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Does an additional load modify the Anticipatory Postural Adjustments in gait initiation?

Teddy Caderby^{a,*}, Georges Dalleau^a, Pierre Leroyer^a, Bruno Bonazzi^a, Daniel Chane-Teng^b, Manh-Cuong Do^c

^a CURAPS-DIMPS, UFR des Sciences de l'Homme et de l'Environnement, Université de la Réunion, 97430 Le Tampon, Ile de la Réunion, France

^b Centre Ylang Ylang Réadaptation Fonctionnelle Jeanne d'Arc, 97420 le Port, Ile de La Réunion, France

^c Laboratoire CIAMS, UR 4532, UFR STAPS, Bât 335, Université Paris-Sud, 91405 Orsay Cedex, France

A B S T R A C T

The objective of the study was to examine whether and how an additional load affects the Anticipatory Postural Adjustments (APA) in gait initiation in able-bodied individuals. Nineteen healthy participants initiated gait at a self-selected speed in two conditions: unloaded and with an overload of 15% body weight. The APA duration, the forward impulse of the APA and the duration of gait initiation increased significantly with the overload, while the other variables did not change. These results indicate that, during gait initiation with overload, able-bodied subjects modulate the APA duration to produce a higher forward impulse in order to achieve the steady-state gait at the end of the first step. These findings could have implications in clinical practice where overloading could be used to improve the gait initiation in pathologic patients. Further investigations are needed to confirm this suggestion.

1. Introduction

Gait initiation is the transition between the upright posture and the steady-state gait. This process consists of two phases, namely, a postural phase (called Anticipatory Postural Adjustments (APA)) followed by an execution phase [1]. The APA contribute to postural stability [2] and create the propulsive forces necessary to reach the steady-state gait at the end of the first step [1,3].

It is known that load carriage alters the postural control mechanisms in quiet standing [4] and affects the balance during walking [5], but its effect on postural control in gait initiation is unclear. To the best of our knowledge, though a recent study has shown that body weight affects gait initiation [6], the effect of an external load on this process has not yet been investigated. Gait initiation with an additional mass should require higher propulsive forces that could affect the APA organization. A better understanding of the effect of load on APA in gait initiation could have

implications for the rehabilitation of gait initiation problems in patient populations (e.g., Parkinsonian patients [7,8]).

The objective of the study was to examine whether and how an additional load affects the APA in gait initiation in able-bodied adults.

2. Methods

Nineteen healthy subjects (mean age 20.3 ± 1.1 years, height 176 ± 8 cm, weight 70 ± 10 kg) participated in the experiment. All participants gave their consent after being fully informed of the test procedure approved by the Institutional Ethics Committee.

Two force-plates (400 mm \times 600 mm, AMTI, USA) embedded in series in a five-meter walkway recorded the ground reaction forces and moments at 1000 Hz. An optoelectronic system (VICON 460, UK) collected the spatial data of two skin markers placed at the subject's heels (200 Hz). All signals were synchronized and transmitted to an acquisition system.

Subjects stood upright, barefoot and as still as possible on the first force-plate. The position of the feet was marked on this force-plate so that the subjects kept the same position for each trial. At the experimenter's signal, they walked at a self-selected speed to the end of the walkway. The swing leg was self-selected and remained the same during all the trials. Six trials were performed without overload (UC) and with an overload (OC). The order of the conditions was randomized across subjects. Familiarization trials were provided in each load condition. A three-minute rest was imposed between conditions. Fig. 1 represents the experimental setting.

The overload was placed at the height of the body center of mass and consisted of a diving belt to which weights were added symmetrically with respect to the frontal and sagittal planes to reach the desired loading. The chosen overload mass was

* Corresponding author at: CURAPS-DIMPS, UFR des Sciences de l'Homme et de l'Environnement, Université de la Réunion, 117 rue du Général Ailleret, 97430 Le Tampon, Ile de la Réunion, France. Tel.: +262 2 62 57 95 91; fax: +262 2 62 57 95 71.

