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Effects of additional external weight on posture and movement adaptations to fatigue induced by a repetitive pointing task

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Fatigue and additional weight are risk factors of injuries by falls. Posture and trunk movement changes occur with fatigue induced by a repetitive pointing task. These changes facilitate arm movement but they may also jeopardize postural stability. When equilibrium is challenged, e.g. with additional weight, strategies that represent less postural threat could develop with fatigue. Nineteen participants performed two sessions (without, with 20% body weight added load (Load)) of a repetitive pointing task until shoulder fatigue (8 on Borg CR-10). There was no difference in time to fatigue between the two sessions. Anterior deltoid, biceps and upper trapezius muscle activity significantly increased with fatigue. Peak medial–lateral center-of-pressure (CoP) velocity and the mean vertical position of the reaching shoulder were both significantly lower with fatigue, though these fatigue-induced decreases were smaller with the added load. Reach-to-reach variability in CoP displacement significantly increased with fatigue, and more so with the added load. With fatigue, significant contralateral shifts occurred at the reaching shoulder and elbow joints, and ranges of motion (RoM) significantly increased at most joints but not at the center-of-mass (CoM). Conversely, Load main effects were mostly seen in CoM dependent measures. Significantly increased variability in mean and range values was seen with fatigue and Load in most of our kinematic and CoP dependent measures, with the most notable effects on CoM dependent

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measures. Findings suggest that the postural control system adapts to combined perturbing factors of fatigue and added load, likely by using parallel control mechanisms.

1. Introduction

Statistics show falls as one of the most common reasons of musculoskeletal injuries and accidents in workplace settings (Bureau of Labor Statistics, 2004). Muscle fatigue has been identified as a potential risk factor of injuries by falls (Parijat & Lockhart, 2008). Induced fatigue, either by a general whole-body task or a local specific muscle task, negatively affects the effectiveness of sensory inputs and motor output involved in postural control (Paillard, 2012). Increased postural sway, suggesting reduced postural stability, has been documented in studies that induced fatigue directly at various joints and in others that induced fatigue indirectly by prolonged standing (Corbeil, Blouin, Bégin, Nougier, & Teasdale, 2003). In addition, when standing, we often perform tasks with our upper limbs during daily activities, oftentimes in a repetitive fashion (Zakaria, Robertson, MacDermid, Hartford, & Koval, 2002). Repetitive and/or prolonged arm movements generally lead to fatigue (Emery & Côté, 2012; Fuller, Fung, & Côté, 2011; Fuller, Lomond, Fung, & Côté, 2009; Lomond & Côté, 2011; Nussbaum, 2003). Physical manifestations of fatigue have been extensively studied; notably, in his pioneer work, De Luca (1984) identifies fatigue as a timed-dependent process illustrated by increased activity amplitude and spectral shift to lower frequencies in the fatigued musculature. Moreover, posture and movement adaptations have been observed as a result of fatigue induced by a repetitive upper limb pointing task, and these adaptations have been interpreted as compensatory strategies to reduce the load on the fatigued musculature (Fuller et al., 2009). Indeed, it has been shown that during various repetitive upper limb tasks (hammering, sawing, reaching), signs of localized arm fatigue were accompanied by increased contribution of trunk muscles and increased trunk movements in the direction of the arm movement (Côté, Feldman, Mathieu, & Levin, 2008; Côté, Mathieu, Levin, & Feldman, 2002; Côté, Raymond, Mathieu, Feldman, & Levin, 2005). Increased postural sway and postural shifts towards the non-moving arm side were also observed. Taken together, these findings suggest that during a repetitive upper limb task performed while standing, compensatory postural strategies that aim to contribute to the arm motion are developed, even though they may at the same time jeopardize postural stability.

The main function of the postural control system (PCS) is to maintain balance (Massion, 1994). However, factors such as additional weight, in the form of external load and/or obesity, impact on postural stability. Qu and Nussbaum (2009) showed increases in center-of-pressure (CoP) displacement and velocity in both anterior–posterior and medial–lateral directions when equipped with an external load, with authors suggesting that increases in these measures contribute to decreasing postural stability. In addition, one study compared the effects of lower limb fatigue and additional external body weight on postural control; larger body sway was observed in response to both, but was more pronounced when adding external loads (Ledin, Fransson, & Magnusson, 2004). Similarly, obesity has been identified as a threat to balance control. Hue et al. (2007) showed that body weight was one of the most important factors affecting postural stability. Reductions in mobility are seen as a consequence of higher loads on body joints due to obesity, which negatively affects human gait, posture and balance (Hills, Hennig, Byrne, & Steele, 2002). When performing a standing task, obese participants showed higher postural sway compared to a control group with significant increases over time for both groups but faster and more pronounced for the obese group (Singh, Park, Levy, & Jung, 2009). Berrigan, Simoneau, Tremblay, Hue, and Teasdale (2006) found greater CoP displacement in obese patients than in normal individuals while standing and performing a pointing task. After obese patients lost weight, reductions in CoP range of motion (RoM) were seen in all directions (Teasdale et al., 2007), further reinforcing the idea that additional weight represents a postural threat, although additional factors such as reduced/altered kinesthesis, possible diabetes and other co-morbidities