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Pedobarographic analysis of body weight distribution on the lower limbs and balance after Ilizarov corticotomies

Piotr Morasiewicz [a,*], Szymon Dragan [a], Szymon Łukasz Dragan [a], Zdzisława Wrzosek [b], Łukasz Pawik [b]

[a] Wrocław Medical University, Department and Clinic of Orthopaedic and Traumatologic Surgery, Borowska 213, 50–556 Wrocław, Poland
[b] University of Physical Education in Wrocław, The Chair of Physiotherapy and occupational therapy in Motor System Dysfunctions, Paderewskiego 35, 51–612 Wrocław, Poland

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ABSTRACT

Background: Symmetrical distribution of the load of the lower limbs and balance are among the determinants of proper biomechanics of the musculoskeletal system. So far, it has not been elucidated whether the correction of the axis and the equalization of the length of the lower limbs allow for achieving proper balance and load distribution. The aim of the present study was to compare load distribution and balance of patients who underwent Ilizarov method corticotomies with healthy controls.
Methods: The clinical studies evaluated 57 patients, who underwent corticotomy with the Ilizarov method. The control group consisted of 59 healthy volunteers. The evaluation assessed the distribution of the load of the lower limbs and balance using pedobarographic platform.
Findings: In the study group operated limb bore 48.02% of the load on average, while the healthy limb 51.98%. These differences were not statistically significant. The average percentage of load in limbs in treated and control groups did not differ significantly. In the study group, the average length of path of the center of gravity was 145.47 cm. In the control group, the average length of path of the center of gravity was 112.69 cm. In the study group, the average area of the center of gravity was 7.54 cm^2, while in the control group it was 5.19 cm^2.
Interpretation: Ilizarov method corticotomy allows for the obtainment value of the load distribution of the lower limbs in the study group not significantly different from those in a control group, but does not ensure the achievement of completely normal balance.

1. Introduction

Distortion of the axis and shortening of the lower limb cause static and dynamic disorders of the musculoskeletal system (Alagha and Gotia, 2009; Altinel et al., 2007; Morasiewicz et al., 2014a; Nakase et al., 2009; Panjavi and Mortazavi, 2007; Piper et al., 2009; Probe, 2003; Staheli, 1994). Restoration of the correct axis and equalization of lower limbs are connected with the optimization of the musculoskeletal system function (Alagha and Gotia, 2009; Morasiewicz et al., 2014a; Probe, 2003).

The Ilizarov method has been widely used in the correction of axis distortion in all planes and equalization of the limbs, but not free of complications (Bor et al., 2011; Morasiewicz et al., 2014a,b; Nakase et al., 2009). To justify the performance of limb lengthening and correction of axis, the benefits must outweigh the risks. One of the hypothetical benefits is an improvement in load distribution and balance.

Load distribution of the lower limbs and balance analysis cause problems for researchers. The Pedobarographic platform enables the assessment of static and dynamic posture, gait, as well as allowing for the testing of load distribution of the lower limbs and the ability to maintain balance, is objective and a reproducible measures instrument (Lorkowski et al., 2008, 2010; Morasiewicz and Dragan, 2013; Morasiewicz et al., 2010; Pataky and Goulermas, 2008; Pataky et al., 2008; Rongies et al., 2009; Santos-Rocha et al., 2009).

Symmetrical distribution of the load of the lower limbs and balance are among the determinants of proper biomechanics of the musculoskeletal system (Jancova, 2008; Morasiewicz and Dragan, 2013; Morasiewicz et al., 2010; Veilleux et al., 2011). Axis distortion and shortened limb result in the asymmetry of load transfer by the joints (Morasiewicz and Dragan, 2013). In the case of limb length discrepancy and disorders in the area of the limbs' axis the body's gravity center gets shifted which leads to increased tension of postural muscles and increased energy demand related to maintaining static and dynamic body balance (Morasiewicz et al., 2010). Proper balance is associated with normal muscle strength and joint mobility and allows freedom of movement, balance abilities are associated with proprioreceptors located in the muscles, tendons, and synovial bursa (Majewski et al., 2005; Morasiewicz and Dragan, 2013; Rongies et al., 2009). Hypothetically correction of limb length discrepancy and axis leads to proper lower limbs anatomy with correct proprioreceptors localisation and affect muscle symmetry which improve balance.

* Corresponding author at: Department and Clinic of Orthopaedic and Traumatologic Surgery, Wrocław Medical University, ul. Borowska 213, 50–556 Wrocław, Poland.
E-mail address: morasp@poczta.onet.pl (P. Morasiewicz).

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The assessment of balance and lower limb load distribution is an important element in evaluating the results of treatment. Proper balance and weight distribution of the lower limbs allow for a return to independent functioning and physical activity (Czerwiński and Kumorek, 2012; Dolganov et al., 1986; Jancova, 2008; Morasiewicz and Dragan, 2013).

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 (Dolganov et al., 1986). Authors' previous work considered pedobarographic analysis of load distribution and balance of the lower extremities in patients with Ilizarov derotational corticotomies, comparing the results with a control group of patients after non-derotational Ilizarov corticotomies (Morasiewicz and Dragan, 2013). Thus far, the available literature does not point to a definite answer whether the correction and alignment of the lower limb axis and length allows for proper balance and load distribution of the lower limbs.

The aim of the study was to investigate if the load distribution and balance of patients who underwent Ilizarov method corticotomies is different from healthy individuals.

