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Three-dimensional kinematics of the cervical spine using an electromagnetic tracking device. Differences between healthy subjects and subjects with non-specific neck pain and the effect of age[☆,☆☆,☆☆☆]

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ABSTRACT

Background: A cross-sectional observational study of three-dimensional cervical kinematics in 35 non-specific neck pain patients and 100 asymptomatic controls.

To compare qualitative and quantitative aspects of cervical kinematics between healthy subjects and subjects with non-specific neck pain and to determine the effect of age on cervical kinematics in healthy subjects.

Methods: Three-dimensional kinematics of active lateral bending and flexion-extension of 35 patients and 100 controls were registered by means of an electromagnetic tracking system. The means of several kinematic parameters were compared using *t*-tests. In addition, we assessed the age-dependency of the three-dimensional kinematic parameters by stratifying the 100 control subjects in 6 age categories.

Findings: Comparison of the patient group with the control group reveals no statistically significant differences in qualitative and quantitative parameters. Analysis of the effect of age showed that the range of motion decreases significantly ($p < 0.01$) with increasing age. In lateral bending, the ratio between axial rotation and lateral bending increases significantly ($p < 0.01$) among older subjects. Differences in acceleration, jerk and polynomial fit are seen between the age categories, but are not significant.

Interpretation: This study demonstrates no significant differences in kinematic parameters between healthy subjects and subjects with non-specific neck pain. Healthy subjects in higher age categories demonstrate higher ratios of coupled movements and lower ranges of motion.

Future research should focus on classifying patients with non-specific neck pain in order to gain a better insight on possible subgroup specific differences in kinematics. More studies on this subject are warranted.

Level of evidence: 4.

1. Introduction

Neck pain is a common condition in primary care with a high prevalence and high costs, affecting up to 65% of adults at some point in their lives (Haldeman et al., 2008; Hogg-Johnson et al., 2008; Martin et al., 2008). Current evidence regarding treatment efficacy for subacute and chronic neck pain is inconclusive (Hoy et al., 2010; Vos et al., 2016).

Cervical movements are biomechanically and neurophysiologically complex. Which parameters cause non-specific neck pain or which parameters have to be addressed to cure this type of pain is unclear (Keshner, 1990; Vasavada et al., 2002; Conley et al., 1995). More knowledge concerning impairments and kinematics of non-specific neck pain is needed to provide better targeted therapy and increase

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treatment efficacy.

Cervical kinematics of a subject suffering from non-specific neck pain could be altered. Whether kinematic changes relate mainly to quantitative or qualitative aspects of movement remains unclear. For example, it is possible for a subject suffering from non-specific neck pain to have a limited Range of Motion (RoM), but an excellent smoothness of a cervical motion or vice versa. Beside kinematic disturbances in quantitative aspects, like range of motion and motion coupling patterns, qualitative changes such as speed, acceleration and rhythm, have been suggested (Cattrysse et al., 2012; Feipel et al., 1999; Sjölander et al., 2008; Waeyaert et al., 2016). To obtain an optimal image of all aspects of cervical motion it is important to record both quantitative and qualitative aspects. Altered or disturbed proprioception or neuromuscular control inhibition might be expressed in changes in motion sequence or the motion stability. In this study, we will use the terms 'qualitative parameters' when referring to kinematic features expressing the amount of motion and the relationship between motion components within a three-dimensional approach. 'Qualitative parameters' will refer to the aspects of kinematics referring to the smoothness of the motion as such expressing a possible relationship with neuromuscular motor control.

The use of three-dimensional analysis enables accurate registrations of active cervical kinematics (Lansade et al., 2009; Mälmstrom et al., 2006; Watanabe et al., 2012). Previous research used radiographs, computed tomography (CT) and magnetic resonance imaging (MRI) for analyzing quantitative kinematic parameters in different angles of the cervical spine (Ishii et al., 2004a, 2004b; Cook et al., 2006; Ishii et al., 2006; Nagamoto et al., 2011; Watanabe et al., 2012; Anderst et al., 2013; Lin et al., 2014). These studies did not report any qualitative data such as smoothness or rhythm. Other methods, such as electrogoniometry (Feipel et al., 1999), electromagnetic tracking devices (Cattrysse et al., 2012; Röijezon et al., 2010; Sjölander et al., 2008) and ultrasound systems (Mälmstrom et al., 2006) offer possibilities to collect and analyze quantitative and qualitative data of active cervical movements.

Currently there is no research analyzing differences in qualitative and quantitative cervical kinematics between healthy subjects and subjects with non-specific neck pain.

