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Technical and measurement report

Reliability of measuring half-cycle cervical range of motion may be increased using a spirit level for calibration

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ABSTRACT

Background: Assessments of range of motion (ROM) represent an essential part of clinical diagnostics. Ultrasonic movement analyses have been demonstrated to provide reliable results when analyzing complete amplitudes (e.g., flexion-extension). However, due to subjective determination of the starting position, the assessment of half-cycle movements (e.g, flexion only) is less reproducible.

Objectives: The present study aimed to examine the reliability of measuring half-cycle cervical ROM using a spirit level for calibration.

Method: 20 healthy subjects (30 ± 12yrs, 7♂, 13♀) participated in the randomized, controlled, cross-over trial. In two testing sessions with one week of wash-out in between, cervical ROM was measured by means of an ultrasonic 3D movement analysis system using a test-retest design (baseline and 5 min post baseline). The sessions differed with reference to the mask carrying the ultrasound markers. It was removed during the 5 min break (mask off) or not (mask on). To determine the resting position, a bull's eye spirit level was used in each measurement.

Results: With ICC values of 0.90–0.98 (mask on, $p < 0.001$) and 0.90 to 0.97 (mask off, $p < 0.001$), both examined conditions demonstrated excellent test-retest reliability for separating the cycles regarding all movement planes.

Conclusion: Cervical ROM during half-cycle movements can be assessed with excellent reliability using a spirit level. In contrast to subjective determination of the starting position, analyzing complete movement planes does not increase reliability. Using a defined and objective zero positioning allows the evaluation of repositioning tasks.

1. Introduction

Several musculoskeletal disorders are associated with impairments of cervical mobility. Recent evidence demonstrates that subjects with whiplash (Cagnie et al., 2007), tension-type headache (Fernández-de-las-Peñas et al., 2007) and chronic unspecific neck pain (Vogt et al., 2007; Niederer et al., 2015) display reduced range of motion (ROM) of the neck. Also, with a hazard ratio of 0.44 (95% CI: 0.19–1.05), an increased cervical ROM might be protective against the occurrence of neck pain in healthy subjects. Although the study indicating this association (Hush et al., 2009) was based on a small sample size, precise assessments of flexibility could help to design adequate treatments and to identify individuals at risk of developing nonspecific cervical diseases.

A variety of methods have been suggested to capture cervical ROM: Besides visual estimation, goniometry, inclinometry, or electromagnetic motion analysis, ultrasound-based measurements are used for diagnostics (Strimpakos, 2001). While most devices provide reliable measurements when assessing complete movement cycles (e.g., combined flexion and extension in the sagittal plane), separate analysis (e.g., flexion only) is less reproducible if the starting position is determined by the subject (Cagnie et al., 2007). This might be explained by the fact that non-objective zero positioning depends on the proprioception of the subject. In this sense, interventions or wait periods can alter the self-perceived neutral position of the head (Fig. 1).

Although evaluating complete movement amplitudes allows judgments of the general degree of mobility, the results of the respective parts provide relevant information regarding concrete hypotheses. For example, myofascial trigger points in the neck

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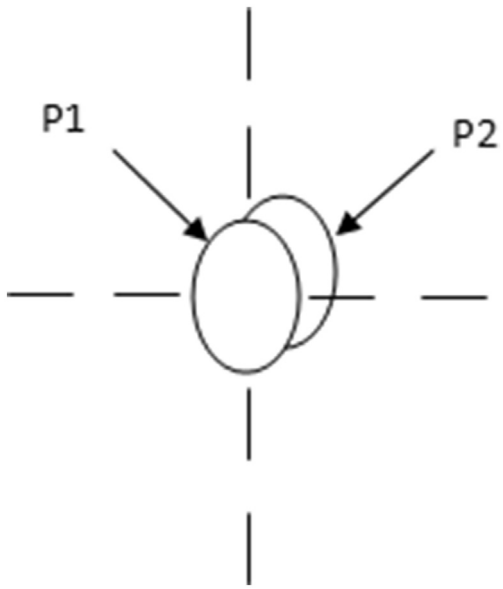

Fig. 1. If the starting position of ROM measurements is determined subjectively by the subject (P1), it can differ at a follow-up measurement (P2).

muscles are suggested to reduce cervical flexion. Global analyses of the sagittal plane (combined flexion and extension) might mask this specific deficit (Wilke et al., 2016a). Against this background, the present study aimed to develop and test a method that provides highly reliable ultrasound measurements of cervical ROM in separated movement cycles. We hypothesized that using a bull's eye spirit level during calibration of the zero position provides highly reproducible results.

