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Annals of Physical and Rehabilitation Medicine 53 (2010) 372–386

Original article / Article original

Gait initiation reflects the adaptive biomechanical strategies of adolescents with idiopathic scoliosis

L'initiation de la marche comme reflet des stratégies adaptatives des patients porteurs d'une scoliose idiopathique de l'adolescence

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Received 3 December 2009; accepted 7 April 2010

Abstract

Background. – The dynamics behavior of patients with idiopathic scoliosis obviously requires some biomechanical compensatory strategies. Our objective is to analyze the ground reaction forces (GRF) exerted during gait initiation in order to determine the dynamic consequences of idiopathic scoliosis.
Methods. – Ten adolescent girls suffering from idiopathic scoliosis with a right thoracic curvature (Cobb > 15°) and 15 healthy adolescents participated in this study. Two force plates were used to record the ground force evolution for the right and left limbs tested during gait initiation.
Results. – Whichever limb was used to initiate gait, gait initiation duration was found to be significantly longer in persons with scoliosis than in healthy subjects. In the scoliosis group (SG), the impulses, occurrences and forces values were also greater than in healthy subjects. Under the stance foot, the anteroposterior and vertical forces were always increased. Under the swing foot, the SG showed the same characteristics associated to decreased mediolateral impulses parameters. Even greater differences were observed between these two groups in terms of peak occurrences during left-limb gait initiation. The intragroup comparisons only unveiled very few differences between the two limbs for the control group (CG), whereas significantly higher values were recorded for the group of scoliosis patients when gait was initiated with the left limb rather than with the right one.
Conclusion. – For patients with scoliosis specific dynamic behavior adjustment are made during gait initiation patterns, for both limbs in order to maintain balance during gait to compensate for their spine deformation. Patients with scoliosis always showed slower dynamic patterns than healthy controls. These results show the importance of including specific evaluation and dynamic physical rehabilitation for patients with idiopathic scoliosis.

Keywords: Dynamics; Idiopathic scoliosis; Gait initiation; Adaptive strategies

Résumé

Objectif. – La scoliose idiopathique induit une réorganisation du comportement dynamique du patient. Notre objectif est d'analyser les conséquences de la déformation rachidienne sur l'initiation de la marche via l'évolution des forces de réaction du sol.
Patients et méthode. – Dix adolescentes présentant une scoliose idiopathique thoracique droite (Cobb > 15°) et 15 sujets témoins ont participé à cette étude. Deux plateformes de forces ont permis d'enregistrer l'évolution de la force de réaction du sol au cours de la réalisation d'une initiation de la marche (pas initiés par les membres inférieurs droit et gauche).
Résultats. – Pour l'ensemble des tests, la durée de l'initiation du pas était significativement augmentée pour les patients par rapport aux sujets témoins. La scoliose idiopathique induit lors de l'initiation du pas une augmentation des impulsions, des occurrences et des amplitudes de la force de réaction du sol. Sous le pied d'appui, c'est principalement les composantes verticales et antéropostérieures qui sont les plus perturbées. Sous le pied initiant le mouvement, ces mêmes caractéristiques ont pu être observées, mais, elles sont associées à une diminution des impulsions pour la

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1877-0657/$ – see front matter
doi:10.1016/j.rehab.2010.06.005

force médiolatérale. Les différences entre les groupes sont particulièrement visibles lorsque le mouvement est initié par le membre du côté concave (gauche). Pour le groupe de patient, l'initiation par ce même côté induit une augmentation systématique de tous les paramètres par rapport à l'initiation du côté droit. Peu de différences ont pu être mises en évidence entre les côtés pour le groupe de sujets témoins.
Conclusion. – La scoliose idiopathique induit le développement de stratégies adaptatives lors de l'initiation de la marche, caractérisées par un ralentissement du mouvement et une asymétrie comportementale entre les pas du côté de la convexité et du côté de la concavité. Ces résultats montrent l'importance d'inclure une évaluation et une rééducation lors du mouvement pour les patientes présentant une scoliose idiopathique.

