Gait & Posture 39 (2014) 745–749

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Interactions of touch feedback with muscle vibration and galvanic vestibular stimulation in the control of trunk posture

E. Maaswinkel, H.E.J. Veeger, J.Hv. Dieen [*]

Research Institute MOVE, Institute for Fundamental and Clinical Human Movement Sciences, Faculty of Human Movement Sciences, 'Vrije Universiteit Amsterdam', Van der Boechorststraat 9, NL-1081 BT Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 19 March 2013
Received in revised form 25 September 2013
Accepted 12 October 2013

Keywords:
Trunk control
Sensory perturbations
Postural sway
Tactile feedback
GVS

ABSTRACT

This study investigated the effect of touch on trunk sway in a seated position. Two touch conditions were included: touching an object with the index finger of the right hand (hand-touch) and maintaining contact with an object at the level of the spine of T10 on the mid back (back-touch). In both touch conditions, the exerted force stayed below 2 N. Furthermore, the interaction of touch with paraspinal muscle vibration and galvanic vestibular stimulation (GVS) was studied. Thirteen healthy subjects with no history of low-back pain participated in this study. Subjects sat on a stool and trunk sway was measured with a motion capture system tracking a cluster marker on the trunk. Subjects performed a total of 12 trials of 60-s duration in a randomized order, combining the experimental conditions of no-touch, hand-touch or back-touch with no sensory perturbation, paraspinal muscle vibration or GVS. The results showed that touch through hand or back decreased trunk sway and decreased the effects of muscle vibration and GVS. GVS led to a large increase in sway whereas the effect of muscle vibration was only observed as an increase of drift and not of sway. In the current experimental set-up, the stabilizing effect of touch was strong enough to mask any effects of perturbations of vestibular and paraspinal muscle spindle afference. In conclusion, tactile information, whenever available, seems to play a dominant role in seated postural sway and therefore has important implications for studying trunk control.

1. Introduction

Control of trunk movement is crucial for maintaining balance during activities of daily living [1,2]. Also, precise hand/arm function is dependent on adequate control of trunk movement [3,4] and it has been suggested that impaired trunk control might induce instability of the lumbar spine and consequently cause low back pain [5,6] or play a role in low back pain recurrence [7,8]. Furthermore, control of trunk movement is affected in neurological disorders such as Parkinson's disease [9], stroke [10] and spinal cord injury [11].

Trunk control is dependent on adequate motor control as the intrinsic stiffness of the trunk is insufficient [12]. In turn, proper motor control depends on adequate sensory feedback. The influence of different sensory modalities in feedback control is often studied by interfering with these modalities and measuring the resulting changes in motion [13–15]. Furthermore, the involuntary/reflexive component of trunk control can be identified by applying external perturbations and measuring the resulting trunk muscle responses [16,17]. These external perturbations require application of time-varying forces to the subject's trunk. This usually involves contact with an external object for the whole or a part of the test duration. However, there is evidence that contact with an external object may, through tactile information, have a profound influence on postural control [18–20].

The effect of tactile stimuli on postural control has been illuminated specifically in studies of standing postural sway. For example, when subjects stand upright and their calf muscles are vibrated, to interfere with muscle spindle information, a large increase in sway is observed [21]. However, when subjects are allowed to keep a very light contact through the hand with an external object, this effect of muscle vibration is strongly reduced. Still, several questions remain unanswered. First, is the effect of touch specific for contact with the hand, or does it apply to other body areas as well? Second, does the effect of touch interact specifically with muscle vibration, or does it interact also with other sensory modalities? Furthermore, for the purpose of understanding trunk control, measurements of standing postural sway provide limited information, since postural adjustments can be made in several joints (e.g. ankle, knee, hip). Therefore, the measured sway can be attributed to several joints and might not accurately reflect trunk control. In sitting, trunk control can be

---

[*] Corresponding author. Tel.: +31 20 598 8501; fax: +31 20 598 8529.
E-mail address: j.h.van.dieen@vu.nl (J.Hv. Dieen).

0966-6362/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gaitpost.2013.10.011

studied without the influence of responses from the lower extremities.

The purpose of the current experiment was to determine the effect of touch on trunk sway in a seated position. To investigate whether the effect is specific for touch with the hand, a second contact condition, namely contact through the back, was included. Finally, to determine whether the effect of touch interacts specifically with muscle vibration, or also with other sensory modalities, a second sensory perturbation, galvanic vestibular stimulation (GVS), was included. It was hypothesized that touch through both hand and back reduces the effects of muscle vibration and GVS. The results obtained may contribute to a better understanding of the influence of touch on the control of trunk posture.

2. Methods

2.1. Experimental setup

The study was approved by the ethical committee of the faculty of human movement sciences of the VU University Amsterdam. 13 Healthy subjects without history of low-back pain participated (10 males, 3 females; age range: 20–35 years; mean mass: 77 (SD 10) kg; mean height: 182 (SD 8) cm). Subjects sat upright on a height adjustable stool with their feet on the ground at shoulder width apart and their knees bent at a 90° angle (Fig. 1). Trunk sway was measured with a motion capture system (Optotrak 3020, Northern Digital Inc., Canada) tracking, at 100 Hz, a cluster of 3 markers attached to the back at the level of the spine T6.