It is crucial to assess and understand the variability of kinematics in healthy subjects before any firm conclusions can be drawn from kinematic studies in patient groups (Bahat et al., 2010; Cattrysse et al., 2012; Feipel et al., 1999; Röijezon et al., 2010; Sjölander et al., 2008).

Previous research focused on comparisons between healthy subjects and subjects suffering from whiplash-associated disorders (WAD), cervical disc hernia or subjects who underwent an anterior cervical fusion arthrodesis (Cattrysse et al., 2012; Feipel et al., 1999; Sjölander et al., 2008; Waeyaert et al., 2016). These studies revealed significant differences in RoM and motion coupling patterns between patients and controls (Cattrysse et al., 2012; Feipel et al., 1999; Sjölander et al., 2008). The most common form of motion coupling in the spine is conjunct lateral bending while rotation of the vertebrae is initiated as the main motion and vice versa (Panjabi et al., 1993). Patients with different underlying cervical health problems demonstrated a decreased motor control as assessed by qualitative parameters. Peak velocity and speed is often decreased in patients compared with healthy subjects (Bahat et al., 2010; Röijezon et al., 2010; Sjölander et al., 2008). Several studies revealed a significantly different jerk-index between patients and controls (Cattrysse et al., 2012; Sjölander et al., 2008). Feipel et al reported the motion curves of patients suffering from WAD or cervical disc hernia as less harmonic, more irregular, plateau-like around the maxima or with an exponential shape compared to asymptomatic volunteers.

Quantitative data of age-related differences in cervical kinematics have been reported by several groups (Feipel et al., 1999; Mälmstrom et al., 2006). This research reveals a significant decrease of the range of the main motion when age increases, while the motion coupling patterns do not change with age (Lansade et al., 2009; Mälmstrom et al., 2006; Trott et al., 1996). Although Lansade et al. report that proprioception was significantly affected by age in the horizontal plane only, qualitative age-related kinematic data have not been studied extensively in patients with non-specific neck pain.

The purpose of this study is 1. to compare quantitative and qualitative aspects of cervical kinematics between healthy subjects and subjects with non-specific neck pain and 2. To evaluate the effect of age on cervical kinematics in healthy subjects. This could provide insight into new diagnostic and therapeutic strategies for subjects with non-specific neck pain and possibly improve our insights in how cervical kinematics alter with age.

2. Materials and methods

The study was designed as a case control study with an additional cross-sectional evaluation of age-dependent effects in the controls only. The protocol was approved by the ethics committee of the University Hospital Brussels.

2.1. Subjects

Consecutive patients who received treatment for musculoskeletal disorders in a private practice for physiotherapy and healthy controls were verbally invited to participate in the study from October 2012 until December 2012. A total of 135 persons participated in this study, 35 patients and 100 controls. The control group was divided in 6 age categories: 1 (age 18–25), 2 (age 26–35), 3 (age 36–45), 4 (age 46–55), 5 (age 56–65), 6 (age ≥ 66).

Inclusion criteria for the patient group were presence of non-specific neck pain at the time of invitation. Non-specific neck pain is defined as 'cervical pain of unknown origin' (Misailidou et al., 2010). Exclusion criteria were the presence of systemic disease, a history of cervical surgery or malignancy, current infections, a recent physical trauma or the presence of neurologic disease. After being informed about the study, all gave their written informed consent to participate.

The control group consisted of 100 healthy subjects with a mean age of 44 years, ranging between 18 and 81 years (Table 1). The inclusion criterion for the control group was absence of neck pain during the last six months prior to the study. Persons were ineligible if they fulfilled any of the exclusion criteria for the patient group.

2.2. Materials

Kinematics of the cervical spine were measured with the Flock of Birds electromagnetic tracking system (Ascension Technologies, Shelburne, USA©). Recent studies show a high reliability and accuracy of the system (Milne et al., 1996; Meskers et al., 1999; LaScalza et al., 2003; Assink et al., 2008, Hassan et al., 2007). Within a low-pulsed

Table 1
Demographic characteristics, pain intensity and Neck Disability Index (NDI) of a group with non-specific neck pain and a control group.

Characteristics	Control group (SD) (n = 100)	Group with non-specific neck pain (SD) (n = 35)
Men (n)	50	16
Women (n)	50	19
Age (years)	44 (16)	48 (15)
Height (cm)	175 (10)	171 (9)
Weight (kg)	75 (12)	73 (14)
Pain intensity average[a]		4 (2)
Pain intensity worst[a]		6 (2)
NDI		11 (6)

Mean values with standard deviation (SD); numbers (n).
[a] Average and worst pain intensity over the last week was assessed on a blank 10 point (Vernon, 2008).