore
angelobasteris@gmail.com

[2] Recover Injury Research Center, Griffith University, Parklands Drive, Gold Coast, QLD 4222, Australia

Abstract. The cervical joint position error test is a method to assess proprioception. This test is particularly relevant for people with neck pain and whiplash associated disorder, and it is of potential interest for people with neurological disorders. In clinical practice, patients are asked to move their head and match the original position while wearing a laser pointer on their head. The error is measured manually as the distance between the projection of the laser on a target before and after neck movement. We developed a web page which delivers this test while measuring the position of the head with a head tracking software. We tested the reliability of our application, using our software simultaneously to the laser method on 14 healthy volunteers. Our results show good correlation ($r = 0.83$, 0.69 and 0.68 after extension, right and left rotation, respectively, all with, $p < 0.001$) and limits of agreement (±2.64 cm) between the two methods, suggesting that our application can be used for measuring the joint position sense error.

Keywords: Neck · Proprioception · Movement analysis · Face tracking

1 Introduction

The cervical joint position error test is a method to assess cervical spine proprioception in people with neck pain. In clinical practice, patients are asked to move their head in a desired position (neutral or rotated with respect to the trunk). They are then instructed to move the head away from this pose and match the original position as accurately as possible. Error from the original starting position is measured using a laser pointer mounted on the head. Although simple and inexpensive, this test is time intensive, requires special equipment, and relies on repositioning of the head by the therapist between trials. This makes the test potentially prone to error, as witnessed by its poor inter- and intra-rater reliability [1].

Movement analysis, and specifically head tracking software, may provide more accurate results while making the test simpler. For this work, we used a free head tracking

P. Perego et al. (Eds.): MobiHealth 2016, LNICST 192, pp. 297–301, 2017.
DOI: 10.1007/978-3-319-58877-3_38

software publicly available for download (xLabs, Australia). This software tracks head motion using the Active Shape Model algorithm via a video acquired from a webcam and it provides a 2D projection of the head position on the screen [2]. We developed a web version of the test which makes the test potentially self-delivered and ready for home use. In a pilot study for testing the viability of this method, we found values comparable to normative values from literature in a population of 22 healthy volunteers [3]. In this work, we test the reliability of our software by comparing the results from our method with those measured using the standard method, i.e. the laser pointer.

2 Methods

2.1 Setup

Figure 1 shows the experimental setup. Participants sat in front of a laptop, lifted on a support so that the embedded camera was in front of their face. The same height was maintained for all subjects.

Fig. 1. Experimental setup

We used our application based on the head tracking software simultaneously to the traditional method – i.e. using a laser pointer mounted on a headband.

Traditionally, the target is positioned in front of the subjects. Because of the presence of the laptop, we mounted a panel with an A3 sized target for measuring the repositioning error behind the participant.

Both the camera and the target were positioned at an approximate distance of 90 cm from the subject's head. The positioning of the target panel, the chair and the laptop stand was controlled for by placing markers on the floor and on the table.

2.2 Task

The task consisted of an active head repositioning task to the neutral position with eyes closed. The experiment consisted of eight repetitions of each of three movement directions (extension, left and right rotation) in pseudo-randomized order. The first two trials in each direction were considered as familiarization and not included in subsequent analyses.

The initial position after the familiarization phase was marked by one experimenter as the initial position (neutral head position). The error was measured with respect to this position for all subsequent trials.

After each trial, the participant confirmed verbally the final position, and one tester marked the position of the laser pointer with a sticker on the target, while another tester clicked so that the software acquired the 2D position of the face (on the frontal plane) as measured by the head tracking software.

After this, the participant was instructed to move the head and then open the eyes, so that there was no feedback about the error in the previous trial.

With the eyes open, the subject moved the head back to the initial position for a new trial, using the feedback provided by a cursor representing the 2D position of the face.

2.3 Subjects

Fourteen healthy subjects (12M, 2F, age 24 ± 4) participated in this study. Subjects were volunteers, with no previous history of injury or surgery to the cervical spine, who had not received or sought treatment for neck pain within the past 6 months. This study was approved by the Griffith University Human Research Ethics Committee.

2.4 Data Analysis

Task performance can be measured by several metrics, with different meaning and implications [4]. For this study, we measured the error in the primary direction of movement only.

For each trial, we measured one value of error on the target (difference between marker and initial position, in cm) and one with the software. Because the software provides dimensionless output, we used a LSE for fitting it to the errors measured with the laser output. For both the camera and the laser method, positive errors indicate overshooting.

The most frequently used test outcome is the average absolute error. We averaged this for each direction and subject, for both the laser-based measure and the software estimate.

We considered as indicators of reliability the root mean squared error and the Pearson correlation coefficient between the laser measurement and the software estimate. We also considered the limits of agreement between the two methods using the Bland-Altman method [5].

3 Results

Figure 2 shows the correlation between all the values measured with the two methods. For all the three directions we observed a significant ($p < 0.001$) Pearson correlation coefficient, substantially higher for the vertical error after extension than for horizontal error after rotation.

