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How does lower limb dominance influence postural control movements during single leg stance?

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ABSTRACT

The main purposes of the current study were to examine bilateral asymmetry in postural control during single-leg standing between the dominant and non-dominant legs using a novel analysis approach based on principal component analysis (PCA). It was hypothesized that the asymmetry might manifest as differences in the coordinative structure (control strategies), or as differences in the frequency or regularity of corrective interventions of the motor control system. The static and dynamic leg dominance of 26 active young adults (14 males and 12 females) was determined from their preferred leg for dynamic and for static tasks. Then postural movements during one-leg standing were recorded with a standard marker-based motion capture system and analyzed by a PCA. The coordinative structure of postural movements was quantified using the relative variance of the principal movement components (PMs). Then the PMs were differentiated to obtain postural accelerations, from which two variables characterizing the activity (frequency and regularity) of the postural control system were derived. There were no differences in the coordinative structure, neither for dynamic nor for static leg preference. However, both variables characterizing asymmetries in the postural accelerations showed significant differences in specific PMs. Dynamic leg dominance yielded more and larger effects than static leg dominance. In the opinion of the authors, the PM-specificity of limb dominance agrees with principles of movement control derived from optimal feedback control theory. In summary, the current study suggests that leg dominance should be considered in clinical testing; different effects in different movement components should be expected; and one-leg standing should be seen as a dynamic, rather than as a static task.

1. Introduction

Leg dominance is an important factor in many lower limb functions, whether in sports or in every-day tasks, and there are also some indications that it may influence injury rates (Beynnon et al., 2006; Brophy et al., 2010; Ruedl et al., 2012). Consequently, leg dominance is often considered in orthopedic or physiotherapeutic practice and testing and in many sports it is specifically addressed in technique training.

Usually, a difference in performance between the two legs, or simply the individual leg preference is used to define the dominant and non-dominant leg (McGrath et al., 2016; Velotta, Weyer, Ramirez, Winstead, & Bahamonde, 2011). In many humans the dominant leg is not as distinct as the dominant hand (Cuk, Leben-Seljak, & Stefancic, 2001), however, the question "what leg would you chose for kicking a ball" will in most cases result in a clear answer (McGrath et al., 2016). The leg not chosen is then often

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characterized as the “stance leg”, however, when asked what leg they would prefer for one-leg standing, many people will still prefer the same leg as the “kicking leg” (Huurnink, Fransz, Kingma, Hupperets, & van Dieën, 2014; Velotta et al., 2011).

Upper limb dominance is often attributed to cerebral hemispheric asymmetry and it has been suggested that each hemisphere/limb is specialized to different functions: the dominant system for controlling trajectory dynamics, the non-dominant limb for controlling limb positioning (Sainburg, 2005). Lower limb laterality also has been shown to associate with different activation characteristics in the primary sensorimotor cortex and the basal ganglia (Kapreli et al., 2006). If differences in sensorimotor control are responsible for limb dominance, then one would expect to observe differences in the movement characteristics between the dominant and non-dominant limb. For example, in one-leg standing such differences could manifest in the between-limb coordination, i.e. as differences in the utilization of different balancing strategies. Or the differences in sensorimotor control could manifest as difference in temporal aspects of the movement, for example, in the frequency or regularity of neuro-muscular interventions correcting the movement trajectories (Haid & Federolf, 2018). Differences in sensorimotor control due to leg dominance, however, seem to be difficult to detect. In fact, many previous studies investigating various motor control variables were not able to identify effects of limb dominance. For example, several previous studies determined various variables characterizing the center of pressure COP movement, for example, sway area (Hoffman, Schrader, Applegate, & Koceja, 1998), standard deviation (King & Wang, 2017), total path length (Hoffman et al., 1998; King & Wang, 2017), speed (Huurnink et al., 2014; King & Wang, 2017), 95% ellipse area (King & Wang, 2017), however, none of these studies found a significant difference between the preferred and non-preferred leg during one-leg standing. In the study of Gstöttner et al (2009), three different balance stability assessment systems were used, the Biodex Stability System, a multiaxial tilting platform with visual feedback; the Tetrax System, a system detecting pressure fluctuations on heel and toe plates underneath the foot; and the Equitest system, which determines center of gravity position with respect to the limits of stability when standing on a platform that exposes the volunteer to sudden horizontally movement perturbations (Gstöttner et al., 2009). Also Alonso, Brech, Bourquin, and Greve (2011) utilized the Biodex Stability System when assessing one leg standing in sedentary adults; however, neither Gstöttner and colleagues nor Alonso and colleagues could detect differences between the preferred and non-preferred leg (Alonso et al., 2011; Gstöttner et al., 2009). A common aspect of all variables determined in these studies is that some form of movement amplitude is assessed. However, the movement amplitude may not necessarily be a suitable variable for characterizing differences in movement control. It may very well be the case that resultant movement amplitudes when standing on the dominant or non-dominant leg are similar, while the control of the movement differs.

In the current study, a novel approach to investigating postural movements during one-leg standing was applied: a principal component analysis (PCA) applied on kinematic marker data (Daffertshofer, Lamoth, Meijer, & Beek, 2004; Federolf, Roos, & Nigg, 2012; Troje, 2002). This analysis allows not only to study the coordination structure of a complex whole-body movement (Lee, Liu, & Newell, 2016; Wang, O’Dwyer, Halaki, & Smith, 2013; Zago, Pacifici, et al., 2017; Zago, Codari, Iaia, & Sforza, 2017) by decomposing the movement into one dimensional movement components (principal movements, PMs), but also to create animated movement components that closely resemble postural control strategies, such as ankle or hip strategies (Federolf, 2016; Federolf, Roos, & Nigg, 2013). Furthermore, calculating the second time-derivative of these movement components (principal accelerations, PAs) provides a set of variables that directly quantify how postural movements are controlled (Federolf, 2016). In a recent paper we introduced two new variables based on the PA time series that characterize how tightly and how regularly the postural movement components are controlled and found that these variables were affected by ageing (Haid, Doix, Nigg, & Federolf, 2018). Therefore, in the current study we speculated that analyzing the characteristics of the PMs and PAs during one-leg stance would reveal differences in the neuromuscular control due to leg dominance.

In summary, the main purposes of the current investigation were to examine bilateral asymmetry in postural control during single-leg standing between the dominant and non-dominant legs. We hypothesized that the asymmetry might manifest as differences in the coordinative structure (control strategies) (H1), or as differences in the frequency or regularity of corrective interventions of the motor control system (H2). We also tested for sex differences and interaction effects between leg preference and sex.

Table 1
Characteristics of participants (mean ± SD).

	Male (n = 14)	Female (n = 12)	*p*-value
Age (yrs.)	25.8 ± 2.9	24.6 ± 5.3	0.478
Weight (kg)	77.5 ± 10.8	62.6 ± 4.9	< 0.001*
Height (m)	180.0 ± 7.2	169.2 ± 4.3	< 0.001*

* Denotes significant difference.