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Original article

The slow and fast components of postural sway in chronic neck pain

Ulrik Röijezon [a,b,c,d,*], Martin Björklund [a,b,c], Mats Djupsjöbacka [a]

[a] Centre for Musculoskeletal Research, University of Gävle, Box 7629, Umeå 90712, Sweden
[b] Department of Community Medicine and Rehabilitation, Physiotherapy, Umeå University, Umeå 90187, Sweden
[c] Alfta Research Foundation, Box 94, Alfta 82222, Sweden
[d] Department of Health Sciences, Luleå University of Technology, 971 87 Luleå, Sweden

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ABSTRACT

Background: Several studies have reported altered postural control in people with neck pain. The aim of this study was to increase the understanding of the nature of altered postural control in neck pain by studying the slow and fast components of body sway.
Methods: Subjects with whiplash associated disorders (WAD, $n = 21$) and chronic non-specific neck pain (NS, $n = 24$) were compared to healthy controls (CON, $n = 21$) in this cross-sectional study. The magnitudes of the slow and fast sway components were assessed in Rhomberg quiet stance for 30 s on a force plate with eyes closed. We also investigated associations between postural sway and symptoms, self-ratings of functioning and kinesiophobia.
Results: Increased magnitude of the slow sway component was found in WAD, but not in NS. Greater magnitude of the slow component in WAD was associated with poorer physical functioning, including balance disturbances, and more severe sensory symptoms.
Conclusions: Increased magnitude of the slow sway component implies an aberration in sensory feedback or processing of sensory information in WAD. The associations between postural sway and self-rated characteristics support the clinical validity of the test. Further investigation into NS, involving a longer test time is warranted.

1. Introduction

Several studies have reported altered postural control in people with neck pain (Karlberg et al., 1995; Michaelson et al., 2003; Madeleine et al., 2004; Treleaven et al., 2005; Field et al., 2008). Most of these studies include assessment of the center of pressure (CoP) migration in unperturbed quiet stance on a force plate (Michaelson et al., 2003; Madeleine et al., 2004; Treleaven et al., 2005; Field et al., 2008). From the CoP migration data a wide range of outcome variables can be calculated. Different studies report different variables, for example CoP migration area (Michaelson et al., 2003), CoP displacement amplitude and path length (Madeleine et al., 2004) and energy of the CoP signal in anterior–posterior and medial–lateral directions (Field et al., 2008). The understanding of the neurophysiologic mechanisms reflected by the different variables from the CoP trajectory is, however, still poor. This may explain the scarceness of theoretical motives for the choice of variables, and the lack of standardization of outcome variables.

Several researchers have concluded that postural sway in quiet stance includes a slow and a fast component (Zatsiorsky and Duarte, 2000; Bottaro et al., 2005; Kiemel et al., 2006). The slow component of the CoP reflects a trajectory that approximates the gravitational line of the body's center of mass (CoM) (Zatsiorsky and Duarte, 1999, 2000). The magnitude of the slow component has been attributed to noise in sensory information transmission and central processing when estimating the location and movement of the CoM (Kiemel et al., 2006). The fast component has been ascribed to restoring forces, generated by mechanical stiffness and tonic and phasic neural commands of the ankle muscles, in order to control CoM location (Bottaro et al., 2005). A method for decomposing the CoP trajectory into its slow and fast component has been presented by Zatsiorsky and Duarte (1999). This allows for a more in depth analysis of the postural sway mechanisms.

Our primary aim was to shed further light on the mechanisms behind increased postural sway in people with chronic neck pain. Therefore, the magnitude of the slow and fast CoP components were calculated to obtain information about possible alterations in

* Corresponding author. Luleå University of Technology, Department of Health Sciences, Luleå 97187, Sweden. Tel.: +46 920 49 29 87.
E-mail address: ulrik.roijezon@ltu.se (U. Röijezon).

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the size of the sway that can be related to noise in the sensory system, and the amplitude of the forces controlling CoM. One group with chronic neck pain with traumatic origin, and another with non-traumatic origin, were compared with a group of healthy controls. Group comparisons were limited to pre-planned contrasts between each of the neck-pain groups and the control group.

A second aim was to investigate the associations between postural sway performance and self-ratings of health, functioning, kinesiophobia and symptoms. Such analysis may provide important clues to the mechanisms behind impairments as well as an indication of the clinical validity of the outcome variables.

2. Methods

This single blinded controlled cross-sectional study was performed at a vocational rehabilitation center (Alfta Rehab Center, Alfta, Sweden). The study was approved by the Regional Ethical Review Board in Uppsala. All participants gave their written consent to participate.