Mots clés : Dynamique ; Scoliose idiopathique ; Initiation de la marche ; Stratégies adaptatives

1. English version

1.1. Introduction

Gait initiation is defined as the transition phase between standing and gait [5]. To start walking, muscular and gravitational actions are required to create the initial posture dynamic condition for moving forward [15]. Thus, gait initiation starts by a backward displacement of the center of pressure (CP) towards the leading limb initiating the movement whereas the center of gravity moves forward towards the stance limb [26]. This center of gravity/CP de-coupling generates the best conditions required for gait initiation [25]. Two factors may influence gait velocity: the length of the anticipatory posture adjustments phase [15], and the initial position of the person's center of gravity [6].

The invariant characteristics of gait initiation result from the interdependence of biomechanical parameters (position of the CP and the center of gravity) and time/distance parameters (stride length, time to start, duration time and velocity) [16].

Some asymmetric pathology affecting the lower limbs (knee osteoarthritis, congenital talipes equinovarus-clubfoot, hemiplegia) also influence gait initiation through spatiotemporal adaptation of the kinetics and kinematics parameters but also with the onset of dynamic asymmetries [4,48,49]. Actually, no asymmetric spinal cord pathology has been tested during gait initiation, even though we believe that the balance mechanisms involve the trunk, as it was reported during gait [23,12].

Studies focusing on gait and posture unveiled some posture dynamic characteristics specific to adolescent idiopathic scoliosis (AIS) [10]. This pathology is characterized by a three-dimensional spine deformation (lateral curvature, decreased sagittal curvature and rib hump) [47] that progresses particularly during adolescence [18]. Despite the latest scientific advances and numerous studies on this pathology, AIS remains an etiological enigma. The answer is most probably an interaction between all these hypotheses [18]. Thus, a defective gene could trigger a disorder in melatonin synthesis [29] that would lead to a temporary dysfunction of the nervous system during the child's growth [14] including vision [9], proprioceptive [45] and vestibular disorders [20,50]. These disorders could be at the source of posture imbalance and compensatory mechanisms used by AIS patients during standing and gait. [7,8,13]. Very recently, it has been proven that kinetics' analysis is more reliable than kinematics' analysis in order to define the posture dynamics behavior of patients affected by AIS [19].

In a standing position, AIS triggers an increase in the amplitude of posture-induced oscillations [43] and a shifting of the CP compared to control subjects [10,41]. Spine deformation changes the relationship between the position of the various body parts (spinal cord and limbs), thus requiring new strategies to achieve and maintain balance control [40]. Two factors of instability were identified in AIS patients:

- single curve scoliosis [20];
- ectomorphic body morphology type (tall and lanky) [1].

The analysis of lateral stepping and forward stepping unveiled a displacement of the CP increased in AIS patients compared to control subjects, associated to an asymmetry in terms of ground reaction forces (GRF) [7]. During gait, AIS involves spatiotemporal GRF disruption mainly characterized by an increased asymmetry of the lower limbs [12,44] and an increased variability of the dynamics parameters [22].

In light of the importance of spatiotemporal disruptions observed during posture and gait, it seemed necessary to define the transition between these two stages (stand to walk) [5]. The displacement of the center of gravity correlated to the spine deformation [46] should mainly impact the strategies and velocity of gait initiation [6]. We could bring up the hypothesis that a three-dimensional asymmetric spine deformation related to disruptions of the sensory systems could generate different kinds of management strategies between AIS patients and control subjects, but also between the steps initiated on the convex side and concave side of the deformity [44]. Such compensatory strategies secondary to the scoliosis pathologies should be more visible on the orthogonal component of the movement direction, since the latter was described as the one most controlled during movement [51].

The aim of the study was to define adaptive strategies in persons with AIS during gait initiation. We analyzed the pathology's influence on gait initiation but also the deformation's influence on the compensatory mechanism of each limb initiating stepping.

1.2. Patients and methods

Twenty-five young adolescent girls participated in the study; 15 of them made up the control group (CG) and the other 10 were in the scoliosis group (SG). Both groups were paired in age (SG: 13.8 ± 2.15 vs 12.57 ± 1.34 for CG), in height (SG: