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Influence of the structural deformity of the spine on the gait pathology in scoliotic patients

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ABSTRACT

Scoliosis is not only a spinal deformity, but also leads to the development of a pathological gait pattern. Nearly all studies examining walking in scoliotic patients report some degree of gait abnormality, however the results are somewhat contradictory. Therefore the aim of this study is to explore the relationship between gait pathology and degree of scoliotic deformity in a group of patients with idiopathic scoliosis.

Sixty three females with idiopathic scoliosis, aged between 12 and 17 participated in the study. They were not treated previously, neither surgically, nor conservatively. They underwent objective gait analysis with a VICON 460 system. Data for the following parameters were analysed: gait velocity, cadence, step length, pelvic tilt, pelvic retraction, pelvic range of motion in the transverse plane, pelvic obliquity, hip and knee range of motion in the sagittal plane, knee flexion at initial contact, ankle dorsiflexion in swing, foot progression angle.

Additionally a Gillette Gait Index (GGI) was calculated.

Prior to the gait analysis all patients underwent a clinical examination, an X-ray, clinical tests and anthropometric measurements.

In conclusion our results indicate that the gait pathology of the patients with idiopathic thoraco-lumbar (i.e. double curve) scoliosis depends on the severity of the spinal deformity and the type of pelvic deformity.

1. Introduction

Scoliosis, the most common orthopaedic problem in children and adolescents [1], is only a spinal deformity, but also leads to the development of a pathological gait pattern. Nearly all studies examining walking in scoliotic patients report some gait abnormality, however the results are somewhat contradictory. Mahaudens and co-workers found that step length is decreased in scoliotic patients in comparison with their peers [2,3]. Reductions were also observed in the ranges of motion of the pelvis, hip and shoulder in frontal plane, and knee in sagittal plane [3]. In contrast to these findings Chen and co-workers stated that, despite the poor postural stability of this group of patients, their gait patterns do not differ from normal [4]. A further study reports that scoliotic patients walk with decreased cadence, decreased pelvic range of motion in the transverse plane and a normal step length [5]. Another study found normal cadence, increased pelvic motion and decreased step length [2].

In our previous study [6] we found that the gait pattern of patients with two-level idiopathic scoliosis differed from that of their healthy peers. They walked with a decreased step length and pelvic tilt but increased range of pelvic motion in transverse plane. The kinematic changes also included decreased hip and knee ranges of motion in the sagittal plane, and. increased knee flexion at initial contact. In another study [7] we found that the step length and pelvic obliquity in scoliotic patients depended on the Cobb angle, and thus the severity of the deformity influenced the gait pathology. This contradicts the findings of the Mahaudens and co-workers [3] who, while reporting pathological gait changes, did not observe any dependency on severity of the deformation.

Therefore the aim of this study is to explore the relationship between gait pathology and degree of scoliotic deformity in a larger group of patients.

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2. Materials and methods

2.1. Material

Sixty three females with scoliosis, aged between 12 and 17 participated in the study. They were selected from the patients with scoliosis starting conservative treatment in The Children's Memorial Health Institute (CMHI) between 2008 and 2009. The range of their body mass was 30.9–73.5 kg (median 45.7 kg), body height 132–179.5 cm (median 161.5 cm), and Body Mass Index 13.16–24.13 (mean 18.3).

The selection criteria were:

- no previous treatment of their scoliosis, conservative or surgical;
- no accompanying disease which could influence the gait;
- no previous accidents or fractures of the lower limbs;
- gait analysis data available for the first visit of the patient to CMHI (i.e. before the beginning of the treatment);
- a diagnosis of idiopathic scoliosis (other types of scoliosis, i.e. of neurological origin was an exclusion criterion);
- deformities present both in the thoracic and lumbar regions;
- Cobb angle greater than 20°;
- deformity with a rotational component in the transverse plane.

The Cobb angle values ranged from 20° to 61° (median value 36°), the rotation ranged from 0° to 45° (median value 15°).

The study was approved by the Local Ethical Committee, the patients and their parents gave informed consent prior to the data collection.

2.2. Methods

The objective gait analysis was performed using a VICON 460 system (ViconPeak). The Helen Hayes marker and Plug-In-Gait model were used. The patients were asked to walk at a self-selected speed along a 6 m walkway. For each patient six trials were collected at each session. The data collected were reported using Polygon (ViconPeak) software. The results from each trial were averaged and presented normalised to the gait cycle. The averaged data were then subjected to further analysis. The spatio-temporal parameters were expressed as a percentage of the reference healthy subjects' data [8].

Based on the literature, data for the following parameters were analysed: gait velocity, cadence, step length, pelvic tilt, pelvic retraction, pelvic range of motion in the transverse plane, pelvic obliquity, hip and knee range of motion in the sagittal plane, knee flexion at initial contact, ankle dorsiflexion in swing, foot progression angle.

