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Neuromechanical adaptation induced by jumping on an elastic surface

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ABSTRACT

Jumping on an elastic surface produces a number of sensory and motor adjustments. This effect caused by jumping on the trampoline has been called “trampoline aftereffect”. The objective of the present study was to investigate the neuromuscular response related with this effect. A group of 15 subjects took part in an experimental session, where simultaneous biomechanical and electromyographic (EMG) recordings were performed during the execution of maximal countermovement jumps (CMJs) before and after jumping on an elastic surface. We assessed motor performance (leg stiffness, jump height, peak force, vertical motion of center of mass and stored and returned energy) and EMG activation patterns of the leg muscles. The results showed a significant increase ($p \leq 0.05$) of the RMS EMG of knee extensors during the eccentric phase of the jump performed immediately after the exposure phase to the elastic surface (CMJ₁), and a significant increase ($p \leq 0.05$) in the levels of co-activation of the muscles crossing the ankle joint during the concentric phase of the same jump. Results related with motor performance of CMJ₁ showed a significant increase in the leg stiffness ($p \leq 0.01$) due to a lower vertical motion of center of mass (CoM) ($p \leq 0.005$), a significant decrease in jump height ($p \leq 0.01$), and a significantly smaller stored and returned energy ($p \leq 0.01$). The changes found during the execution of CMJ₁ may result from a mismatch between sensory feedback and the efferent copy.

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1. Introduction

Adapting the stiffness of our musculoskeletal system to different surfaces is a daily process in our lives. For example, we adapt our musculoskeletal system during walking (MacLellan and Patla, 2006; Marigold and Patla, 2008), running (Ferris et al., 1998, 1999) and jumping (Ferris and Farley, 1997; Moritz and Farley, 2004, 2005). These adaptations can be explained by a simple biomechanical model, called “spring-mass model”, so that when the surface stiffness decreases, the stiffness of the legs is increased, and vice versa (Ferris and Farley, 1997). Studies have shown that sudden and unexpected changes in the stiffness of the surface result in adjustments in the dynamics of the passive properties of body segments that can accommodate the stiffness of the legs immediately [52 ms] (Moritz and Farley, 2004; van der Krogt et al., 2009). These changes in stiffness appear to be associated with perceptual changes. For example, it was found that after a brief exposure of repeated jumps on an elastic surface, subjects show sensory-motor changes when they jump again on a rigid

surface (Márquez et al., 2010). Repeated jumps on a trampoline cause an increase of the leg stiffness, a decrease of the height reached in the jump, an underestimation of the jump height and altered perceptual sensations, of the subsequent CMJ performed on the ground. The effects caused by jumping on the elastic surface have been called “trampoline aftereffect” (Márquez et al., 2010). Indeed, this phenomenon occurs even though the subjects are fully aware of the changes in the stiffness of the surface, suggesting the existence of a strong adaptive process.

The mechanism underlying the “trampoline aftereffect” remains unclear. Studies showing sensory and motor adaptations after the exposure to variations in the gravito-inertial force level (Lackner and Graybiel, 1980, 1981) have suggested that these effects are caused by a mismatch between the efferent copy and sensory feedback (Lackner and DiZio, 2000). This is an adaptive process that allows the generation of anticipatory motor commands to compensate for the changes occurring in the environment (Lackner and DiZio, 1994). Moreover, these adaptations have been linked to alterations in the discharge of the muscle spindles (Lackner and Graybiel, 1980, 1981), since they are essential for the limb position sense (Proske et al., 2000; Proske, 2005, 2006). Therefore, it is likely that the effect of repeated jumps on an elastic surface are associated with neuromuscular changes caused by the above mentioned factors.

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