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The influence of adolescent idiopathic scoliosis on the dynamic adaptive behaviour

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ABSTRACT

The idiopathic scoliosis is characterized by a three-dimensional spinal deformity involving new dynamical strategies to regulate the posture. The aim is to analyze the centre of pressure (CP) behaviour in forward stepping (FS) and lateral stepping (LS) to determine the dynamical consequences of scoliosis. Ten adolescents suffering from right thoracic scoliosis (Cobb $\geq 18^{\circ}$) and 15 healthy adolescents participated in this study. Two forceplates recorded the CP evolution in medio-lateral and antero-posterior axes resulting from FS and, LS with the dominant (D) and with the non-dominant (nD) limbs. Our results showed between groups and within groups differences respect to axis of motion. The comparison between groups in the LS showed the increase of the CP total displacement only when stepping with nD limb. Conversely no major evidence emerges from the FS analysis. Whatever the axis was, the CP total displacement of the D limb did not differ between groups. The comparison between lower limbs for healthy subjects was always different for FS whereas this comparison became non-significant for LS. For patients the same analysis showed results less systematically different. The correlation analysis, only when LS is initiated with nD limb, revealed opposite CP dynamical strategies between groups. These results may be explained by the influence of the spinal deformation on internal mass distribution and the asymmetrical neurophysiological factors previously described. Therefore, to perform LS the patients develop an asymmetry between both limbs to guarantee the balance despite scoliosis. Thus LS reveals the differences between groups and between initiation limbs.

The adolescent idiopathic scoliosis (AIS) is defined as a three-dimensional deformation of the spine without any associated pathology, which develops most rapidly during child growing [9]. In spite of an unclear origin, several hypotheses and troubles were associated to this pathology. Genetic troubles due to family heredity [9], an endocrine factor, an histological factor at the origin of a modification in the percentage of fast and low muscle fibers in spinal muscles [8] and neurophysiological factors causing postural troubles [16] have been separately reported in AIS patients. It may also well be that all these hypotheses interact with each other. A defective gene could thus provoke a default of melatonin synthesis that would temporarily disrupt the nervous system during growth [8]. Such a genetic deficiency might generate alterations of sensory information in patients. Associated to these etiological hypotheses, AIS subjects show behavioural abnormalities linked to troubles of the visual system [3] and/or proprioceptive deficiencies [16] and/or vestibular issues [19,10] and consequently involves perturbations in the control of the postural balance [14].

The adaptability of static postural behaviour in AIS subjects revealed an increase in the oscillation range [14] associated to an increase in both centre of pressure (CP) [4] and centre of mass [13] displacements. These authors showed a significant increase in the distance between the CP and the centre of mass displacements in AIS subjects in contrast to a healthy group. The initial spinal torsion is one solution to restore balance [8]. Such a specific motor behaviour thus implies new adaptive strategies to maintain equilibrium despite trunk deformation. This peculiarity might be a consequence in the modification of the interaction between spine and limbs segments. The scoliosis deformation induces dynamic postural perturbations that strengthen the asymmetry between the lower limbs in terms of ground reaction forces during various normal gait phases [6,15]. Ground reaction forces adaptation was also observed for the different phases of the lateral step [2]. Moreover, AIS patients asked to step forward or laterally presented an

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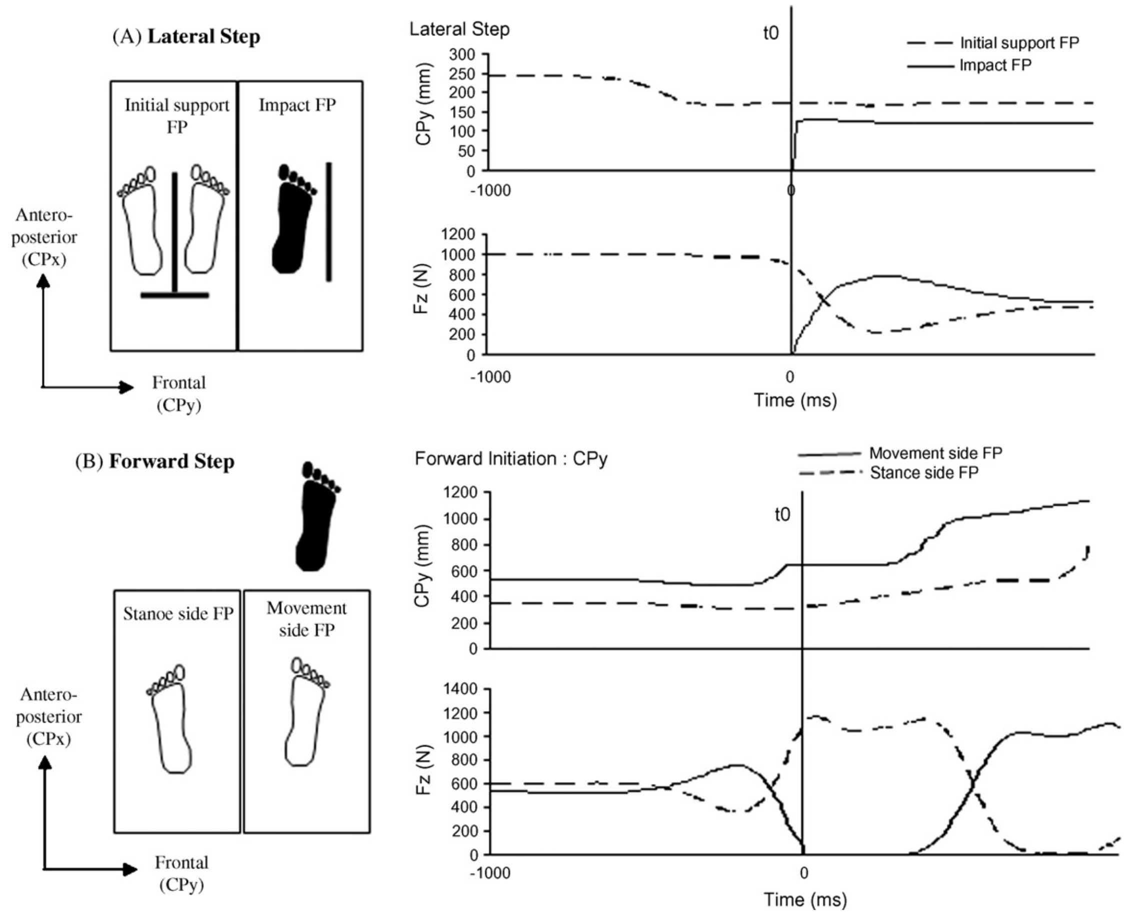

