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ORIGINAL ARTICLE/ARTICLE ORIGINAL

Biomechanical mechanisms and centre of pressure trajectory during planned gait termination

Mécanismes biomécaniques et trajectoire du centre des pressions durant l'arrêt de la marche

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KEYWORDS
Gait termination;
Trajectory;
Centre of pressure

Summary
Aim. — Although gait initiation has been extensively studied, gait termination has received less attention. In particular, the trajectory of the centre of pressure (CoP) during gait termination, as well as the trajectory's determinants, has not yet been described. The purpose of the present study was to characterize the kinetic components of planned gait termination (including the CoP trajectory) with respect to the various gait events and centre of mass speed and trajectory.
Methods. — Thirty healthy subjects were asked to walk along a test track and stop on a force platform while an optoelectronic system recorded temporal and spatial parameters. A total of 90 trials were analysed.
Results. — Subjects needed two steps to stop on the force platform. The CoP trajectory during gait termination was composed of three phases. During the first phase, the CoP moved forward under the stance foot, which was in contact with the ground. The ground reaction forces exerted a sagittal braking action. The second phase showed a lateral CoP shift and was correlated with braking; this may correspond to anticipatory postural adjustments for gait termination. The third and last phase might correspond to compensatory adjustments before the stance phase.

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Conclusions. — CoP trajectory is more complex during gait termination than during gait initiation. Gait termination comprises several specific sequences in the gait-stance transition. A better understanding of the kinetic parameters in gait termination should enable us to identify which kinetic parameters could be considered as risk factors for falls.

MOTS CLÉS
Arrêt de la marche ;
Trajectoire ;
Centre des pressions

Résumé
But de l'étude. — Alors que l'initiation de la marche est souvent décrite dans la littérature, ce n'est pas le cas de l'arrêt de la marche. En particulier, la trajectoire du centre des pressions (CdP) durant l'arrêt de la marche et ses déterminants n'ont pas encore été réellement étudiés. Le but de cette étude était de décrire les caractéristiques cinétiques de l'arrêt de la marche (en particulier la trajectoire du CdP) en fonction des différents événements cinématiques de marche (décollage et contact des pieds) et de la vitesse et trajectoire du centre de masse.
Méthodes. — Trente sujets sains étaient enregistrés par un système opto-électronique alors qu'ils marchaient et s'arrêtaient sur une plate-forme de forces. Il était demandé au sujet de s'arrêter avec les deux pieds sur la plate-forme de forces. Quatre-vingt-dix essais ont été analysés.
Résultats. — La trajectoire du CdP lors de l'arrêt comprenait trois phases. Durant la première, le CdP se déplaçait vers l'avant sous le pied en appui sur le sol. Les forces de réaction au sol exerçaient alors un freinage sagittal. Durant la seconde, le CdP se déplaçait latéralement et était également corrélé au freinage ; en relation avec de probables ajustements posturaux anticipés lors de l'arrêt. La troisième phase correspondait à une phase d'ajustements tardifs immédiatement avant la phase posturale.
Conclusions. — La trajectoire du CdP lors de l'arrêt apparaît plus complexe que lors de l'initiation de la marche. Une meilleure compréhension des aspects cinétiques de l'arrêt de la marche devrait nous permettre d'identifier quels paramètres cinétiques pourraient être considérés comme facteur de risque de chutes.

Introduction

Most locomotion studies in humans have concentrated on steady-state gait or gait initiation. In contrast, the mechanism of gait termination has received less attention. Gait termination corresponds to the transition from rhythmic, repetitive gait to a complete stop [9]. Some aspects of gait termination have already been investigated, such as leg muscle activation during stopping [1,2,4], the braking impulse [1], and various gait termination programmes [6]. Although these phenomena have been well described, the kinetic aspects of gait termination (such as the trajectory of the centre of pressure [CoP]) are still poorly known. Moreover, most previous gait termination gait studies have focused on unplanned stopping [14] and so kinetic studies have been often confined to the analysis of ground reaction forces. In most published studies [14], subjects were instructed to stop without warning [8] and in response to an external signal given at various phases of the gait cycles. These conditions do not correspond to normal gait termination. In contrast, intentionally planned stopping has received less attention [14] and is of particular interest in certain neurological diseases. For example, patients with Parkinson's disease are known to have difficulty to terminate locomotor activity [1].

Three studies briefly described the CoP trajectory during planned stopping but did not examine trajectory's determinants, ground reaction forces or relationship with kinematic parameters [9,11,13]. The CoP trajectory displayed forward displacement followed by lateral displacement [9,11,13]. This trajectory has been considered to be the reverse of the CoP trajectory during gait initiation, in which the CoP shifts backward and towards the swing limb during an anticipatory postural adjustment [10]. The correspondence between the CoP trajectory and the various kinematic and kinetic events (such as the final steps) remains to be established. In particular, the times of occurrence of key gait events (e.g. foot-off and foot contact) during this trajectory are not known [9,11,13]. The kinetic determinants of this CoP trajectory (such as the braking forces that are activated to permit gait termination and the achievement of a stable, upright stance) could also be analysed. Therefore, we decided to address all these various aspects of planned stopping and hypothesized that the various phases of the CoP trajectory during gait termination would reflect different components of these braking forces.

Methods

Participants

Thirty healthy volunteers (16 men and 14 women) participated in the study after giving informed consent. The mean (± standard deviation) age was 43 (±22) years and the mean height was 171 (±11) cm. None of the subjects were taking