Pedobarographic evaluation of body weight distribution on the lower limbs and balance after derotation corticotomies using the Ilizarov method

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Distortion of the axis and shortening of the limbs result in multiple musculoskeletal pathologies. Rotation disorders should also be included among the disorders of the axis of the lower limb. In the case of rotational distortion, only derotation osteotomy can effectively correct torsion-associated deformations. Rotational distortion correction is accompanied by translational displacement and torsion, which results in more complex biomechanics. Using the pedobarographic platform, it is possible to evaluate static and dynamic posture and gait, percentage of body weight distribution on the lower limbs, and balance. Physiological gait and distribution of weight on the lower extremities are symmetrical. Balance is one of the determinants of proper biomechanics of the musculoskeletal system. An important aspect of treatment evaluation is pedobarographic assessment of balance and body weight distribution on the lower extremities ratio. The aim of this work was to evaluate the pedobarographic assessment of body weight distribution on the lower limbs and balance in patients with derotation corticotomies using the Ilizarov method.

The study examined a group of 56 patients, who underwent derotation corticotomy using the Illizarov method between 1996 and 2012 at the Clinic of Orthopaedics and Traumatology of the Musculoskeletal System in Wrocław. The control group consisted of 54 patients, who were treated with correctional derotation-free corticotomy using the Ilizarov. Distribution of body weight on the lower limbs and balance were assessed with the pedobarographic platform.

Following derotation corticotomy, the amount of body weight placed on the operated limb by subjects from the study group averaged 47.81%, 52.19% in the case of the healthy limb. These differences were not statistically significant. The difference between the average percentage of body weight placed on the diseased and healthy limb in the study group and the controls were not found to be statistically significant. There were no statistical differences in the average length of the gravity line or in the average surface area of the center of gravity position between the study and control groups.

Balanced distribution of body weight on the lower limbs was achieved following derotation corticotomies using the Ilizarov method. Derotation corticotomies performed with the Ilizarov method allow for achieving normalization of body weight distribution on the lower limbs and balance, with values similar to those resulting from Ilizarov method derotation-free osteotomy.

Key words: *Ilizarov external fixator, derotation, pedobarography, balance*

1. Introduction

Deformation axis and uneven leg length is a common pathology of the musculoskeletal system [1]–[7]. Unequal limb length and axis distortions constitute an important public health problem. They cause functional impairment and increasing compensatory deformations during movement and verticalization. Axis distortion and shortened limb result in the asymmetry of load transfer by the joints, which disturbs the statics and dynamics of the musculoskeletal system [3], [8]–[12]. Restoration of normal anatomy is associated with the optimization of functioning of the musculoskeletal system.

In the case of rotational deformities, non-operative methods are inefficient; therefore, only derotation osteotomy can effectively correct these distortions [13]

–[15]. Illizarov stabilizer allows for limb equalization, it also enables simultaneous precise correction of the deformity in the coronal, sagittal, and horizontal plane.

Limb biomechanics change during correction by distraction corticotomy. Rotational distortion correction is accompanied by translational displacement and torsion, which results in more complex biomechanics. Analysis of the biomechanics of the lower extremities can be made using the pedobarographic platform [16]–[19].

Pedobarographic platform is an effective research tool that enables monitoring treatment and rehabilitation, as well as the outcomes. It allows accurate and reproducible assessment of the posture and gait, as well as the displacement of the center of gravity, which is limited in the case of visual evaluation [16], [18]–[23]. Using the pedobarographic platform, it is possible to evaluate impairment in biomechanics in short-term (static assessment) and long-term (postural assessment) standing, dynamic gait, plantar area of contact, total foot–ground pressure while standing and walking, percentage of body weight distribution on the lower limbs, and balance. Pedobarographic platform allows for analysis of individual components of pressure originating from various anatomical sites and computer-assisted transformation of this information into digital images [16]–[19], [22]–[24].

In his work, Bhave has shown that equalization of the limbs results in the abolition of differences with respect to gait parameters, such as pressure time and ground reaction force, in the pedobarographic study [25]. Limb shortening causes the asymmetry in the distribution of ground reaction and limb pressure forces, and timing of gait phases [19], [25].

Physiological gait and weight distribution on the lower extremities are symmetrical [19], [25]. Balance is one of the determinants of proper biomechanics of the musculoskeletal system [26]. Improved balance can result from an increase in muscle strength and joint mobility. Balance abilities are associated with proprioreceptors located in the muscles, tendons, and synovial bursa [26]. Proper balance reduces pain and allows for free movements [23], [26].

