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Slipping during side-step cutting: Anticipatory effects and familiarization

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ABSTRACT

The aim of the present study was to verify whether the expectation of perturbations while performing side-step cutting manoeuvres influences lower limb EMG activity, heel kinematics and ground reaction forces. Eighteen healthy men performed two sets of 90° side-step cutting manoeuvres. In the first set, 10 unperturbed trials (Base) were performed while stepping over a moveable force platform. In the second set, subjects were informed about the random possibility of perturbations to balance throughout 32 trials, of which eight were perturbed (Pert, 10 cm translation triggered at initial contact), and the others were "catch" trials (Catch). Center of mass velocity (CoM_{VEL}), heel acceleration (H_{AC}), ground reaction forces (GRF) and surface electromyography (EMG) from lower limb and trunk muscles were recorded for each trial. Surface EMG was analyzed prior to initial contact (PRE), during load acceptance (LA) and propulsion (PRP) periods of the stance phase. In addition, hamstrings-quadriceps co-contraction ratios (CCR) were calculated for these time-windows. The results showed no changes in CoM_{VEL}, H_{AC}, peak GRF and surface EMG PRE among conditions. However, during LA, there were increases in tibialis anterior EMG (30–50%) concomitant to reduced EMG for quadriceps muscles, gluteus and rectus abdominis for Catch and Pert conditions (15–40%). In addition, quadriceps EMG was still reduced during PRP ($p < .05$). Consequently, CCR was greater for Catch and Pert in comparison to Base

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($p < .05$). These results suggest that there is modulation of muscle activity towards anticipating potential instability in the lower limb joints and assure safety to complete the task.

1. Introduction

Human locomotion requires a complex integration of commands from many sources such as the brain, spinal cord, muscles and skin (Cappellini, Ivanenko, Dominici, Poppele, & Lacquaniti, 2010; Lacquaniti, Ivanenko, & Zago, 2012; Rossignol, Dubuc, & Gossard, 2006). Muscle recruitment during locomotion is constantly tuned to assure safe displacement, which relies on superior inputs from the vestibular system and peripheral information regarding muscle tension and joint positioning (Daley & Biewener, 2006; Duysens, Beerepoot, Veltink, Weerdesteyn, & Smits-Engelsman, 2008; Rossignol et al., 2006). In this way, it is possible to also rapidly react to unexpected perturbations to balance while walking or running.

Interestingly, there are other features of the central nervous system that may trigger protective motion patterns if locomotion deviates from what is anticipated. For example, Cappellini et al. (2010) have observed substantial changes in the walking pattern of healthy subjects while walking over a slippery surface. In addition, reduced ground reaction force, heel acceleration, flatter foot orientation and more vertical shank positioning are usual modifications of the gait pattern when expecting perturbations (Beschorner & Cham, 2008; Cham & Redfern, 2002; Marigold & Patla, 2002; Oliveira, Farina, & Kersting, 2012). Awareness of perturbations to balance also alters muscular activity (measured by electromyography, EMG) as an attempt to unconsciously provide a more cautious gait pattern, especially after experiencing perturbations (Bunday et al., 2006; Reynolds & Bronstein, 2003).

Although there are many protective mechanisms to avoid falls, these features are not sufficient to provide stability and/or protection during some sports gestures such as cutting manoeuvres which are intimately related to knee injuries, especially sprains and ligament ruptures (Alentorn-Geli et al., 2009; Drakos et al., 2010; Zebis, Andersen, Bencke, Kjær, & Aagaard, 2009). Previous investigations have shown that the activation of knee flexor muscles at initial contact may not be fast and strong enough for maintaining joint stability during an injury event (Oliveira, Silva, Lund, Gizzi, et al., 2013; Zebis et al., 2009). In addition, the EMG patterns of activation during unplanned cutting manoeuvres are different from planned tasks (Besier, Lloyd, & Ackland, 2003), suggesting that muscle recruitment to perform cutting manoeuvres is susceptible to alterations on various levels of the neuromuscular system. As a result of this, unexpected changes in the environment during cutting manoeuvres may lead to severe injuries. Indeed, unexpected perturbations to balance while performing cutting manoeuvres may reduce activation of knee flexors and consequently reduce knee stability shortly after perturbation onset (Oliveira, Silva, Lund, Gizzi, et al., 2013). However, little is known about the effects of anticipation on the performance of cutting manoeuvres that might be perturbed.

It has been suggested that protective mechanisms to maintain balance are formed by experiencing previous perturbations, allowing optimized proactive strategies for safer displacement (Cappellini et al., 2010; Marigold & Patla, 2002; Oliveira et al., 2012; Parijat & Lockhart, 2011). Therefore, the aim of the present investigation was to verify whether anticipation of perturbations while performing cutting manoeuvres influence lower limb EMG activity, heel kinematics and forces applied to the ground. We hypothesized that specific changes in loading, kinematics and lower limb muscle activity are triggered by expecting perturbations to balance during the execution of side-step cutting movements. The results from this investigation may have implications for the understanding of protective mechanisms during unexpected and expected perturbations to balance while performing sports gestures.