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Postural stability with exhaustive repetitive sit-to-stand exercise in young adults

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ABSTRACT

Previous research has indicated that muscle fatigue due to repeated bouts of physical activity can have negative residual effects on balance; however investigations using multi-joint forms of exercise involved in everyday settings and determination of how control of posture is altered during the physical activity itself are limited. The purpose of this investigation was to evaluate alterations in postural stability before, during, and after prolonged multi-joint STS exercise in healthy young adults. Center of pressure (COP) acquisitions were collected during repetitive STS exercise, while voluntary limits of stability (LOS) testing was performed before, immediately after, and 10 min after STS exercise. By 50% total STS exercise time, fatigue resulted in increased anterio-posterior (y) and medio-lateral (x) COP path lengths ($p = 0.003$ and $p = 0.018$ respectively) and an anterior shift of COP at *seat-off* towards the mid-foot ($p = 0.010$). No significant change in LOS mean amplitude was found after STS exercise; however a significant fatigue effect resulted in increased COPy sway velocity at maximal lean positions ($p = 0.006$), but returned to PRE values after 10 min of rest. Declines in postural stability during repetitive STS exercise was associated with reduced control of COP, as well as a reduced ability to stably control COP at extreme postural limits; however, 10 min was adequate in young adults for recovery. These results may have important implications for monitoring fall risk due to acute bouts of exercise induced muscle fatigue from repetitive multi-joint activities such as the STS.

1. Introduction

Performing physical activities, either through exercise or repetitive daily actions has been shown to be beneficial for the maintenance of functional mobility of the lower extremity (French et al., 2010). However the associated accumulation of muscular fatigue can have negative consequences for balance control and prolonged physical activity can increase the risk of falling during the activity itself and residual effects on balance control may remain after the cessation of exercise (Chaubet & Paillard, 2012; Paillard, 2012). Postural control is commonly described as the ability to maintain or restore balance, reflected by a greater ability to control body sway, and commonly evaluated using acquisitions of either body Center of mass (COM) or center of pressures (COP) with respect to the base of support (Pollack, Durward, Rowe, & Paul, 2000; Ruhe, Fejer, & Walker, 2010).

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Previous investigations have indicated that with fatiguing exercise, and increase in COP sway area and velocity reflects poorer balance capabilities during quiet standing (Ruhe et al., 2010); however, the influence of fatigue on postural stability during dynamic tasks is less explored. In comparison to bouts of quiet standing, multi-joint transfer tasks of daily living involve large displacements of COM and require that segment positions are controlled in an accurate and coordinated fashion to prevent COP from deviating outside of one's functional postural boundaries about the base of support, or limits of stability (LOS). Sparto, Parnianpour, Reinsel, and Simon (1997) investigated the effects of prolonged repetitive lifting on joint dynamics and postural stability in young adults by measuring anterio-posterior (A-P) excursions of COP and trunk COM. They noted significantly increased A-P COP excursions by the end of the lifting protocol, which was reflective of COM trunk excursion. Thus, COP movements during dynamic repetitive lifting were reflective of whole body control dynamics, and may be a feasible measurement technique to detect instability during multi-joint tasks.

Another commonly investigated multi-joint task is the sit-to-stand (STS) due its association with muscular performance of the lower extremities and functional capabilities (Bohannon, 1995; Lazaro, Gonzalez, Latorre, Fernandez, & Ribera, 2011; Tiedemann, Shimada, Sherrington, Murray, & Lord, 2008). The ability to rise from a seated position is a basic, but challenging skill associated with numerous activities of daily living that requires the development of relatively high muscular efforts even in healthy young adults (Bieryla, Anderson, & Madigan, 2009; Hortobágyi, Mizelle, Beam, & DeVita, 2003), which may lead to substantial accumulation of fatigue with repetitive actions. Additionally, STS exercise is especially demanding in terms of its reliance on balance control capabilities in order to achieve an upright standing position as it requires the precise control of COM over a rapid reduction in support surface the moment contact is lost with the seat (Akram & McIlroy, 2011; Doorenbosch, Harlaar, Roenbroeck, & Lankhorts, 1994; Fugimoto & Chou, 2012; Shultz, Alexander, & Ashton-Miller, 1992). Therefore it is understandable why its capacity has been shown to be a predictor of disability in populations experiencing functional declines (Tiedemann et al., 2008). Consequently, determining indicators of compromised postural control during the STS warrants further investigation.

Considering this, it would be beneficial to evaluate COP control capabilities not only before and after exercise, but also during a STS fatiguing task itself and the ability to recover after the cessation of exercise. The purpose of this investigation was to evaluate alterations in dynamic postural stability during exhaustive STS exercise in young adults through evaluation of COP excursions with respect to protocol progression. In turn, to see if this is associated with any stabilization strategies to cope with instability, COP positions at the moment contact is lost with the seat was also evaluated since this is the most unstable point in time during the STS. Secondly, to confirm that such supposed instability was associated with reduction in balance control during another postural task, LOS testing was performed prior to and immediately after the cessation of STS exercise. Lastly, to test the ability to recover from any postural instability, LOS testing was also performed 10 min afterwards. We hypothesized prolonged STS exercise would result in increased COP path excursions when ascending from a seated position and would be directly related to the adoption of preparatory stabilization strategies when losing contact with the seat, through the anterior relocation of COP towards the mid-foot, away from posterior boundaries of stability. This would also be associated with reduced LOS performance immediately after multi-joint exercise to prevent COP from deviating toward extreme postural limits and reduce risk of falling due to reduce control of COP about one's base of support.

2. Methods

2.1. Participants

Ten health young adult men (n = 6) and women (n = 4) between the ages of 18–35 years (26.4 ± 3.6 yrs.) from a convenience sample of the university community participated in this investigation. Participants were instructed to refrain from any strenuous lower extremity activities prior to visiting the laboratory. The study was approved under the University of Ottawa and Bruyère Continuing Care Institutional Review Boards and prior to testing, written informed consent was obtained from each participant.

2.2. Procedures

2.2.1. Limits of stability (LOS) testing

The LOS task was performed on an AMTI Acu-Gait force platform (Watertown, MA) where net ground reaction forces were collected at a sampling rate of 100 Hz using NetForce v. 2.2 (AMTI, Watertown, MA). Participants were asked to stand barefoot with feet together on the platform to measure their maximal voluntary range of anterio-posterior (A-P) COP displacement (Blaszczyk, Cieslinska-Swider, Plewa, & Zahorska-Markiewicz, 2009), which was calculated using BioAnalysis 2.3 software (AMTI, Watertown, MA). To do so, participants were instructed to lean forward toward their toes and then heels, over the largest possible amplitude by rotating about the ankle, maintaining full contact between their feet and the plate (i.e., avoiding toes or heels off), and while keeping their body as rigid as possible. Each maximum lean position was maintained for 10 s in order to determine average COP acquisitions about the feet over the sustained period. The LOS testing was performed before (PRE), after (POST), and 10 min after (RECOV) a fatiguing STS exercise protocol. A total of three successive leaning trials were performed at each of the three time points in order to be further averaged in subsequent analyses.