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Methodological requirement to analyze biomechanical postural control mechanisms with two platforms

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ABSTRACT

In 1996, Winter and colleagues proposed the existence of two postural control mechanisms in both the anteroposterior and mediolateral axes: a bodyweight (loading/unloading) distribution mechanism and a complementary center of pressure location mechanism. To measure the loading/unloading forces under each foot, the feet had to be placed side by side in the mediolateral axis and one foot ahead of the other in the anteroposterior axis. Our first objective was to reexamine the validity of anteroposterior data published with the feet side by side. In that foot condition, we expected no change in the anteroposterior loading/unloading forces (regardless of the task performed), and consequently no change in the complementary mechanism. Our second objective was to confirm our hypotheses with experimental data. Twelve healthy, young adults performed three types of body oscillation in the anteroposterior axis (at the hips, at the ankles and alternately at the ankles and hips) and a quiet stance condition with the feet side by side. As expected, the bodyweight mechanism did not vary significantly. Although the complementary mechanism was significantly higher in the ankle and alternating conditions, the change was very tiny (<0.3%). Thus, we propose methodological requirements to analyze both mechanisms.

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1. Introduction

In stance, individuals sway all the time (Winter, 1995) but rarely fall. Since the mid-19th century, researchers have sought to understand how postural control operates, with a view to improving quality of life, preventing falls and creating humanoid robots. Two decades ago, Winter and colleagues (Winter, Prince, Frank, Powell, & Zabjek, 1996; Winter, Prince, Stergiou, & Powell, 1993) showed the existence of a mediolateral (ML) loading/unloading mode of coordination consisting of loading the bodyweight under one foot and thus unloading the bodyweight under the other. This mechanism seemed to act at the proximal level by using lateral hip muscles (Winter et al., 1993, 1996). This postural mechanism can be referred to as the bodyweight distribution mechanism or the loading/unloading distribution mechanism. The other ML mechanism, the center of pressure (COP) location mechanism, was assumed to act at the ankle level through inversion/eversion. This mechanism is performed by changing the COP location under the left and right foot. Both bodyweight distribution and COP location mechanisms are necessary and complementary in explaining different proportions of COP displacement (Winter et al., 1993, 1996; cf. equations in the Method).

In order to measure ML loading/unloading forces, Winter et al. (1993, 1996) clearly explained the need to have a ML foot-platform pair, that is two feet and two platforms side by side (Fig. 1A). With only one platform, it would not be possible to measure two vertical reaction forces and two center of pressure displacements, one under each foot. Winter et al. (1996) extended the existence of a loading/unloading mechanism to the anteroposterior (AP) axis. Logically, the AP loading/unloading mechanism has to be measured separately, using another foot-platform pair (forward and backward platforms and the feet in the Tandem Romberg position; Fig. 1B; cf. Winter et al., 1996). Therefore, based on these theoretical arguments, the ML loading/unloading of each foot cannot be measured in the Tandem Romberg (TR) foot position. Similarly, the AP loading/unloading forces under each foot cannot be measured with the feet side by side. In other words, to measure the loading/unloading forces under each foot, the feet need to be side by side in the ML axis (Fig. 1A) and one foot ahead of the other in the AP axis (Fig. 1B). Therefore, if both the ML and the AP COP loading/unloading forces have to be calculated accurately in the same trial, the only possible foot position may be the semi-tandem or 45° condition (Fig. 1C) with no overlap between the feet. For all these reasons, we do not understand why Lafond, Corriveau, and Prince (2004), Rougier (2007, 2008), Termoz et al. (2008) and Winter et al. (1993, 1996) calculated the AP contribution of the bodyweight distribution mechanism with the feet side by side (Fig. 1A). How can the loading of the forward foot be measured separately from the unloading of the backward foot with no foot ahead of the other? What are the "forward" foot-platform and "backward" foot-platform pairs in that side-by-side condition?

In the present study, we did not contest the validity of Winter et al.'s (1993, 1996) bodyweight distribution and COP location mechanisms. Our primary objective was to question the validity of AP loading/unloading results published with the feet side by side and to discuss a relevant methodology to measure and compute these mechanisms. Our primary hypothesis was that the computation of AP

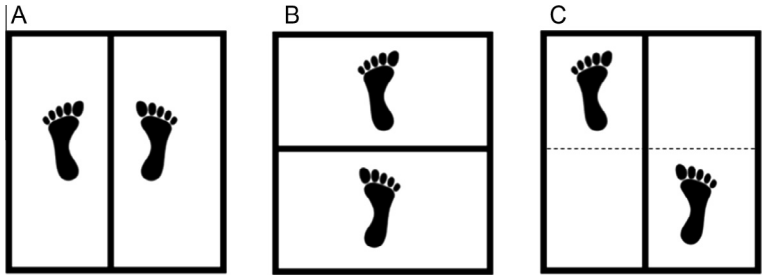

Fig. 1. (A) Representation of the foot position on each of two adjacent force platforms; (B) representation of the foot position with one platform forward and one platform backward; (C) representation of the 45° condition in which one foot is strictly ahead of the other and one foot is strictly to the right of the other. The feet can be placed on two (or four) adjacent force platforms.