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How Does Physical Activity Impact Postural Stability?

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Abstract

Physical activity has been associated with an overall improvement in health by reducing disease and assisting in weight management. However, varying levels of physical activity has been shown to have immediate adverse effects on measures of postural stability. Increases in postural sway occur as a result of performing fatiguing exercise to specific muscles in addition to moderate to maximal intensity exercise. While this is often not problematic for healthy young adults this could produce challenges to individuals with balance impairments and older adults. This review investigates the immediate impact that various physical activity levels have on postural stability. In addition, the areas that require further investigation will be highlighted.

Keywords: Physical activity; Postural sway; Fatigue; Center of Pressure (COP)

Introduction

Physical activity has been associated with improving overall mental and physical health, reducing the risk of chronic disease such as Cardiovascular Disease (CVD), stroke, some strains of cancer, and type II diabetes [1]. The American College of Sports Medicine (ACSM) defines physical activity as "any bodily movement that increases energy expenditure above resting basal levels. This broadly encompasses exercise, sports, and physical activities performed as a part of daily living, occupation, leisure, or active transportation" [1]. The physiological impact of physical activity is also responsible for a range of acute fatigue effects on the neuromotor system that can adversely impact postural control [2-4].

Standing posture is a complex motor skill that involves the coordination of multiple body segments and sensory input [5,6]. Postural control during standing is defined as the ability for individuals to maintain their Center Of Mass (COM) within the limits of the Center Of Pressure (COP) without having to change the base of support (i.e., take a step or lift feet from surface) [7]. Even while standing still, there is a high degree of motion that occurs to establish equilibrium within the system [8]. As a result of the constant search for equilibrium to adjust the COM over the smaller COP, many researchers have referred to movement of the body to control the amount of postural sway as an inverted pendulum. This theory indicates that the COP is directly correlated with the horizontal acceleration of the COM in either the AP or the ML directions the amount of motion around the small base of support is referred to as postural sway [6,9]. Postural sway is the variable most commonly reported to assess postural instability however, current research indicates that identifying postural stability only through the magnitude of sway does not accurately reflect postural instability [10-12]. Recently, nonlinear analyses have been used to provide researchers more tools to describe the changes in a physiological time series thus providing a greater understanding of the motor control processes as a result of specific task demands [13,14]. Over the past several years, nonlinear analyses have been used to identify the different properties of change in motor control that are not reflected in traditional analyses [10-12,15]. While the purpose of this review is not to discuss all of those analyses that more appropriately assess stability, it is important to note that many of the studies investigating the impact of physical activity on posture have primarily used magnitude of sway as a measure of instability [16-20]. In the healthy sensorimotor system the control of posture is highly complex and reliant upon the interaction between the motor cortex, cerebellum, and basal ganglia, along with feedback provided from visual, vestibular, and somatosensory input [20-22]. The interactions between the sensory input enables human beings to stand upright for long periods of time, reach for an object while standing in one place, and provide the basis for locomotion [8]. Changes in the dynamics of posture are a result of the functional task which can be manifested at a variety of different levels of the system, from the cell to the muscle and individual segments [23]. Physical activity has been reported to immediately impact postural stability and under maximal exertion, up to 10 min after activity has ended [3]. Whether the amount of exertion during the activity is pushed to a level of fatigue to test the boundaries of the system [4,17,18] or enough to moderately perturb the system [15,24] to mimic daily activity, the impact on postural motion can last up to 10 min following cessation of the activity [3,4]. While young healthy adults have the ability to quickly adapt to immediate changes in postural control due to physical activity this could present challenges to individuals with balance impairments resulting from concussion, disease, or aging [25].

Postural Changes as a Result of Physical Activity

One of the byproducts of physical activity is muscular fatigue. Fatigue is commonly defined as the inability to maintain a required or expected force output [26], or as a transient decrease in the ability to perform physical activities [27]. Irrespective of the definition, the consequences of fatigue tend to be a decrement in movement output. Predictably, the rate of decline progresses during the course of the specified activity, with the overall rate of decline dependent on the type of activity, intensity, and duration [28,29].

