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Intended and non-intended kinematic effects of atlanto-axial rotational high-velocity, low-amplitude techniques

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ABSTRACT

Introduction: The study of neck kinematics during high-velocity, low-amplitude manipulations of the atlanto-axial segment is essential to understanding cervical motion mechanisms and their impact and possible risk for soft-tissue injuries during treatment of spine disorders.
Methods: Twenty fresh-frozen specimens were tested during manual application of an axial rotation technique.
Findings: The kinematics indicate the thrust induced motion components of approximately 1° at the treated segment around all three axes of the local embedded reference frame. Moreover, an equal amount of axial rotation motion took place at the adjacent atlanto-occipital joint.
Interpretation: Overall atlanto-axial motion remained below the level of slow regional mobilization of the cervical spine. These findings can be correlated to literature data concerning the limited increase in vertebral artery strain during high-velocity, low-amplitude manipulation.

1. Introduction

Neck problems are very common in western populations. Besides pain, reduced cervical range of motion and reduced joint position sense are common features of neck disorders (McNair et al., 2007; Murphy et al., 2010; Woodhouse and Vasseljen, 2008).

Spinal manual therapy techniques are commonly used in the management of musculoskeletal disorders of spinal origin. Spinal manipulation has been defined as a high-velocity, low-amplitude thrust applied to a bony prominence of a vertebral motion segment, whereas a mobilization is generally regarded as a lower-velocity movement which may be applied over a broader area. Few studies have examined the effect of spinal manipulation and mobilization (Bolton and Budgell, 2006; Feipel et al., 2000; Klein et al., 2003).

The study of neck kinematics is essential to understanding cervical motion mechanisms and their impact on spine disorders. Moreover, cervical kinematics can be a tool to quantitatively and qualitatively evaluate the efficacy of therapeutic treatments (Lansade et al., 2009).

Recently, a number of 3-dimensional studies have focused on the kinematics of regional motion coupling. Limited but important information on 3-dimensional segmental coupled motions of the cervical spine is derived from studies applying well-controlled, pure movements of force in an in vitro laboratory setup (Dugailly et al., 2005; Panjabi et al., 1988). Although an important number of publications have reported on the kinematics of manual mobilizations and manipulations at the level of the peripheral joints and spine (Klein et al., 2003; Martinez-Segura et al., 2006; Ngan et al., 2005), few studies have been performed on joint movements produced by manual interventions at the cervical spine (Cattrysse et al., 2007a,b). In some studies, the focus has been on the global range of motion of the cervical spine at pre-manipulative positioning and on the effect on the vertebral artery (Beckers et al., 2012; Herzog et al., 2012; Salem and Klein, 2013)

The aim of the present study was to collect quantitative information on the kinematics of the atlanto-axial motion segment using a rotational high-velocity, low-amplitude (HVLA) technique.

Special attention is given to the analysis of intended motion components in the direction and at the level of the treated segment, and unintended additional or coupled motion components that occur in other directions and at the adjacent atlanto-occipital level.

2. Methods

2.1. Specimens

Twenty fresh-frozen Caucasian human spinal specimens were included in the study. Nine specimens from male and 11 from female subjects were recruited from a body donation program. Each specimen included the occiput, the cervical segments and the first two thoracic vertebrae. The mean age of the specimens was 80 years (±11 years) ranging between 59 and 97 years. Room temperature was controlled

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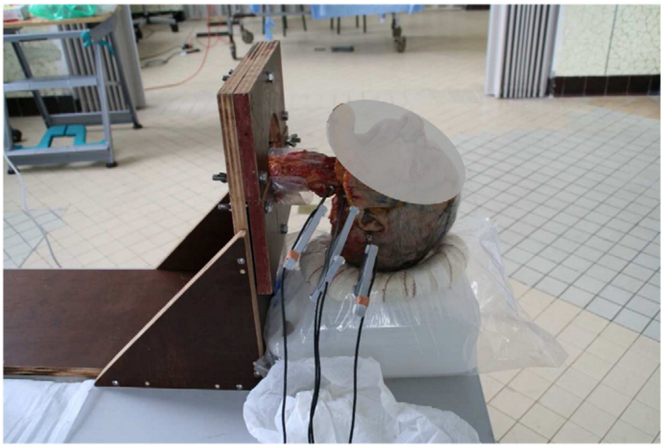

Fig. 1. Experimental setup with the specimen in supine position and fixation of the Zebris ultrasound-based motion tracking system.

between 15° and 20 °C and humidity was above 60% to prevent dehydration of the specimens during the test procedure.

2.2. Instruments

An adapted Zebris CMS20 ultrasound-based motion tracking system (Zebris Medical GmbH, Germany) was used in this study. The accuracy of the system has been reported previously, demonstrating an angular accuracy of 0.1° for the main motion component and 0.2° for the coupled components (Cattrysse et al., 2009).

