Journal of Biomechanics 44 (2011) 1466–1470

Contents lists available at ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Frontal plane standing balance with an ambulation aid: Upper limb biomechanics

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ARTICLE INFO

Article history:
Accepted 12 March 2011

Keywords:
Human balance
Ambulation aids
Quiet standing

ABSTRACT

Despite widespread acceptance of clinical benefits, empirical evidence to evaluate the advantages and limitations of ambulation aids for balance control is limited. The current study investigates the upper limb biomechanical contributions to the control of frontal plane stability while using a 4-wheeled walker in quiet standing. We hypothesized that: (1) upper limb stabilizing moments would be significant, and (2) would increase under conditions of increased stability demand. Factors influencing upper limb moment generation were also examined. Specifically, the contributions of upper limb center-of-pressure (COP_{hands}), vertical and horizontal loads applied to the assistive device were assessed. The results support a significant mechanical role for the upper limbs, generating 27.1% and 58.8% of overall stabilizing moments under baseline and challenged stability demand conditions, respectively. The increased moment was achieved primarily through the preferential use of phasic upper limb control, reflected by increased COP_{hands} (baseline vs. challenged conditions: 0.29 vs. 0.72 cm). Vertical, but not horizontal, was the primary force direction contributing to stabilizing moments in quiet standing. The key finding that the upper limbs play an important role in effecting frontal plane balance control has important implications for ambulation aid users (e.g., elderly, stroke, and traumatic brain injury).

1. Introduction

Worldwide, millions of people rely on ambulation aids to address mobility impairments (LaPlante, 1992; Statistics Canada, 2007). The 4-wheeled walker is a device frequently prescribed to facilitate independent standing and walking despite high rates of injury and deaths associated with walker use (Charron et al., 1995). While studies have reported improved walking distance (Solway et al., 2002) and efficiency (Probst et al., 2004) in cardiopulmonary populations, little empirical evidence exists to evaluate 4-wheeled walker use for balance (Bateni and Maki, 2005). Bateni et al. (2004) demonstrated that healthy young adults reduced the need for compensatory stepping in response to lateral perturbations when using standard (4-footed) walkers. However, this benefit may be offset by the restrictions to lateral stepping and the potential tripping hazard imposed by the walking frame. Importantly, the role of the upper limbs in whole-body balance control has received little attention compared to the body of research investigating lower limb control.

While the upper limbs can provide tactile input when touch is applied to a stationary object (Jeka, 1997), the mechanical role of the upper limbs in control of standing balance remains to be examined. Cordo and Nashner (1982) and Elger et al. (1999) examined upper limb responses to perturbations while grasping handholds highlighting the potential importance of rapid upper limb reactions to maintain stability. The focus of the present study was to investigate the mechanical contributions of the upper limbs to the control of frontal plane stability in quiet standing with a fixed 4-wheeled walker. Specifically, the objective was to determine if the upper limbs play a significant mechanical role in maintaining standing balance with an ambulation aid and to detail the upper limb strategies and control characteristics.

Considering the inverted pendulum model for standing balance in (unassisted) bipedal standing, frontal plane stability is controlled by modulating the magnitude of the vertical ground

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doi:10.1016/j.jbiomech.2011.03.015