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ScienceDirect
Journal of Electromyography and Kinesiology 18 (2008) 838–848
Journal of Electromyography and Kinesiology
www.elsevier.com/locate/jelekin

Does manual mobilization influence motion coupling patterns in the atlanto-axial joint?

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Received 21 April 2006; received in revised form 20 February 2007; accepted 22 February 2007

Abstract

Background: A restricted number of publications have reported on the analysis of coupling patterns in the atlanto-axial joint using an in vitro set-up applying pure moments of forces. The aim of this study is to analyze segmental motion coupling patterns during cervical manual mobilization.

Methods: The position and attitudes of sensors mounted on the atlas and axis were traced in nine embalmed and one fresh human spinal specimen using an electromagnetic tracking system. Segmental bony reference points were registered using a 3D-digitizing stylus for the definition of bone embedded coordinate systems.

Segmental motion coupling was recorded for the atlanto-axial joints during manual mobilization through the full range of axial rotation and lateral bending.

Results: Coupled motions were described by the direction of the associated motion and by cross-correlation analysis. The results confirm the contra-lateral coupling pattern of axial rotation with lateral bending at C1–C2 observed in previous studies. The cross-correlation analysis offered a more objective interpretation of the coupling pattern for the analysis of the more irregular coupling patterns during lateral bending. Inter-individual differences in coupling patterns were observed.

Interpretations: The presented method provides possibilities for the study of coupled motion during manual diagnostic and therapeutic practice. Practitioners should be aware of the segmental 3D-aspects of manually induced so called planar mobilizations and their possible influence on motion coupling. Motion coupling patterns may be related to specimen specific anatomy.

Keywords: Atlas; Axis; In vitro; Motion analysis; Cross-correlation; Manual mobilization

1. Introduction

Coupled motion patterning of the cervical spine has been based on a regional approach in previous research (Trott et al., 1996; Walmsley et al., 1996; Harrison et al., 1998; Chen et al., 1999; Lantz et al., 1999; Koerhuis et al., 2003; Van Roy et al., 2000, 2004). Segmental motion analysis of the cervical spine has been mainly approached two dimensionally (Panjabi et al., 1975; Penning, 1978; Penning and Wilmink, 1987; Van Mameren et al., 1990; Amevo et al., 1991; Panjabi, 1997; Hino et al., 1999). Limited information on 3D coupling between the cervical segments has been derived from controlled studies applying pure moments of forces, meaning that controlled forces are applied at fixed distances in specific directions according to a predefined local reference system (Panjabi et al., 1986, 1993; Milne, 1993).

Additional information has been gained by dynamic studies concerning the load ability of cervical vertebrae, discs and ligaments (Dvorak et al., 1988; Chang et al., 1992; Lee et al., 1993; Panjabi et al., 2001; Kettler et al., 2002). Although Panjabi studied the influence of ligament transsection on the range of motion in the cervical spine

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1050-6411/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jelekin.2007.02.015

(Panjabi et al., 1975, 1991a,b), there is still a lack of information on the relationship between segmental motion and anatomical and spatial features of joints, ligaments and muscles (Nowitzke et al., 1994). Preliminary attempts to construct mathematic models (Panjabi, 1998; Bozkus et al., 2001) as well as animal studies (Zdeblick et al., 1998) demonstrated important limitations.

Recent 3D-arthrokinematic information supports the point of view that the true shapes of articular surfaces do not reflect homogenous solids of revolution and that intra-articular movements can not be explained solely with reference to the shape of the articular surfaces (Baeyens et al., 2000; Cattrysse et al., 2005).

The idea of fixed articular motion axes is thus replaced by concepts of motion coupling between different rotations and between rotations and translations. The finite helical axis (FHA) analysis offers a possibility to reveal these actual 3D-motion components.[1] In this way an attempt is made to relate functional anatomical realism to intra-articular kinematic analysis.

The purpose of the present study was to present a 3D-motion analysis of planar manually induced axial rotation and lateral bending mobilization techniques using a previously developed method combining an electromagnetic tracking device (flock of birds – FOB) and a 3D-digitiser (Microscribe) (Baeyens et al., 2005; Cattrysse et al., 2005). In this study the results were related to bone embedded coordinate systems defined on the upper cervical spine segments, and the rotational components of coupled motion were analyzed. Movements were induced manually to simulate passive mobilizing techniques as used for assessment and treatment in manual medicine.