Pedobarographic assessment of balance and lower body weight distribution ratio is an important aspect of treatment evaluation. Proper posture control is important to human ambulation. Balance disorders are associated with an increased risk of falls and injuries. Fear of falling decreases physical activity of patients, resulting in a greater dependence on their surroundings and reduced quality of life [20], [27]. Appropriate body weight distribution on the lower limbs allows for return to physical activity [28].

In the absence of papers assessing balance and lower limbs weight distribution after derotation corticotomies in international literature, we aimed to provide pedobarographic evaluation of lower limbs weight distribution and balance in patients with derotation corticotomies using the Ilizarov method.

2. Materials and methods

The subject of clinical studies was a group of 56 patients, including 27 women and 29 men, who underwent derotation osteotomy with the Ilizarov method within the distal epiphysis of the femur or proximal epiphysis of tibia, treated at the Department of Orthopaedics and Traumatology of the Musculoskeletal System in Wrocław in the years 1996–2010. The control group consisted of 54 patients, who underwent distraction by correction corticotomy using the Ilizarov method without corrective derotation. The etiology in 27 cases was congenital, in 14 inflammatory, in 11 traumatic, and neurogenic in 4.

This work aimed to assess static data, such as balance and percentage of weight distribution on the lower limbs. The balance was evaluated by two parameters: line of gravity and the surface area of the center of gravity position.

Fig. 1. Zebris pedobarographic platform

Assessment of balance and weight distribution on the operated and healthy limbs was performed on Zebris Medical Gmbh pedobarographic platform (Fig. 1). The dimensions of the plate were 470 mm × 320 mm, including 1 504 sensors. The platform was connected to a computer with installed software (FootPrint version 1.2.4.9) via an USB cable. Computer software allowed for processing and archiving static posture parameters, which were then subjected to statistical analysis. The subjects participating in the study performed the trials without shoes, with eyes open. Before each measurement,
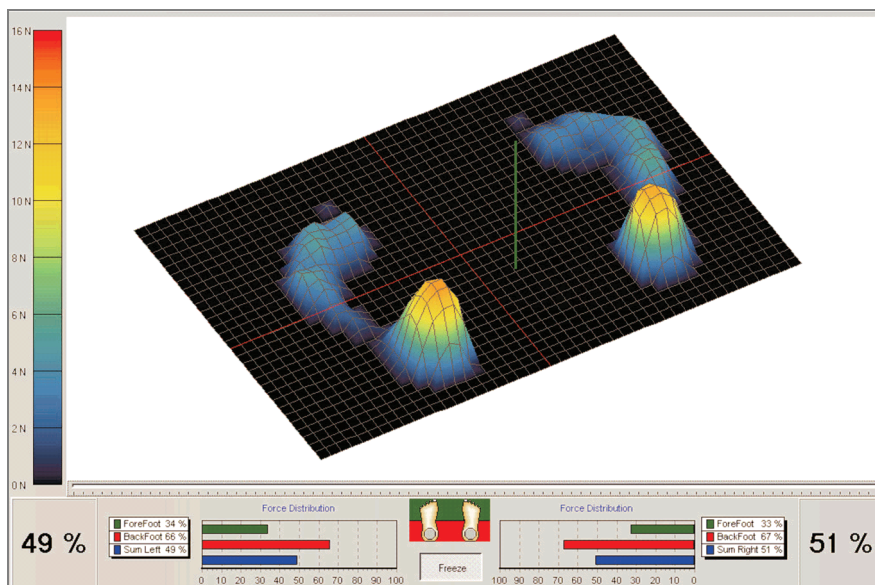
Fig. 2. An example of the measured percentage of body weight distribution on the lower limbs
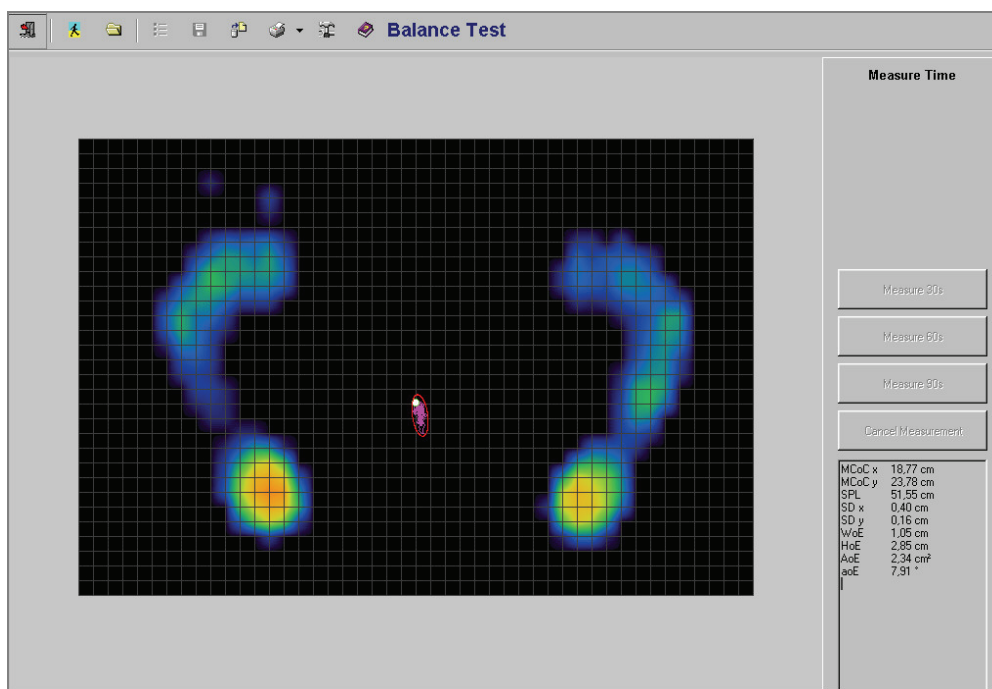