2. Methods

2.1. Ethical standards

The present randomized, two-armed crossover trial was registered at clinicaltrials.gov (NCT02716389) and followed the GRRAS (Guidelines for Reporting Reliability and Agreement Studies) guidelines (Kottner et al., 2011). It was conducted in accordance with the Declaration of Helsinki and approval of the local ethics committee was obtained. Each subject signed informed consent prior to study inclusion.

2.2. Participants

Twenty healthy, pain-free individuals (30 ± 12yrs, 7♂, 13♀, BMI: 23 ± 2) were recruited by means of personal addressing and poster advertising. Exclusion criteria (checked with medical records and self-reports) encompassed a) severe orthopaedic, cardiovascular, pulmonary, neurological, psychiatric or inflammatory rheumatic diseases, b) analgesic intake in the past 48 h, and c) history of surgery or trauma in the upper extremity, shoulder or spine.

2.3. Outcome

To examine the test-retest-reliability of the new measurement protocol for the assessment of cervical ROM, all participants underwent multiple examinations (see testing sessions) with an ultrasonic 3D movement analysis system (Zebris CMS 70, Zebris Medical GmbH, Isny, Germany; error in measurement 0.58 ± 1.29 mm, (Himmelreich et al., 1998)), which collects external kinematic data at a sampling rate of 30 Hz. According to Strimpakos (2001), it is the most precise available device to collect data on cervical ROM.

The movement analysis system consists of three microphones collecting the signals of six markers (diameter 10 mm, weight 3 g each). For the measurements, a tripod with the ultrasound microphones was positioned in proximity to the subject. Three reference markers, mounted on a small, lightweight T-plate, were attached to the lateral aspect of the shoulder girdle. A mask-like carrier unit with a second similar triangular base plate and the three primary markers was placed on the head of the participants (Fig. 2).

After three familiarization trials, each subject, sitting on a height adjustable chair with the knees flexed 90°, performed ten maximal movement cycles of flexion-extension (sagittal plane) at self-paced velocity. The same procedure was applied for the transversal (rotation) and frontal (lateral flexion) plane. In each measurement, the starting zero position was determined by an investigator using a bull's eye spirit level (Fig. 2).

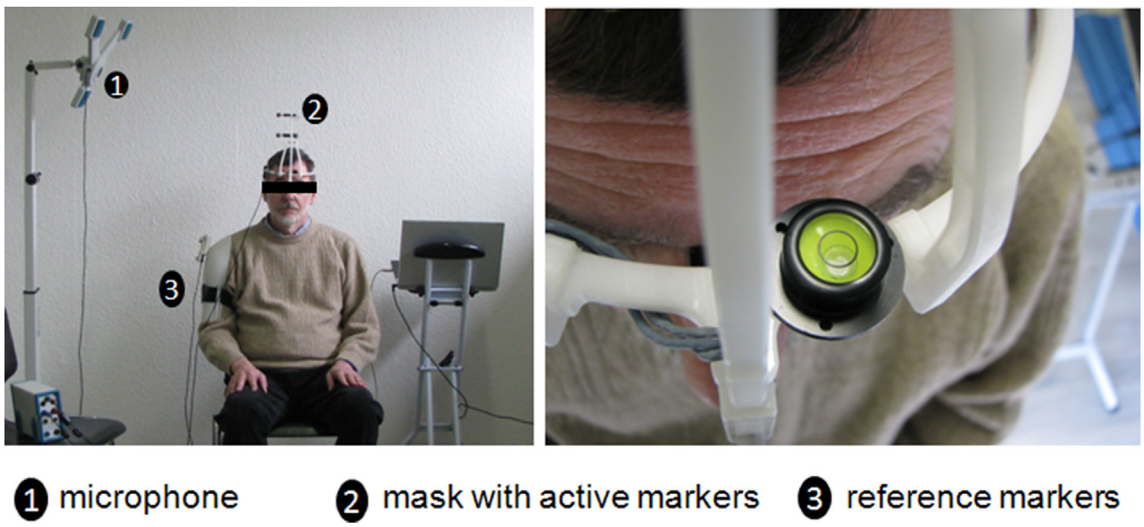

Fig. 2. The ultrasound-based movement analysis system (left). The mask was positioned on nose and ears of the subjects and secured with a strap. For calibration, a spirit level was positioned on the mask (right).

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