Additionally a Gillette Gait Index (GGI) was calculated (separately for each leg). GGI [9] is a single number, derived from gait kinematics and spatio-temporal parameters, which quantifies the deviation of a pathological gait from normal. This index has been validated in several patient populations [10–13]. The calculation of the GGI is based on 16 gait parameters: stance phase expressed as the percentage of the gait cycle, walking speed normalized to leg length, cadence, mean pelvic tilt, pelvic range of motion in sagittal plane, mean pelvic rotation, minimum hip flexion, hip range of movement in sagittal plane, peak abduction in swing, mean hip rotation in stance, knee flexion at initial contact, time to peak knee flexion in swing expressed as percentage of the gait cycle, knee range of movement in sagittal plane, peak dorsiflexion in stance and swing, and mean foot progression [9].

2.3. Clinical evaluation

Prior to the gait analysis patients underwent a clinical examination. It consisted of an X-ray, clinical tests and anthropometric measurements. The following clinical variables were derived:

- The level of the most severe deformity in frontal plane (thoracic, lumbar or thoraco-lumbar), based on X-ray;
- The level of the most severe rotation (thoracic, lumbar or thoraco-lumbar), measured on X-ray with Perdriolle torsiometer [14];
- The severity of the scoliosis based on the Cobb angle and the degree of rotation (three groups), criteria: mild – Cobb angle + rotation up to 40°, considerable – Cobb angle + rotation from 41° to 60°, severe – Cobb angle + rotation over 60°;
- The type of pelvic deformation, based on anthropometric measurements, four measurements were taken from basis: to left and right anterior superior iliac spines and to left and right posterior iliac spine, pelvis is oblique when anterior and posterior iliac spines on the same side are lower than on the opposite side; pelvis is rotated when anterior spine is higher than posterior one on the same side; mixed type is when all four measurements are different; assumed level of the cut-off difference between levels was 0.5 cm;
- The Cobb angle (in degrees);
- The sum of the Cobb and rotation angles (in degrees);
- The side of the more severe deformity (left, right or equal), based on X-ray.

Table 1
Number of patients in clinical groups.

Clinical group	1	2	3	4
1. Most severe deformity in frontal plane	14	25	24	–
2. Level of most severe rotation	16	35	12	–
3. Severity of scoliosis based on Cobb angle and degree of rotation	23	25	15	–
4. Asymmetry (side of most severe deformity)	14	24	25	–
5. Type of pelvic deformity	2	22	36	3

Most severe deformity in frontal plane: 1 – thoracic, 2 – lumbar, 3 – thoraco-lumbar.
Level of most severe rotation: 1 – thoracic, 2 – lumbar, 3 – thoraco-lumbar.
Severity of scoliosis: 1 – mild, 2 – considerable, 3 – severe.
Asymmetry: 1 – left, 2 – right, 3 – equal.
Pelvic deformity: 1 – none, 2 – pelvis oblique, 3 – iliac bone rotated in respect to each other, 4 – both obliquity and rotation present.

As the level of the leg length discrepancy in all patients was within physiological limit (up to 2 cm) this factor was not taken into account. Table 1 presents the number of patients in groups, in which division was based on clinical evaluation.

2.4. Statistical analysis

The distribution of the quantitative variables was established using the Kolmogorov–Smirnov and Shapiro–Wilk's tests. The following tests were used to establish the dependence of the gait data on the severity of the scoliosis: ANOVA Kruskal–Wallis, Spearman rank correlation, and Wilcoxon test for matched pairs. Additionally the discriminant analysis and multiple correlation methods were used. The significance level was 0.05. The calculations were done using Statistica and MedCalc softwares.

For the establishment of the dependence of the gait data on: level of the most severe deformity, level of the most sever rotation, the severity of scoliosis, level of the most severe deformity, type of pelvis deformation, Cobb angle, and sum of the Cobb angle and rotation the gait data from left and right leg were pooled together. The influence of the side deformation on the gait data was analysed separately for left and right leg gait variables.

3. Results

Table 2 presents the summary of all gait parameters in clinical groups, and Table 3 the statistical significant correlations between the gait and clinical data.

Table 4 presents the results of the multiple correlation between Cobb angle (expressed in degrees) and sum of the Cobb angle and rotation (expressed in degrees). In both cases the two gait variables which were statistically significantly correlated with clinical variables were knee flexion at initial contact and knee range of movement. The β coefficients indicate that the knee angle at initial flexion increases with deformity, while knee range of movement decreases.

Fig. 1 shows the dependence of GGI on the sum of the Cobb and rotation angles.

The knee flexion at initial contact and knee range of motion were significantly dependent on the severity of the scoliosis ($H = 6.5$, $p = 0.039$, $H = 10.5$, $p = 0.005$ respectively).

Discriminant analysis (Table 5) revealed that several gait parameters depended on the severity of scoliosis: cadence, pelvic range of movement in sagittal plane, knee flexion at initial contact, GGI, gait speed, step length, and hip range of movement.

The type of pelvic deformation influenced the following variables, while analysing the dependence separately: knee range of motion ($H = 8.188$, $p = 0.043$), GGI ($H = 8.569$, $p = 0.036$), gait speed ($H = 8.893$, $p = 0.031$), and step length ($H = 18.119$, $p < 0.001$). Discriminant analysis (Table 6) show that the most influenced gait parameters are: gait speed, dorsiflexion in swing and GGI.

The side of the deformity (Fig. 2) was significant for the hip range of motion where the deformity was more pronounced on the right side ($Z = 2.042$, $p = 0.041$) or equally distributed between