E-mail addresses: teddy.caderby@univ-reunion.fr, caderby.t@hotmail.fr (T. Caderby)

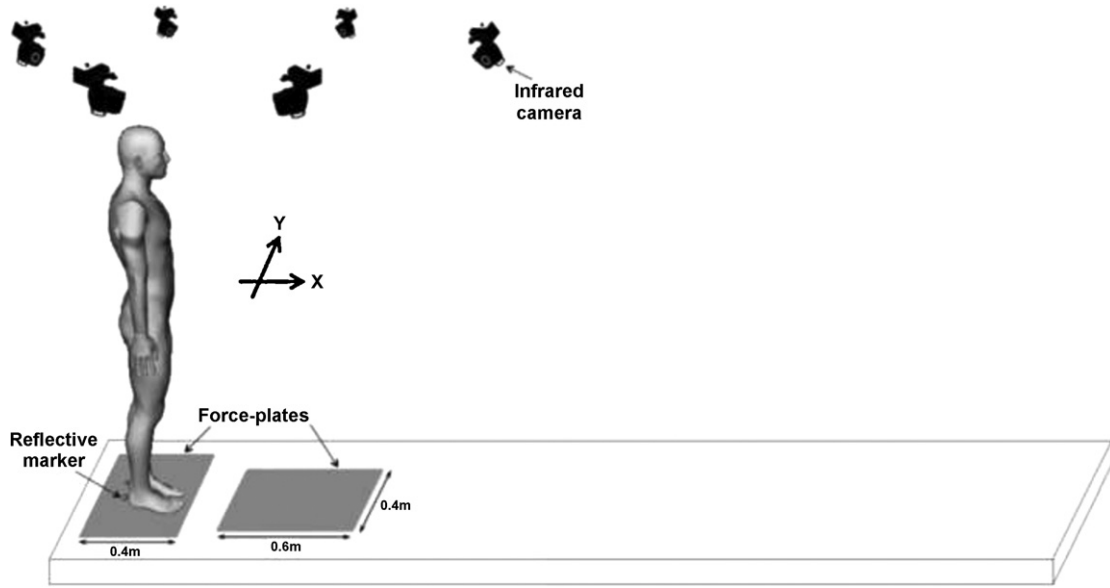


Fig. 1. Schematic illustration of the experimental set up.

fifteen percent of the subject's body mass as this magnitude has been shown to affect gait kinematics [9].

The anteroposterior Center of Gravity (CG) velocity and coordinates of Center of Pressure (CP) were calculated from the force-plate data [10]. The heel-off occurrence of the swing limb was determined from the kinematics of the heel marker [11]. Seven dependent variables were calculated (Fig. 2):

- APA duration (D_{APA}), i.e. time between the onset of the first dynamic phenomena (t_0) [12] and the heel-off of the swing limb (t_{HO}).
- Anteroposterior CG velocity at t_{HO} (V_{HO}).
- Maximal backward shift of CP during the APA (xP_{max}).
- Forward impulse of the APA (Imp_{AP}), calculated by integrating the anteroposterior ground reaction force during the APA period.
- Anteroposterior peak velocity of CG at the end of the first step (V).
- Duration of step execution (D_{EXE}), i.e. time between t_{HO} and the time to reach V (t_V).
- Duration of gait initiation (D_{GI}), i.e. the sum of D_{APA} and D_{EXE} .

The effect of the overload on the dependent variables was evaluated by using a Student's t -test for paired samples. A statistical significance level at $P < 0.05$ was chosen.

3. Results

All results are summarized in Table 1. The APA duration ($t = -2.250$, $P = 0.037$), the forward impulse of the APA ($t = -4.377$, $P < 0.001$) and the duration of gait initiation ($t = -2.230$, $P = 0.039$)

Table 1
Mean and standard deviation of the dependent variables in unloaded (UC) and overloaded (OC) conditions.

Parameters	UC	OC	P-value
D_{APA} (ms)	536 ± 75	573 ± 72	$P = 0.037$
V_{HO} ($m s^{-1}$)	0.22 ± 0.06	0.22 ± 0.05	
xP_{max} (mm)	-20 ± 15	-19 ± 11	
Imp_{AP} (Ns)	10 ± 5	13 ± 5	$P < 0.001$
V ($m s^{-1}$)	1.22 ± 0.15	1.21 ± 0.10	
D_{EXE} (ms)	705 ± 76	709 ± 72	
D_{GI} (ms)	1241 ± 101	1281 ± 81	$P = 0.039$

D_{APA} , APA duration; V_{HO} , anteroposterior velocity of CG at heel-off of the swing limb; xP_{max} , maximal backward shift of CP during the APA; Imp_{AP} , forward impulse of the APA; V , anteroposterior peak velocity of CG at the end of the first step; D_{EXE} , duration of step execution; D_{GI} , duration of gait initiation.

increased significantly with the overload. There was no significant effect of the overload for the other variables.