Fig. 3. An example of measured length of the gravity line and the surface area of the position of the center of gravity

the device was calibrated and the tested person was carefully instructed on the test method. The patient stood on the platform on both feet for 90 seconds. For each patient, the trial was repeated three times; next, the average value of the results was calculated for further analysis.

Assessment of the percentage of weight distribution on the operated and healthy limb was performed during two-legged, 90 seconds-long stand on the platform (Fig. 2). For each patient, the trial was repeated 3 times, followed by calculating the average

value of measurements for the purposes of further analysis.

The assessment of the length of gravity line and the surface area of the center of gravity position was performed during a two-legged, 90 seconds-long stand on the platform (Fig. 3).

For each patient, the trial was repeated 3 times, followed by calculating the average value of results for the purposes of further analysis.

The resulting values were normalized. For operated and healthy limbs, weight distribution was pre-

sented as a percentage. The length of the gravity line is shown in cm, while the surface area of the center of gravity position in cm^2.

The Mann–Whitney test and Student's *t*-test were used to analyze the statistical significance of differences between mean values of the variables. All analyses were carried out at the level of significance set at $\alpha = 0.05$ using Statistica 10.0 software.

3. Results

During the static trial, pedobarography showed that the study group participants, who underwent derotation corticotomy, placed on average 47.81% of weight on the operated limb and 52.19%, on average, on the healthy limb. These differences were not statistically significant. In the control group, the operated limb was loaded with an average of 48.4%, while the healthy limb 51.6%. These differences were not statistically significant. The difference in the average percentage of weight distribution on the diseased limb in the study group and the controls was not significant statistically (Table 1). There were no statistically significant differences in the mean percentage of body weight distributed on the healthy limb between the study and control group (Table 2). In the study group, the average length of the gravity line was 145.78 cm, while in the control group it was 144.82 cm. The differences were not statistically significant. In the study group, the average surface area of the center of gravity position was 7.68 cm^2, whereas in the control group it was 7.06 cm^2. The differences were not statistically significant.