2. Materials and methods

2.1. Specimens

Ten human spinal specimens – nine embalmed and one fresh – were used in this study. Each specimen consisted of the occiput and all cervical vertebrae down to and including the first thoracic vertebra.

The exact age of each specimen was not available but all specimens were over 60 years of age.[2] Room temperature was controlled between 15 °C and 20 °C and humidity to 60% to prevent dehydration of the specimens during the test procedure. The specimens were rapped in saline moistened towels during the registration set-up and between tests. The wraps were removed before mobilization to provide full free movement of the segments.

2.2. Instruments

An electromagnetic tracking device ('Flock of Birds' – Ascension technologies Corporation – USA) was used in this study for registering positions and attitudes. Recent studies show a high reliability and accuracy of the system (Milne et al., 1996; Bull and Amis, 1997; Meskers et al., 1999; Mc Quade et al., 2002; LaScalza et al., 2003). The electromagnetic tracking device was used in conjunction with a 3D-digitiser (Microscribe™ G2X – Immersion Corporation – USA). The digitizing stylus allows the registration of 3D features of an object in order to reconstruct the object digitally or to process the data mathematically. According to the manufacturer, the model has an accuracy of 0.003 in. (0.25 mm) and a workspace size of 66 in. (1.67 m).

Data were registered on a common portable PC and analyzed with 'Mathcad Professional' mathematical software (©1986–2000 MathSoft, Inc.).

2.3. Methodology

2.3.1. Test-procedure

All muscular tissues were dissected, keeping the joint capsules, the ligaments and the muscular insertions intact. Next, three sensors were rigidly fixed on the skull, the atlas and the axis of the specimens. The first sensor was fixed on the skull using a specially developed hard plastic sensor holder. This sensor holder was used in previous arthrokinematic studies on the shoulder and elbow joint (Baeyens, 1997; Cattrysse et al., 2005). The other two sensors were fixed on the transverse processes of the atlas and axis using a newly developed non-ferro-magnetic sensor holder. These holders were designed in such a way that they could be screwed in the bone to hold the sensor rigidly away from the vertebrae, without limiting normal joint motion. In the present study only the registrations of the sensors on the atlas and the axis were processed.

The specimens were fixed in a wooden frame by two non-ferro-magnetic pins drilled through the vertebral body of the first thoracic vertebra allowing motion of the cervical spine with respect to the first thoracic vertebra (Fig. 1). In this way full free movements of the cervical spine were allowed.

A typical mobilization consisted of three cycles in which the specimen was manually moved through its full range of motion. In the present study no axial preload was applied to compensate for muscle tone. Instead a horizontal set-up was chosen because it mimics the clinical situation in which the supine position provides optimal muscle relaxation for the patient. Clinically, relevant passive axial rotation and lateral bending mobilizations were performed. While manually moving the specimen by the occiput through the full range of motion, the positions and orientations of each sensor were collected. Subsequently, the spatial coordinates of local anatomical landmarks were digitized using the 3D-drawing stylus. Digitization was performed twice and results were accepted when the difference between two measurements was less than 0.05 in. (1.25 mm). This procedure was repeated until all results of two consecutive measurements were valid.

2.3.2. Calculation of the FHA and finite helical angles $(\theta_k)_0$, $(\theta_k)_1$ and $(\theta_k)_2$

The data of each sensor were used to determine the parameters of the FHA for discrete sampling ranges of motion. The FHA can

[1] The Finite Helical Axis can be defined as a momentary axis in space around which an object rotates while at the same time translating along this axis. The FHA is described by its position in space (position vector), its orientation (orientation vector), the rotation around the axis (rotation vector) and the translation along the axis (shift).

[2] The specimens were gathered at the anatomical laboratory of the Vrije Universiteit Brussel. Most of the anatomical specimens were provided by people who died aged 60–90 years. The use of their bodies for scientific purposes was dedicated by testimony. For reasons of confidentiality no personal history or medical antecedents were available.