4. Discussion

The addition of the overload did not modify the initial coordinates of CP indicating that it did not affect the weight distribution on each leg. We did observe that the overload induced an increase in the APA duration. This result was associated with a higher forward impulse of the APA (Imp_{AP}) in OC than in UC. Previous studies have shown that a higher Imp_{AP} may be obtained by increasing the maximal backward shift of CP (xP_{max}) [13] and/or the APA duration [14]. In the current study, since xP_{max} did not vary, the increase of Imp_{AP} in OC may be ascribed to the lengthening of the APA. This APA adaptation allowed for the maintenance of the anteroposterior CG velocity at heel-off and hence the gait velocity at the end of the first step during gait initiation with overload.

As the duration of step execution did not vary, the lengthening of the APA caused an increase of the duration of gait initiation (D_{GI}) in OC. Previously, Colné et al. [6] showed that the APA and gait initiation durations did not differ between obese and normal adolescents. These disagreeing results could be because of the type of overloading (body overweight vs. external load) and of the gait velocity that was different between the obese and normal adolescents. Though it is known that the duration of gait initiation depends on anthropometric characteristics of the subjects [15], the increase of D_{GI} in the current study was attributed to the need to produce a greater impulse with the overload.

The present results underline that overloading challenges the propulsion that could be exacerbated in pathologic patients. Constraint-induced therapy, e.g. based on walking training with an additional load, is already conducted to improve gait in Parkinsonian patients [7,8]. As overloading influences the APA, it could be interesting to verify the APA adaptation of Parkinsonian subjects under overload.

In conclusion, during gait initiation with overload, able-bodied subjects modulate the APA duration to produce a higher forward impulse in order to achieve the steady-state gait at the end of the first step. These findings could have implications in clinical practice where overloading could be used to improve gait initiation

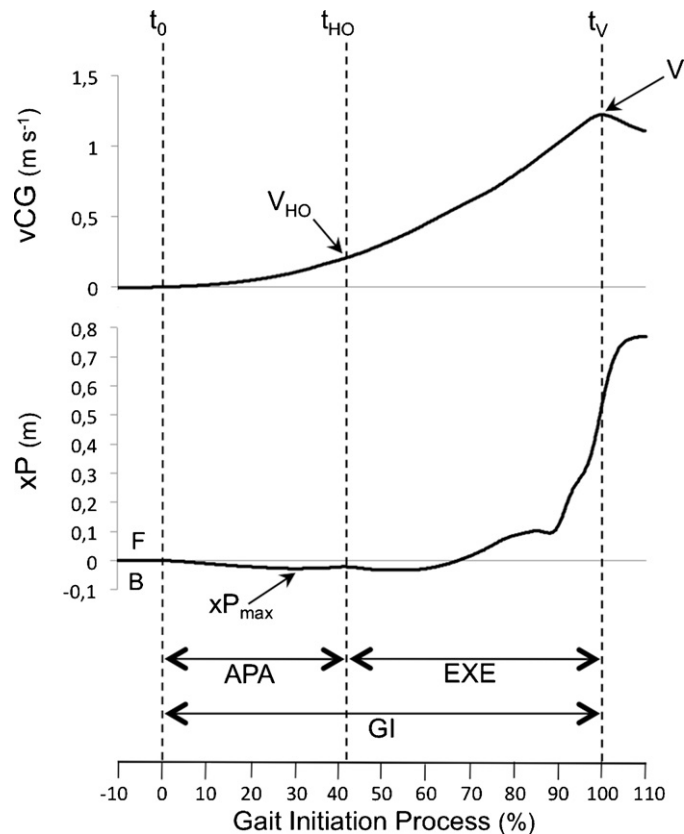


Fig. 2. Illustration of the dependant variables. The displayed traces correspond to mean curves obtained for gait initiation without overload. vCG is the anteroposterior velocity of CG; xP is the anteroposterior displacement of CP. t_0 , t_{HO} , t_v were the onset variation of the xP trace from the baseline, heel-off instant, and end of gait initiation, respectively. F and B indicate forward and backward, respectively. APA, EXE, GI indicate Anticipatory Postural Adjustments, step execution and gait initiation phases, respectively. V_{HO} , V and xP_{max} : anteroposterior velocity of CG at heel-off, anteroposterior peak velocity of CG at the end of the first step, maximal backward shift of CP during the APA, respectively.

in pathologic patients. Further investigations are needed to confirm this suggestion.

Conflicts of interest statement

None of the authors have financial or other conflicts of interest in regards to this research.

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