Influence of temporal pressure constraint on the biomechanical organisation of gait initiation made with or without an obstacle to clear

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E. Yiou[a], P. Fourcade[a], R. Artico[a] and T. Caderby[b]

[a]CIAMS Laboratory, EA 4532, UFR STAPS, University of Paris-Sud, Orsay, France; [b]DIMPS Laboratory, EA 4075, UFR STAPS, University of La Réunion, Saint Denis, France

1. Introduction

Many daily motor tasks have to be performed under a temporal pressure constraint. This study aimed to explore the influence of such constraint on motor performance and postural stability during gait initiation made with or without an obstacle to be cleared.

Gait initiation, which corresponds to the transient period from an upright stance to steady-state walking, is a classical paradigm for studying the coordination between posture, equilibrium and movement. It is composed of a postural phase ending at swing heel-off, during which dynamic phenomena called 'anticipatory postural adjustments' (APA) are developed, followed by step execution phase ending at the time when the swing foot touches the ground (Brenière et al. 1987). These APA are manifested as a backward and lateral center-of-pressure (CoP) shift towards the swing-leg side, which promotes centre-of-mass acceleration in the opposite direction, i.e. forwardly and towards the stance-leg side. APA dynamics along the mediolateral (ML) direction is known to be predictive of postural stability reached at the end of gait initiation (Caderby et al. 2014), while APA dynamics along the anteroposterior direction is predictive of motor performance, in term of peak centre-of-mass velocity (Brenière et al. 1987).

Recent studies have shown that temporal pressure constraint influences the temporo-spatial features of APA associated with leg flexion from the erect posture tasks (Yiou et al. 2012, 2014; Hussein et al. 2013). Specifically, APA duration was shorter in the condition with a high temporal pressure (the leg flexion was triggered in a reaction-time [RT] condition) as compared to condition with a low temporal pressure (the leg flexion was self-initiated [SI]); this shortening was compensated by an increase in the peak of anticipatory ML CoP shift so that the dynamic conditions required to maintain stability in the final posture could be reached. The question of whether the central nervous system (CNS) is able to develop similar adaptive strategy during more functional and more complex tasks involving a whole-body progression such as in gait initiation made with or without an obstacle to be cleared remains to be explored. The present study tested the hypothesis that the CNS is able to adapt the temporo-spatial features of APA along the ML and AP directions to high temporal pressure constraint so as to maintain both motor performance and postural stability unchanged compared to the condition with low temporal pressure.

2. Methods

Ten healthy young adults performed series of gait initiation in two blocks of conditions: a RT and a SI block. Gait was initiated at maximal velocity, under two conditions of environmental constraint, i.e. in the presence (obstacle condition) or absence (no-obstacle condition) of an obstacle placed in front of the participant. Gait was initiated on a force-plate located at the beginning of a five-meter track. A V8i VICON eight-camera motion capture system was used to record heel and toe movement of swing and stance leg and to detect the position of the obstacle. Classical biomechanical variables related to gait initiation (APA amplitude/duration, step execution duration, step length etc.) were quantified. Motor performance was expressed in term of AP centre-of-gravity velocity at swing foot contact. An adaptation of the 'margin of stability' (MOS) introduced by Hof et al. (2005) was used to quantify ML dynamic stability at

CONTACT R. Artico romain.artico@u-psud.f

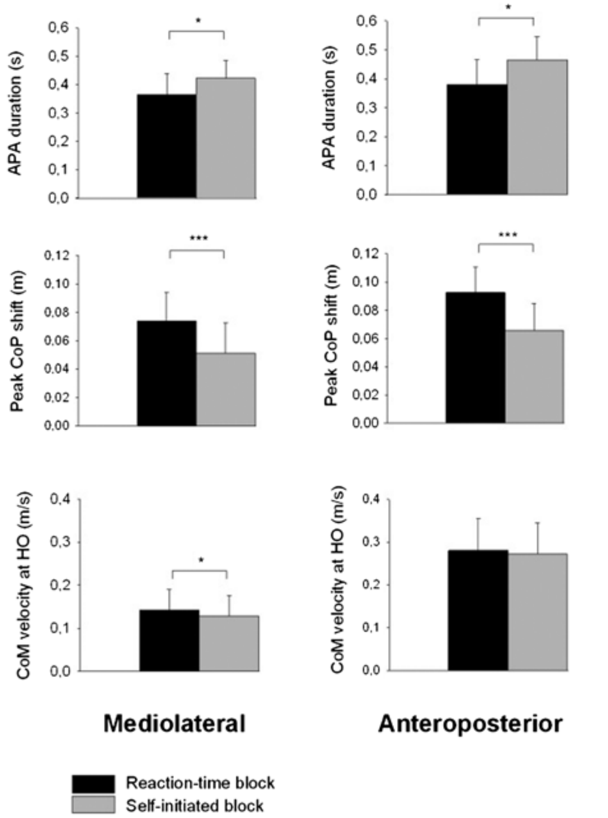

Figure 1. Main effect of the temporal pressure constraint on selected temporo-spatial parameters of APA. HO: swing heel-off. CoM, CoP: centre of mass, centre of pressure.
Notes: Bars are means ± one standard deviation (all participants combined). *, ***: significant main effect of the temporal pressure constraint with $p < 0.05$ and $p < 0.001$.

heel contact (Caderby et al. 2014). In the present study, the MOS corresponded to the difference between the ML boundary of the base of support and the ML position of the 'extrapolated centre of mass' (Hof et al. 2005) at swing heel-contact. A [2 temporal pressure constraint × 2 environmental constraint] ANOVA with repeated measures on each factor was used to test differences between mean values of biomechanical variables.

3. Results and discussion

The duration of APA along both the ML ($F[1,9] = 9.15$, $p < 0.05$) and AP direction ($F[1,9] = 16.19$; $p < 0.01$) was shorter in the RT block compared to the SI block. In contrast, ML APA ($F[1,9] = 75.54$, $p < 0.001$) and AP APA amplitude ($F[1,9] = 83.28$; $p < 0.001$), in terms of anticipatory peak CoP shift, increased (Figure 1). This increase allowed participants to reach equivalent postural stability and motor performance in both RT and SI blocks. In addition, the duration of the execution phase of gait initiation increased greatly in the condition with an obstacle to be cleared (OBST) compared to the condition without an obstacle (NO OBST; ($F[1,9] = 108.02$, $p < 0.001$), thereby increasing lateral instability and thus, involving larger ML APA ($F[1,9] = 49.05$, $p < 0.001$). However, similar effects of temporal pressure were obtained in the NO OBST and OBST conditions.

The present study shows that the CNS is able to adapt the features of APA associated with gait initiation made with and without environmental constraint to temporal pressure so as to hasten swing foot-off and keep both postural stability and motor performance invariant.

4. Conclusion

These results suggest that it might be possible to generalise the postural system's ability to adapt to temporal pressure – which was previously outlined during a leg flexion task (Yiou et al. 2012, 2014; Hussein et al. 2013) – to more complex and more common motor tasks of daily living, such as gait initiation made with or without an obstacle to be cleared. This study was carried out in young active adults. It will serve as a basis for future studies in the elderly in the perspective to provide a better understanding of the aetiology of lateral balance impairments with a risk of falling while performing daily tasks involving whole-body progression.

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