Fig. 1. Experimental setup design for lateral (A) and forward (B) stepping. Light foot corresponded to the initial position. Dark foot corresponded to the impacting foot on the right side. (A) CPx evolution (expressed in mm) associated to the vertical reaction force (expressed in N) shown for the lateral step on the initial support forceplate (FP) and the impact forceplate. (B) CPy evolution (expressed in mm) associated to the vertical reaction force (expressed in N) shown for the forward step on the stance side forceplate and the initiation forceplate.

increased variability of many dynamic parameters (ground reaction forces, CP, center of mass), observed in the medio-lateral as well as in the antero-posterior axes [2,11]. The modification observed during posture and gait led to focus on the transition from a static position to a dynamic one by means of analysis or step initiation [1]. Previous studies on gait initiation showed asymmetries in the dynamical parameters for several pathologies [18], but no spinal pathology was reported. As scoliosis is a three-dimensional pathology, testing two perpendicular movements in two dynamical orthogonal axes was assumed relevant. As demonstrated in normal gait [20], we hypothesized that the control of the orthogonal component of ground reaction forces represents the mandatory foundation of balance in AIS patients.

The aim of this study was to highlight the adaptive dynamic behaviour of scoliotic patients compared to healthy subjects. The effects of the scoliotic curvature should reveal specific dynamic strategies triggered by various stepping initiations in orthogonal axes.

Two groups participated in the study: 15 young non-scoliotic girls (NG), and 10 scoliotic girls (SG) with right thoracic or thoraco-lumbar AIS without any compensatory curvature. This specific curvature implied larger modifications in terms of dynamic control than for the lumbar or compensatory curvature [10]. An orthopaedic surgeon observed every subject to eliminate spinal, neurological and orthopaedic pathologies, and he diagnosed and assessed AIS curvature with the Cobb method (angle: $\geq 18^\circ$). The AIS patients did not undergo prior surgical treatment of spine nor of lower limbs. Both groups matched for age (average: 13 years ± 1.7), height (1.57 ± 0.08 m), and weight (48.3 ± 9.3 kg). The experimental protocol was approved by the local ethics committee (RCBID: 2006-A00289-42).

The dynamic analysis was performed using 2 forceplates side by side (AMTI®), providing CP data in antero-posterior (CPy) and medio-lateral (CPx) axes. The foot laterality of the adolescent girls was assessed via foot dominance testing (posterior push reaction) to identify the dominant (D) and the non-dominant (nD) limb. The foot initiating movement was defined as the "dominant foot". All subjects were right-footed. Each subject was asked to step according to the side of limb initiation (D vs. nD) and according to the step axis (forward step – FS vs. lateral step – LS). In LS, there was a target on the floor on which subjects were asked to step without visual feedback. Each subject randomly performed 5 trials per variable (the order of trials was randomised). The sampling frequency of both forceplates was 100 Hz [7]. The dependent variables were CPx and CPy.

Data processing was run in successive stages using programming routines (MATLAB v.6, *Matworks*) in order to precisely characterize stepping. The first stage estimated the signal from each forceplate for all steps. Then, data was sorted as follows: for the FS – the "stance side" forceplate and the "movement side" forceplate, and for the LS – the "initial support" forceplate and the "impact" forceplate. During the LS, the upright standing position was kept with both feet on the "support" forceplate until the stepping limb contacted the "impact" forceplate. The initial contact on the