Human Movement Science 30 (2011) 238–248

Contents lists available at ScienceDirect

Human Movement Science

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

Tonic postural lean after-effects influenced by support surface stability and dynamics

W.G. Wright *

Department of Physical Therapy, Temple University, 3307 N. Broad St., Philadelphia, PA 19140, USA
Department of Mechanical Engineering, Temple University, 1947 N. 12th St., Philadelphia, PA 19122, USA

ARTICLE INFO

Article history:
Available online 31 July 2010

PsycINFO classification:
2330

Keywords:
Postural tone
COP
Sway-reference surface
Kohnstamm phenomenon
Post-contractory after-contraction
Motor Processes

ABSTRACT

Tonic neuromuscular processes are evident during lean after-effects, which occur after prolonged standing on a fixed ramp. Postural processes underlying lean after-effects were examined here using dynamic surface conditions. Three tilt adaptation conditions were tested with eyes-closed ($n = 11$). Tilt adaptation conditions involved standing for 120 s on a fixed toes-up ramp (7°) or on a toes-up sinusoidally tilted surface (7° ± 3°), which was followed by 120 s of standing on either a fixed horizontal surface or sway-referenced surface. All participants showed postural after-effects ($p < .003$). Specifically, standing on a fixed horizontal surface after sine-tilt adaptation, resulted in forward leaning which decayed over 120 s back to baseline. Standing on a sway-referenced surface after tilt-adaptation, initially showed no lean after-effect, however over the course of the trial the center-of-pressure shifted backward ($p < .02$). This after-effect during sway-reference conditions was also evident in the sway-induced surface tilt, which increased in dorsiflexion ($p < .002$), rather than decaying back to baseline. Thus, adaptation occurs on a dynamically tilted surface, while reliability of the surface as a stable reference affects the return of the center-of-pressure and surface tilt to baseline. These findings relate to changes in flexor/extensor muscle tonic set-point which also occur following a prolonged voluntary isometric contraction.

* Address: Department of Physical Therapy, Temple University, 1947 N. 12th St., Philadelphia, PA 19122, USA. Tel.: +1 215 707 9519; fax: +1 215 707 7500.
E-mail addresses: geoff.wright@temple.edu, wrightw@temple.edu

0167-9457/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.humov.2010.05.006

1. Introduction

Postural tone is an important mechanism involved in normal postural control. Posture is commonly considered the combination of tonic and phasic muscular responses (Gurfinkel et al., 2006; Sherrington, 1909; Sherrington, 1915; Shumway-Cook & Wollacott, 2007), with the tonic processes constantly employed to counteract the force of gravity. Although some have classified postural maintenance as voluntary control on one end of the spectrum and automatic reflex control on the other end, it has also been referred to as a kind of sustained contraction produced by a descending tonic drive from tonigenic sub-cortical structures (Gurfinkel, Levik, & Lebedev, 1989). One of the tonic processes involved in posture involves an internal representation of verticality which is used as a reference for upright.

The postural reference, as Gurfinkel and colleagues define it, is formed in the central nervous system using multiple sensory inputs combined with a current representation of the body parameters. The reference is then used to set the postural tone of flexor and extensor muscle activity about a joint involved in postural maintenance (i.e., the flexor/extensor muscle tone set-point). Only changes to inputs or body parameters, which are of considerable duration result in a stable change to this internal representation of verticality (Clement, Gurfinkel, Lestienne, Lipshits, & Popov, 1984; Gurfinkel, Ivanenko, Levik, & Babakova, 1995). Since online phasic postural adjustments tend to have latencies more than an order of magnitude less than tonic processes, these phasic processes are thought to be stabilized about this change-resistant tonic reference when maintaining balance. Investigation into this conservative verticality reference can be accomplished by dissociating the sensory sources that are used to make online postural adjustments during upright stance. These sources include visual, vestibular, and somatosensory channels. Clinical cases such as contraversive pusher syndrome (Karnath, Ferber, & Dichgans, 2000) and unilateral vestibular loss (Bisdorff, Anastasopoulos, Bronstein, & Gresty, 1995) have shown that these sensory channels can be dissociated and pathologically altered resulting in perceptual and postural impairment.

Normal upright stance is typically aligned closely to gravity and orthogonal to a horizontal surface. In many cases, individuals use the support surface as a somatosensory reference for orientation, as evidenced by the close alignment of the body to the surface that is maintained when the surface is slowly tilted (Creath, Kiemel, Horak, & Jeka, 2002; Gurfinkel, Lipshits, Mori, & Popov, 1981; Walsh, 1973; Wright & Horak, 2007). However, it has been proposed that the relation of the surface reference to the vertical reference is updated if it is altered for an extended period of time (Kluzik, Horak, & Peterka, 2005). The evidence for this comes from having participants stand on a tilted surface for a few minutes, followed by a period of eyes closed standing on a horizontal surface. Many participants will continue to align to the surface in the same surface-to-body angular configuration as when the surface was tilted. In other words, if a participant were standing upright on a toes-up ramp, then this dorsiflexed posture will be maintained when the surface is returned to horizontal, which would result in a forward leaning posture. It has been argued that this forward lean is due to an adaptive recalibration in the postural reference frame with a new tonic set-point of muscle activity resulting. Evidence that this after-effect is centrally driven has been suggested by the fact that global postural variables, not simply the local muscle group set-point, are altered (Kluzik, Peterka, & Horak, 2007). Although this lean after-effect may in fact be centrally driven, it is unclear from previous studies whether this effect could be due to post-contractory muscle effects at each segmental level of the body (e.g., ankles, hips, vertebrae, neck) or whether it must be a change in a global variable which represents verticality. This can be tested by dissociating body lean from changes in the flexor/extensor muscle set-point of the involved postural muscles. Specifically, if changes in the flexor muscle tone relative to the extensor muscle tone can be seen independent of whole-body lean, then post-contractory after-contraction may underlie lean after-effects, rather than a change in a global variable which represents verticality.

The change in the flexor/extensor muscle tonic set-point after a prolonged isometric contraction is most easily observed, if the distal segment of the involved body part is unconstrained. By using a sway-referenced tilting surface the ankle joint will have an increased level of independence from the overall goal of maintaining postural verticality. Therefore, two possible outcomes may occur if a participant stands on a sway-referenced surface after adapting to a toes-up ramp: (1) If the internal representation of verticality is the variable that has been altered, then the lean after-effect should