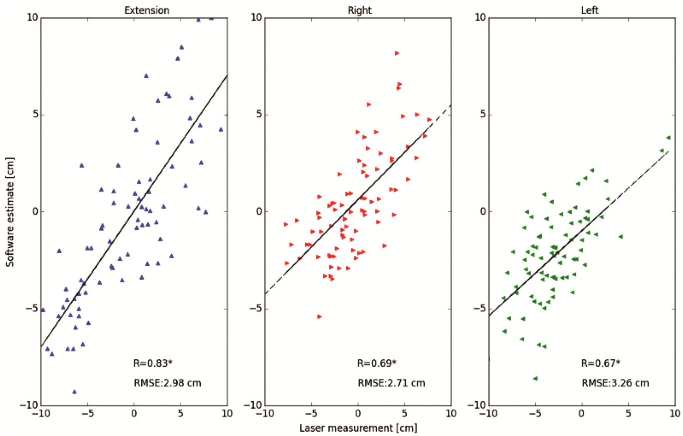

Fig. 2. Correlation for laser measurement in primary direction only and estimate based on software for all trials, all subjects, for different movement directions.

Figure 3 shows the level of agreement between the two methods for the mean value (across repetitions) for all subjects. The bias of 0.93 cm indicates that the software tends to underestimate the error in comparison to the laser, while the 95% limit of agreement is at ±2.64 cm.

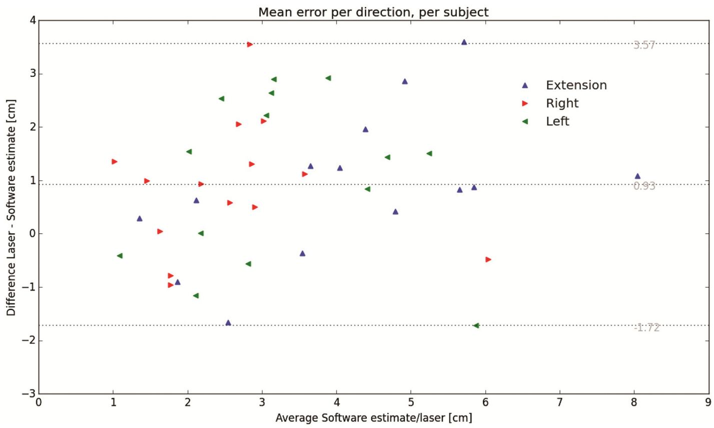

Fig. 3. Level of agreement for the mean value of absolute error across direction for all subjects.

4 Discussion and Conclusions

Our results show the viability of our application for measuring the joint position sense error. We found good correlations between the software and laser methods across all directions, and our results suggest that the face tracking software is more reliable in measuring the error after extension than after rotation. This is in contrast with our previous experience, where lateral movements appeared to be tracked more accurately than vertical movements.

When considering the mean value of absolute error for each direction, which is the standard measurement of task performance, we observed that the software tends to underestimate the error measured with the laser procedure. It is noteworthy that using the laser involves the tester's intervention for placing the marker in the final position and measuring the distance between final and initial position. Movement of the headband that is used to mount the laser on the subject's head may also affect the measurement.

The measured 95% level of agreement between the two methods corresponds to an angular error of 1.68° (at a distance of 90 cm from the target), well within the suggested cut-off scores for "normal" cervical proprioception (4.5°, [6]).

Our system is web-based and uses a Google Chrome browser extension for measuring the position and orientation of the head. While at this stage extensions are not supported for the smartphone version of the browser, once this becomes possible our tool will be available on smartphones and tablets too, regardless of their operating system. Future work will aim at overcoming the limitations of this work, namely the small population and the use of a calibration matrix for transforming the dimensionless camera coordinates in absolute values.

Acknowledgments. MS receives a fellowship from the National Medical and Research Council of Australia. AB and AP salaries are funded from an unrestricted grant from the Motor Accident Insurance Commission of Queensland.

References

1. Strimpakos, N., Sakellari, V., Gioftsos, G., Kapreli, E., Oldham, J.: Cervical joint position sense: an intra- and inter-examiner reliability study. Gait Posture **23**, 22–31 (2006). doi: 10.1016/j.gaitpost.2004.11.019
2. Cootes, T.F., Taylor, C.J., Cooper, D.H., Graham, J.: Active Shape Models-Their Training and Application. Comput. Vis. Image Underst. **61**, 38–59 (1995). doi:10.1006/cviu.1995.1004
3. Basteris, A., Pedler, A., Sterling, M.: Evaluating the neck joint position sense error with a standard computer and a webcam. Manual Ther. **26**, 231–234 (2016). doi:10.1016/j.math.2016.04.008
4. Lee, H.-Y., Teng, C.-C., Chai, H.-M., Wang, S.-F.: Test-retest reliability of cervicocephalic kinesthetic sensibility in three cardinal planes. Manual Ther. **11**, 61–68 (2006). doi:10.1016/j.math.2005.03.008
5. Bland, J.M., Altman, D.G.: Statistical methods for assessing agreement between two methods of clinical measurement. Lancet **1**, 307–310 (1986)
6. Revel, M., Andre-Deshays, C., Minguet, M.: Cervicocephalic kinesthetic sensibility in patients with cervical pain. Arch. Phys. Med. Rehabil. **72**, 288–291 (1991)