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Lower limb kinematic variability in dancers performing drop landings onto floor surfaces with varied mechanical properties

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ABSTRACT

Elite dancers perform highly skilled and consistent movements. These movements require effective regulation of the intrinsic and extrinsic forces acting within and on the body. Customized, compliant floors typically used in dance are assumed to enhance dance performance and reduce injury risk by dampening ground reaction forces during tasks such as landings. As floor compliance can affect the extrinsic forces applied to the body, secondary effects of floor properties may be observed in the movement consistency or kinematic variability exhibited during dance performance. The aim of this study was to investigate the effects of floor mechanical properties on lower extremity kinematic variability in dancers performing landing tasks. A vector coding technique was used to analyze sagittal plane knee and ankle joint kinematic variability, in a cohort of 12 pre-professional dancers, through discrete phases of drop landings from a height of 0.2 m. No effect on kinematic variability was observed between floors, indicating that dancers could accommodate the changing extrinsic floor conditions. Future research may consider repeat analysis under more dynamic task constraints with a less experienced cohort. However, knee/ankle joint kinematic variability was observed to increase late in the landing phase which was predominantly comprised of knee flexion coupled with the terminal range of ankle dorsiflexion. These findings may be the result of greater neural input late in the landing phase as opposed to the suggested passive mechanical interaction of the foot and ankle complex at initial contact with a

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floor. Analysis of joint coordination in discrete movement phases may be of benefit in identifying intrinsic sources of variability in dynamic tasks that involve multiple movement phases.

1. Introduction

Dancers typically perform on floors that are constructed from a superficial layer of wood suspended over a substructure that will depress under load (Foley, 1991). These floor properties enable the dampening of ground reaction forces during dance movements (Laws, 2008) and are referred to by European standards BSEN 14808 (British Standards Institution, 2006a) and 14904 (British Standards Institution, 2006b) as force reduction [FR]. The premise for the use of these customized dance floors is that dancers require some form of extrinsic force dampening to reduce loading on the body given the large volumes of work required in dance training (Foley, 1991). In addition, dancers typically do not wear footwear that is capable of shock absorption as is commonly used in more mainstream forms of sport and exercise (Kadel, 2006). It is well established that humans can accommodate changes in floor properties, such as FR (Ferris, Liang, & Farley, 1999; Moritz & Farley, 2005; Moritz, Greene, & Farley, 2004). This phenomenon has recently been observed in dancers (Hackney, Brummel, Jungblut, & Edge, 2011; Hopper, 2011). However, Hopper (2011) reported that the adaptations to low FR floors demonstrated by dancers may destabilize the ankle joint within a short latency from contact with the floor. Subsequently, the adaptations of dancers to decreasing levels of floor FR have the potential to affect joint coordination and associated kinematic variability.

Stable human movement requires effective regulation of the complex intrinsic and extrinsic forces that act on the body. To date, the primary focus of research into kinematic variability has considered the effects of intrinsically generated forces in individuals with varied movement experience or clinical conditions (Stergiou & Decker, 2011). Little investigation has considered the effects on human kinematic variability of varied extrinsic conditions such as changing floor properties. Humans adapt leg mechanics to changes in floor mechanical properties during landings and locomotion, and these adaptations result in consistent ground reaction force dynamics (Ferris et al., 1999; Hackney et al., 2011; Hopper, 2011; Moritz & Farley, 2005; Moritz et al., 2004). If leg mechanics were maintained across varied surfaces, peak ground reaction forces would theoretically increase in conjunction with decreases in floor FR. By reducing floor FR, the individual performs more work and generates more torque within the lower limbs during landings or weight acceptance (Hopper, 2011; Kerdok, Biewener, McMahon, Weyand, & Herr, 2002). As increases in muscle force generation have been associated with increased kinematic variability (Jones, Hamilton, & Wolpert, 2002), the mechanical adaptations at the lower limbs as a result of landing on low FR floors may be associated with resultant increases in kinematic variability.

Elite dance performance requires the production of aesthetically pleasing and consistent movement patterns. More specifically, the technical requirements of classical ballet dictate very stringent planar joint ranges of motion, with little scope for kinematic variability (Royal Academy of Dance, 2008; Warren, 1989). The first analysis of kinematic variability demonstrated by experienced dancers has only recently been reported by Kiefer et al. (2011), who observed lower kinematic variability in a standing balance task in dancers as compared to controls. Dance training involves dedicated repetition of complex motor patterns in the interests of improving movement consistency. A concurrent reduction in kinematic variability theoretically improves a dancer's ability to reliably perform complex dance movements on demand. Expert dancers with high technical proficiency should therefore be capable of regulating segment kinematics in close proximity to the technical requirements of dance, with minimal kinematic variability, similar to that observed by Kiefer et al. (2011). Orishimo, Kremenic, Pappas, Hagins, and Liederbach (2009) also proposed that during landings, the consistent movement patterns used by dancers enhance adaptive reactions to perturbations from the floor, thereby reducing injury risk. However, recent enquiry into the potential value of kinematic variability for health and athletic performance has provided evidence suggesting that kinematic variability can be