The paper presents an assessment of the balance and the percentage distribution of the load of the lower limbs. The balance was evaluated by two parameters: the length of the path of the center of gravity and area of the center of gravity.

2. Methods

The subject of the clinical trials constituted patients who underwent corticotomy with the Ilizarov method within the femur or tibia. Criteria for inclusion in the study consisted of: implementation of at least one distraction–correction corticotomy with the Ilizarov method within the distal epiphysis of the femur or proximal tibia during treatment; equalization of limbs and full correction of distortion of the axis in all planes; more than three years since the conclusion of the treatment; patient's consent for the study; presence of baseline values of distortion and shortening in medical records; presence of pedobarographic data; and lack of mental disorders. Exclusion criteria consisted of: lack of patient's consent for the study, lack of contact with the patient; lack of pedobarographic data; lack of equalization of limbs and full correction of distortion of the axis in all planes; follow-up period shorter than three years; and lack of baseline values of distortion and shortening in medical records. Patients were enrolled into the study based on medical history, physical examination, pedobarographic examination, analysis of medical records, and radiological assessment performed before and after treatment. In total, 1445 patients underwent distraction–correction corticotomy with the Ilizarov method in our clinic between 1994 and 2011. After applying the exclusion criteria, 57 patients of both sexes (28 females, 29 males) were enrolled into the study. The control group consisted of 59 healthy volunteers of both sexes (29 women, 30 men), and who were concordant with the study group in terms of gender and age. In the control group, the dominant limb was adopted as the healthy limb, while the non-dominant limb stood in for the compromised limb. The control group was recruited from students and clinic workers. Criteria for inclusion in the control group consisted of: lack of surgery of lower limbs, and lack of dysfunction or pain in the lower extremities. The other criteria for inclusion and exclusion criteria were the same like for the study group.

The mean age in the study group was 24 years and 10 months (SD — 8 years and 8 months), while in the control group it was 24 years and 9 months (SD — 6 years and 7 months). The difference in age between the study and control group was not statistically significant.

All patients were informed about the voluntary nature of participation in the study. All study participants gave their consent to participate in the study, complete questionnaires, and process personal data. In the case of minors, the consent was obtained from their legal guardians. Research was approved by the Bioethics Committee.

Assessment of the balance (Fig. 1) and load distribution on the operated and healthy limbs (Fig. 2) were performed on the pedobarographic platform manufactured by Zebris Medical Gmbh (Fig. 3). The platform measures 470 × 320 mm and possesses 1504 sensors. USB connected the platform and PC on which FootPrint software (version 1.2.4.9) was installed. The computer software allowed for processing and archiving of static posture parameters, which were then subjected to statistical analysis. Subjects were without shoes and every attempt was made with open eyes. Before each measurement, the device was calibrated and each subject was instructed on the specific test method. The patient had both feet on the platform for 90 s. For each patient, the study was repeated three times, and then the average score was calculated for further analysis. Inside the calculated ellipse, is 95% of measurement data of location of center of gravity.

Lower limb load distribution of the healthy and operated limbs is shown as percentage. The length of the path of the center of gravity is shown in centimeters (cm), while the area of the center of gravity is given in centimeters squared (cm^2).

The Levene's test was performed to assess normal distribution. Mann–Whitney *U*-test and Students *t*-test were used to analyze the statistical significance of differences between mean values of variables. All analyses were carried out on the assumed significance level of $\alpha = 0.05$ using Statistica 10.0 software.

3. Results

Statistical analysis using the pedobarographic platform revealed that in the study group of corticotomy patients treated using the Ilizarov apparatus operated limb bore 48.02% (SD — 4.92%) of the load on average, while the healthy limb 51.98% (SD — 4.9%). These differences were not statistically significant ($p = 0.37$). In the control group, healthy and non-dominant leg bore on average 49.03% (SD — 2.3%). of the load, while the non-dominant limb 50.97% (SD — 2.25%). These differences were not statistically significant ($p = 0.44$). The average percentage of diseased limb load in the study group and the non-dominant limb in the control group did not differ significantly ($p = 0.54$). The comparison of the average percentage of healthy limb load in the study group and the average percentage of the dominant limb load in the control group did not demonstrate statistically significant differences ($p = 0.66$). In the study group, the average path length of the center of gravity was 145.47 cm (SD — 25.03 cm), while in the control group it was 112.69 cm (SD — 18.05 cm). These differences were statistically significant ($p = 0.003$). In the study group, the average area of the center of gravity was 7.54 cm^2 (SD — 4.02 cm^2) while in the control group it was 5.19 cm^2 (SD — 2.5 cm^2). These differences were statistically significant ($p = 0.013$).

4. Discussion

Researchers concentrate on dynamic gait analysis of patients with limb shortening and axis deformities. Radler and colleagues observed the impact of compensatory mechanisms on gait in patients with limb deformities (Radler et al., 2010). Morasiewicz showed that equalization and correction of the lower limb axis allowed obtaining normal, and symmetrical gait parameters (Morasiewicz et al., 2010). We concentrate on static pedobarographic posture evaluation — load distribution of the lower limbs and ability to maintain balance. Dolganov et al. presented the results of measuring the percentage load distribution in patients treated with the Ilizarov method. Following treatment, both limbs were loaded to a similar extent (Dolganov et al., 1986). In their work, Bhave and colleagues concluded that equalization of the limbs resulted in a symmetrical stress distribution of both lower limbs (Bhave et al., 1999). In our study load distribution of lower limbs was symmetrical, which is similar to Dolganov and Bhave results.