2.3. Methods

Specimens were dissected from skin, subcutaneous tissue and muscles, leaving the muscular insertions and ligaments intact. This approach is necessary to prevent interaction between soft tissues and the fixation of the motion tracking system on the segments. Moreover, although it has been demonstrated that the biomechanical properties of the tendons and ligaments do not change due to conservation by freezing, biomechanical changes within the muscles might still alter the kinematics (Panjabi et al., 1985; Wilke et al., 1996). Specially fabricated fixation tools were inserted in the parietal part of the cranium, the transverse process of the atlas and the transverse process of the axis. The transmitters and receiver of the Zebris system were mounted on these fixation tools. Fixation pins were drilled cross-linked through the corpus of the second thoracic vertebra (T2) to fix the specimen in a wooden frame. In this way, the specimen was positioned as if the subject was in a supine position on a treatment splint (Fig. 1). The preliminary dissection and the optimal positioning of the fixation tools assured free mobility of the cervical spine trough full range of motion in axial rotation, lateral bending, flexion–extension and combined directions.

Each specimen was first moved in the three major cardinal planes of cervical motion as a 'warming-up' procedure. Consequently, in all specimens, a C1–C2 segmental manipulative high-velocity thrust with axial rotation was performed and registered.

This end-range rotational thrust technique was performed directing the thrust on the posterolateral arc and transverse process of the atlas, while the lower segments were prepositionally fixed using a combined movement locking technique. This locking was achieved by positioning the cervical spine inferior to the treated level into end range flexion, axial rotation and contralateral bending. Finally, the segment to treat was prepositioned in axial rotation.

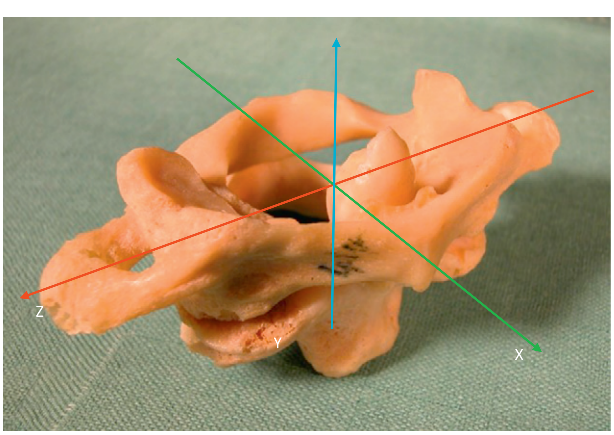

Fig. 2. Bone embedded coordinate system on C1: *Z*-axis (+ = segmental extension), *Y*-axis (+ = left segmental axial rotation), *X*-axis (+ = right segmental lateral bending).

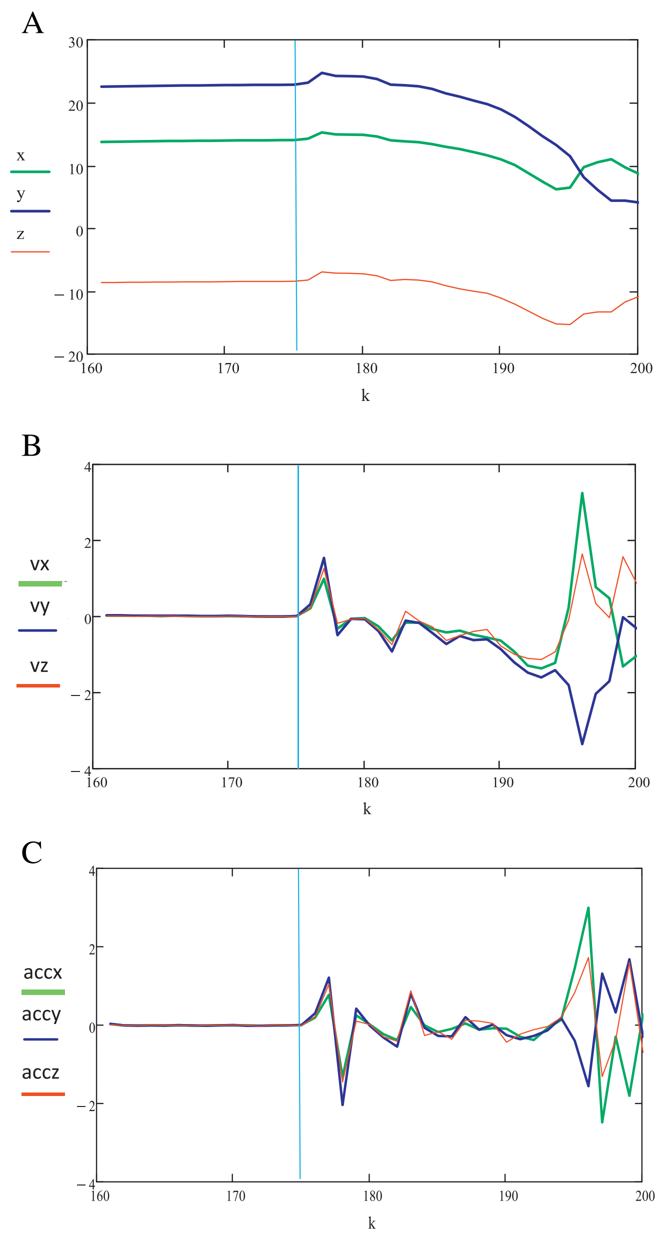

Fig. 3. Angular position (A), angular velocity (B) and angular acceleration (C) of C1–C2 during rotational high-velocity, low-amplitude technique according to local reference frame on axis (specimen number 11): green = lateral bending; blue = axial rotation; red = flexion–extension. k = sampling moment at 100 Hz (selected region of interest); *x*, *y*, *z*: angular position data; *vx*, *vy*, *vz*: angular velocity data; *accx*, *accy*, *accz*: angular acceleration data.