Subjects performed a total of 12 trials of 60-s duration in a randomized order, combining the experimental conditions of no-touch, hand-touch or back-touch, with no sensory perturbation, muscle vibration or GVS. Since the eyes were closed for the muscle vibration and GVS to have a stronger effect, an eyes open condition was included to check whether closing the eyes affects trunk sway. During selected trials, subjects were allowed to touch a solid object attached to a force sensor. During all touch conditions, the force exerted on the force sensor was monitored by the experimenter and never exceeded 2 N to assure that the mechanical stabilizing advantage was kept to a minimum. Hand-touch was provided between shoulder and elbow height in the mid-sagittal plane and back-touch was provided at the level of the spine of T10 in the mid-sagittal plane. During all trials, the subject's arm was held in the same (hand-touch) position to prevent any effects of changing arm posture. During the trials with muscle vibration, a custom made vibrator was attached bilaterally to the lower back at the level of L4, 5 cm lateral of the spine. The vibrator was turned on right before the onset of the trial and the vibration frequency was set to 90 Hz.

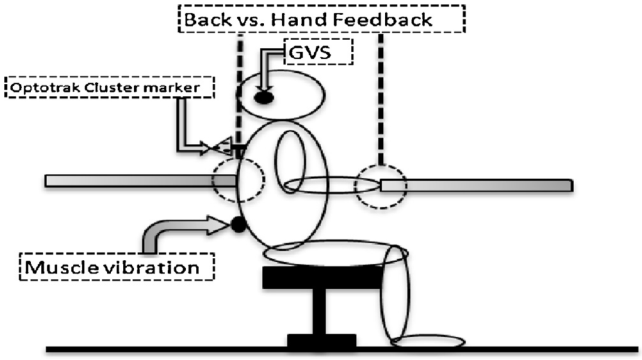

Fig. 1. A schematic drawing of the experimental set-up. Trunk sway was measured with a cluster marker attached on the back at the level of the spine T6. Muscle vibration was applied bilaterally on the lower back at the level of the spine L4. Hand-touch was provided at elbow height in front of the body while back-touch was provided in the mid-sagittal plane at the level of the spine T10.

For the GVS trials, a direct current was applied to the mastoid processes by a custom-made constant current stimulator (Balance Lab, Maastricht Instruments, The Netherlands). The current was applied as a sinusoid with a frequency of 1 Hz and 1.5 mA amplitude [22]. Subjects were instructed to rotate their head sideways ('look over your shoulder') to induce illusory movement in the fore-aft direction. Furthermore, to eliminate possible effects of turning the head, subjects were instructed to maintain their head turned sideways during all trials.

2.2. Data analysis

Per trial, the first and last 10 s of the signal were discarded to eliminate transient behavior, leaving 40 s which were used for further data analysis. The average position of the cluster marker in the sagittal plane was calculated. Preliminary analysis showed that a considerable drift occurred, especially during the vibration trials. Accordingly, the analysis was split into two parts. First, the signals were corrected for drift by applying a linear piecewise detrend and, subsequently, trunk sway in the fore-aft direction (sagittal plane) was quantified by calculating the standard deviation of the detrended signals. Second, to analyze the effects of touch condition on drift, the drift of the raw data was quantified by calculating the difference between the average position during the first and last second of the 40-s signal. Quantifying the drift by a 3- or 5-s window led to similar results.

2.3. Statistical analysis

To investigate whether closing the eyes affected trunk postural sway, a repeated measures ANOVA with 2 factors (touch condition, eyes open vs. closed) was performed. To determine whether trunk sway was affected by touch and/or perturbation conditions, a 2 factor (touch condition, perturbation condition) repeated measures ANOVA was performed. Furthermore, a similar ANOVA was performed on the calculated drift. Significant main effects were followed up by Bonferroni corrected pair-wise comparisons. Effects were considered significant when the corrected $p < 0.05$. The assumption of normality was checked by visual inspection of the q–q plots and box plots of the residuals. A Shapiro–Wilk test was also performed on the residuals. There was no violation of the assumption of normality. Sphericity was checked using Mauchly's test. If the assumption of sphericity was violated, a Greenhouse–Geisser correction was used [23].

3. Results

A typical example of the measured position of the trunk in fore-aft direction for a reference (eyes closed) and muscle vibration trial is presented in Fig. 2.

The ANOVA results are presented in Table 1. Closing the eyes did not significantly affect trunk sway ($p = 0.6$) (Fig. 3, top panel). Trunk postural sway was significantly reduced in the hand-touch ($p = 0.01$, 95% CI $[-0.371\ \ -0.050]$) as well as in the back-touch condition ($p = 0.016$, 95% CI $[-0.425\ \ -0.042]$) (Fig. 3, top panel). For the perturbation conditions, only GVS led to a significant increase in sway ($p = 0.015$, 95% CI [0.036 0.337]). A trend for an increase in trunk sway could be observed for the muscle vibration condition (Fig. 3, top panel), but failed to reach statistical significance (95% CI $[-0.062\ \ 0.193]$). There was no significant interaction of perturbation and touch condition.

Significantly more drift was observed for the muscle vibration condition compared to the reference ($p < 0.001$, 95% CI [3.920 13.413]) and GVS conditions ($p < 0.001$, 95% CI [4.973 13.359])