Several studies have investigated the effects of muscle fatigue on quiet stance following some fatiguing event [2,29-33]. These include investigations on localized fatigue in the extensor muscles of the low back [29,31,34,35], ankle musculature [2,16,33,36,37], lower extremity muscles such as the quadriceps and hips [37-46], cervical muscles [32,47,48], and the shoulder [49]. In addition, changes in postural

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stability as a result of moderate levels of physical activity or those performed at or near maximal heart rate have also been investigated [15,18,24,50,51]. Numerous changes in the postural dynamics can be observed as a result of the effects of fatigue. This is partially due to changes in the somatosensory feedback and increased heart rate that result in deficits during quiet stance following exercise [5]. For example, localized fatigue in the distal muscles of the lower limb (e.g. tibialis anterior, gastrocnemius) has resulted in increased postural sway in both the Anterior-Posterior (AP) and Medial-Lateral (ML) directions and in sway velocity [2,16,17,33,36,37,52] thus placing greater demands on the postural control system to maintain quiet stance [17]. Muscular fatigue in the lumbar extensor muscles produced changes in body movements was evidenced by the adoption of a slight forward lean and increased joint angle variability at multiple joints [34,35]. Fatigue to the hip and knee flexor/extensor muscles and the ankle dorsiflexion/plantarflexion muscles produced an increase in COP velocity in the AP direction and fatigue to the hip and knee musculature produced an increase in COP velocity in the ML direction [2].

In addition to localized fatigue, whole body fatigue has been shown to impact optimal postural control. Aerobic activities performed at or near maximal heart rate elicited increased postural sway in healthy young adults during quiet stance. Nardone et al. had 8 young healthy adults walk on a treadmill with an incline that was increased to 14% while also increasing the speed to 5.5 kmh. Prior to treadmill walking, all subjects performed 10-52s quiet standing trials on a force plate under both eyes open and closed conditions. Following a 25 min walk the same amount of posture trials were collected. Trials collected immediately following the walking session had a 130-180% increase in both sway path and sway area than at baseline however, these changes did not last longer than 10-15 minutes following exercise [3]. This behavior was observed regardless of whether fatigue was induced by treadmill walking or ergometer cycling [3,4,18,50,51].

While high intensity activity has revealed changes in postural sway, previous work by Simoneau et al. reported that moderate fatigue induced by fast walking also resulted in an immediate increase in postural sway. However, these initial increases in COP motion gradually declined over three fatigue blocks, indicating that subjects were able to adapt their balance control to accommodate the fatigue effects [24]. Likewise, Thomas et al. found that changes in postural sway values taken at discrete time intervals following treadmill walking at 140% of Preferred Walking Speed (PWS) produced an increase in the amount, structure, and variability in the COP measures compared to baseline values. In subsequent trials following pre-walking assessments a leveling-off for specific COP variables (range, variability, and structure) and a decline in path length occurred even though measures of physical exertion (HR, RPE) continued to increase over the entire walking trial. Indicating that, despite the constant task demands induced by fast walking, the postural system was able to rapidly compensate and adjust appropriately [15].

Regardless of the postural task performed (one-legged stance, two-legged stance), muscles involved (proximal, distal), exercise type (aerobic, specific muscle groups), or visual input (eyes open, eyes closed) the presence of fatigue has a negative effect on the control of standing posture [2,4,15,17,24,51-53]. Nevertheless, even under conditions of maximal exertion, the changes in COP motion appear transient, gradually returning to baseline levels over time [15]. This decline is, in part, due to the ability of healthy young adults to adapt to the fatigue effects by appropriately scaling the amount/frequency of sway [3,4,54].

Postural Changes as a Result Of Physical Activity in Balance Impaired and Older Adults

How does this translate to those individuals with balance impairment as a result of injury, disease, or age? According to Egerton et al., physical activity that is similar to that experienced in daily living does not adversely impact dynamic postural stability in balance impaired or healthy older adults compared to young adults [55]. However, these results conflict with the findings of Alderton and Moritz, who found fatiguing exercise to the calf muscle resulted in detrimental effects on postural stability [25] during single-legged stance.

Fatigue conditions have also been shown to have negative effects on postural control in athletes with a history of ankle sprains. Steib et al. found that in an unfatigued state there was no difference in static and dynamic measures of postural control. Following treadmill running (approximately 14 min) to exhaustion (between 12 and 20 km/h) all postural control measures were negatively affected indicating that sensorimotor impairments are impacted long after the athlete has been returned to play [56]. Physical activity in athletes that have suffered sports related concussion has been noted to worsen the neurological symptoms associated with the injury [57]. Often, exercise is used to assess an athlete's ability to return to play. In this case, physical activity (moderate and high levels of intensity) places increased stress placed upon the central nervous system is often evidenced physically by a decline in postural control [58]. However, as stated earlier, the immediate impact of physical activity also reduces postural control in neurologically healthy individuals and should be taken into consideration when assessing athletes following competition.

Conclusion

Indeed physical activity is an important factor in reducing a large majority of lifestyle diseases (heart disease, stroke, cancer, and diabetes) and a regular exercise program is indicated to improve stability and reduce the risk of falls in the elderly and individuals with balance impairments. However dependent upon the amount and intensity of physical activity it can adversely impact postural control for up to 15 min after discontinuing activity. While this does not pose a problem to young healthy adults this factor should be taken into consideration when working with older adults or those with balance impairments.

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