Table 1. Percentage of body weight distribution
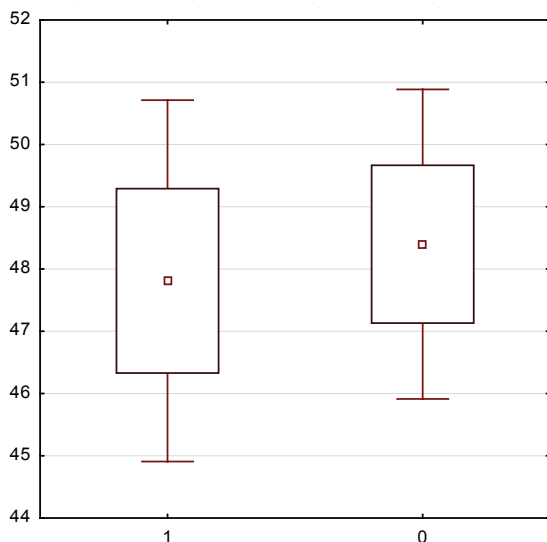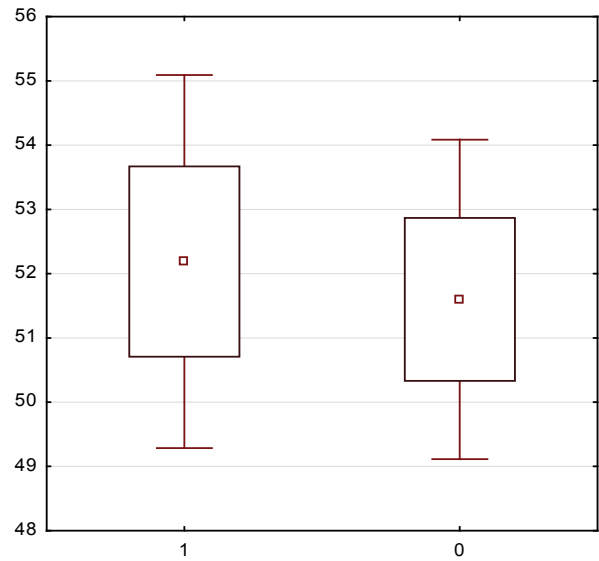on the diseased limb in the study (1) and control (0) group

Table 2. Percentage of body weight distribution
on the healthy limb in the study (1) and control (0) group

4. Discussion

Radler et al. recommended that patients with rotational deformities should undergo gait analysis before the planned treatment. They showed the impact of compensatory mechanisms on gait in patients with torsion deformities and reported a correlation between femoral neck anteversion and mobility of the pelvis, as well as foot progression angle and torsion of thigh and lower leg [29]. Koczewski, analyzing gait parameters in patients treated with the Ilizarov method, noticed abnormal vertical pressure forces during static and dynamic tests [30]. Dolganov et al. presented the results of the percentage distribution of body weight in patients treated with the Ilizarov method. In the group of 75 patients, body weight distribution on the limb before treatment ranged from 21% to 32% of the healthy limb, while during extension it ranged from 30% to 100% of the healthy limbs. After the treatment, both limbs received similar degree of body weight distribution [28]. Balance is one of the determinants of proper biomechanics of the musculoskeletal system [26]. Improvement in balance can result from an increase in muscle strength and joint mobility. Balance abilities are associated with proprioreceptors located in the muscles, tendons, and synovial bursa [26]. Rongies evaluated the impact of rehabilitation on the balance of patients with coxarthrosis using the pedobarographic platform. He observed an improvement in the balance after a series of exercises, and a cor-

relation between the reduction in pain and a decrease in the deflection in the center of gravity [23]. Majewski et al. assessed the balance in patients following hip arthroplasty, comparing the results with a control group of healthy volunteers. The average anterior-posterior deflection in the center of gravity of patients who underwent hip alloplasty was 3.20, as compared to 3.30 in the control group. Average torsional deflection in the center of gravity was 1.40 in patients with hip alloplasty, and 1.70 in the control group [26]. In his work, Bhave showed that equalization of the limbs normalized biomechanical symmetry of limb parameters [25]. Morasiewcz showed that equalization and axis correction of the lower limb allowed for normal, symmetrical gait parameters [19]. Equalizing limb shortening results in symmetrical distribution of ground pressure for both lower limbs [25]. There is no published data on using the pedobarographic platform to assess the percentage of body weight distribution on the lower limbs and balance in patients with derotation corticotomies performed with the Ilizarov method. According to our data, following derotation corticotomy procedure, the study group showed an average body weight distribution of 47.81% in the operated limb and 52.19% in the healthy limb. These differences were not statistically significant; therefore, a symmetrical distribution of body weight was obtained in the lower limbs after treatment. The difference in the average percentage of body weight distribution on the diseased and healthy limb in the study group and the controls was not statistically significant. The parameters describing the balance, the average length of the gravity line, and the average surface area of the center of gravity position did not differ significantly between the study group and the controls.

Derotation corticotomy using the Ilizarov method allows for the normalization of body weight distribution on the lower limbs, and achieving balance similar to that of derotation-free osteotomy with the Ilizarov method.

Acknowledgements

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