2.1. Subjects

Sixty-seven subjects, age 20–50 years, were included. Forty-five had chronic neck pain while the remaining 22 constituted an age- and sex-matched control group. The posturography measurement was invalid for one control subject due to technical problems. Analysis was therefore based on 66 subjects. The inclusion criteria for the neck pain subjects were pain in the neck region, validated by a pain drawing (Margolis et al., 1986), of at least three months duration and a score above 10 (0–100) on the Neck Disability Index (NDI) (Vernon and Mior, 1991). Subjects with neck pain associated with trauma to the head or neck were referred to as Whiplash Associated Disorder (WAD, $n = 21$), while subjects with neck pain without traumatic association were referred to as non-specific (NS, $n = 24$). To be classified as WAD the subject should relate the onset of the symptoms to the accident and the symptoms should appear within two weeks after the accident. Since the medical records from the acute stage of these patients were unavailable, a further classification of the participants in the WAD group was not done. The control subjects (CON, $n = 21$) were included if they had no current neck or shoulder pain and no history of longer periods of constant or intermittent neck-shoulder pain. Subjects were excluded if they had had surgery in the neck, shoulder or back region, had injuries with fractures or luxation of neck or shoulder or had suffered from neurological or rheumatic disease.

Subjects were recruited from a vocational rehabilitation center, from general practitioners and physiotherapists in the community and by advertisements in local newspapers. Inclusion–exclusion and group allocation of the subjects were accomplished by a structured telephone interview by the administrator. Thereafter, VAS-ratings and questionnaires were posted and filled in by the subjects prior to attending the test. Characteristics of the study groups are given in Table 1.

2.2. Quiet stance test

A force plate (Kistler Force Measurements, type 9807, Kistler Instrumente AG, Switzerland) was used for measuring the CoP migration and horizontal forces. The sampling frequency was 30 Hz. The test was performed standing barefooted in the Rhomberg position; with feet together, heel-to-heel and toe-to-toe, with closed eyes and arms crossed over the chest. The instruction given was: *Stand as still as possible*. The test duration was 30 s. A 10 s training session was given prior to the test.

Table 1
Characteristics of the study sample. Values are n or mean ± one standard deviation, except for Duration which is given in median and range. The NDI and TSK scores are normalized to the range of 0–100.

Characteristics	CON ($n = 21$)	NS ($n = 24$)	WAD ($n = 21$)
Women	13	14	11
Men	8	10	10
Age	38 ± 9	37 ± 9	36 ± 5
BMI	25 ± 3	26 ± 4	26 ± 4
Weight (kg)	77 ± 12	77 ± 15	78 ± 15
Height (cm)	174 ± 9	172 ± 10	173 ± 7
Shoe size	40.2 ± 2.3	40.2 ± 3.1	40.8 ± 2.4
SF-36 PCS	55 ± 6	41 ± 11*	34 ± 8*
SF-36 MCS	51 ± 8	41 ± 12*	36 ± 14*
Duration (months)	NA	60 (12–368)	73 (22–215)
VAS pain	NA	47 ± 23	60 ± 22
Dizziness (1–6)	NA	2.8 ± 1.5	3.8 ± 1.5
Balance disturbance (1–6)	NA	2.4 ± 1.2	2.9 ± 1.7
NDI	NA	30 ± 13	45 ± 16
TSK	NA	37 ± 15	46 ± 14

BMI: Body mass index; VAS pain: Visual analogue scale rating of pain; SF-36 PCS: The Short Form Health Survey physical component summary; SF-36 MCS: The Short Form Health Survey mental component summary; NDI: Neck Disability Index; TSK: the TAMPA Scale of Kinesiophobia; NA: Not answered.
*$p < 0.05$ (Dunnett's t two-sided post-hoc with the CON group).

2.3. Pain measurement

Within a week before testing, the subjects with neck pain were instructed to rate their "pain right now" on a blank 100 mm visual analogue scale (VAS) where 0 mm corresponds to "no pain at all" and 100 mm to "worst imaginable pain" (Huskisson, 1974).

2.4. Questionnaires

Questionnaires were filled in together with the VAS ratings, i.e. within a week before testing day. The Short Form Health Survey (SF-36) was used as a measure of general health and well-being (Ware and Sherbourne, 1992). Neck-related disability was measured using the Neck Disability Index (NDI) (Vernon and Mior, 1991) and the disability of the arm, shoulder and hand (DASH) questionnaire was used to measure upper extremity disability (Hudak et al., 1996). Fear of re-injury due to movement was assessed using the Tampa Scale of Kinesiophobia (TSK) (Kori et al., 1990). Greater scores of SF-36 reflect better health status, while a greater score on NDI and DASH indicates more disability and a greater score on TSK indicates greater kinesiophobia.

Symptoms and signs that we considered to be of interest, but not covered by the questionnaires, were addressed by supplementary questions (Table 2). A six-level scale was used for each question with alternatives corresponding to 1. Not at all/nothing, 2. Weak/mildly, 3. Moderate, 4. Quiet high/somewhat strong, 5. High/strong, 6. Almost unbearable/maximal.

2.5. Data processing and analysis

The CoP trajectories from 26 s of the trials were used for analysis. Four seconds at the beginning of the trial were excluded to avoid any possible random sways at the initiation of the test. The CoP trajectories were decomposed into the slow and fast components, denoted rambling (Ra) and trembling (Tr) respectively, according to the method described by Zatsiorsky and Duarte (1999). The decomposition was made separately for the anterior–posterior (Y) and medio-lateral (X) directions. First, the trajectory of the slow component was separated from the CoP trajectory by interpolation of the CoP positions where the horizontal forces equaled zero, by using a "cubic spline function". Thereafter, the trajectory of the fast