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ORIGINAL STUDY

Sport and physical activity in patients after derotational corticotomies with the Ilizarov method

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Background : **Torsional distortion causes numerous musculoskeletal pathologies. Effective treatment allows restoring limb function and return to sport activity. Objectives was to assess the sport activity in patients with derotational corticotomies using the Ilizarov method.**

Methods : **It was case series retrospective study. The study examined 56 patients. The control group consisted of 54 patients. A mean follow-up time was 5 years and 6 months. A mean age at the start of treatment was 19 years and 10 months. Patients underwent derotational corticotomies of distal epiphysis of the femur or proximal epiphysis of the tibia using the Ilizarov method. The effect of etiology, type of treatment strategy, and rate, size, and level of derotation on the scores of four activity scales was evaluated ; additionally, the activity was compared with the control group.**

Results : **There were no differences in the scales of activity before and after treatment in the study and control groups. In the study group, higher activity after treatment was reported in the level of GRIMBY activity. Patients with internal torsion had a higher VAS activity level after treatment as compared to patients with external torsion.**

Conclusions : **Derotational corticotomies allow returning to or increasing physical and sport activity ; they do not have a negative influence on physical activity after treatment as compared to the control group.**

Keywords : Sport activity ; derotational corticotomies ; Ilizarov method.

INTRODUCTION

Unequal limb length and axis distortion constitute an important social problem. They cause functional disorders and subsequently compensational distortions, which intensify during motion and verticalization. This leads to the deterioration of limb function, reduction of gait efficiency, reduced muscle strength, and limitations in joint mobility, making sport and physical activity difficult (*4-6,27,35,39,48,49*). It is important to quickly identify and correct axis distortions and reduce shortening in order to prevent or minimize damage to the muscu-

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loskeletal system. Axis distortions of the lower limb should also include torsional deformations.

Derotational corticotomies with the Ilizarov method are considered one of the most effective treatments for torsional deformations (*4,23,25,26, 30,35*).

Following osteotomy, Ilizarov apparatus is usually applied for a period of few months ; the treatment is, in some cases, long-term and multi-stage, and connected with a restricted social life, which can cause psychological problems (*45*).

Achieving good outcomes is affected by etiology, size of the shortening, coexistence of distortion, plan and strategy of treatment (*23,33,35*).

Currently, it can be observed that the patients desire a quick return to independence, work, and physical activity (*12*). Limb elongation carries a risk of reduced sport and physical activity after treatment (*3*). One of the measures of treatment effectiveness is to evaluate the physical activity of patients. Effective treatment allows restoration of limb function and return or start of sport activity. Quick return to daily activities and sport has an osteogenic effect ; it increases bone density and reduces the risk of bone demineralization, osteoporotic fractures, loss of muscle mass and increase in the amount of body fat (*7,28,34*). It is important to define the indications and contraindications for axis correction and limb elongation in order to allow for a good therapeutic effect. Therefore, comprehensive evaluation of treatment outcomes, taking into account physical and sport activity (*43*), is essential.

In literature, studies assessing sport and physical activity of patients treated with the Ilizarov method are scarce, incomplete, and based on a small number of patients. The aim of the current study, due to the lack of publications on the subject, is to assess sport and physical activity of patients after derotational corticotomies with the Ilizarov method.

METHODS

The subject of the clinical trials constituted patients who underwent derotational corticotomy with the Ilizarov method within the femur or tibia. Criteria for inclusion in the study consisted of : implementation of at least one derotational corticotomy with +/- lengthening with +/- correction in coronal and/or sagittal plane with the Ilizarov method within the distal epiphysis of the femur or the proximal part of the lower leg during treatment ; more than two years since the conclusion of the treatment ; patient's consent for the study ; presence of baseline values of distortion and shortening in medical records ; lack of mental disorders. Exclusion criteria consisted of : lack of patient's consent for the study, lack of contact with the patient ; follow-up period shorter than two years ; lack of baseline values of distortion and shortening in medical records. Patients were enrolled into the study based on medical history, physical examination, analysis of medical records, and radiological assessment performed before and after treatment. In total, 87 patients underwent derotational corticotomy with the Ilizarov method in our clinic between 1996 and 2010. After applying the exclusion criteria, 56 patients were enrolled into the study. The control group consisted of 54 patients treated in our clinic between 1988-2010, who underwent non-derotational distraction-correction corticotomy with the Ilizarov method within the femur and lower leg. Criteria for inclusion in the control group consisted of : implementation of at least one corticotomy correction in coronal and/or sagittal plane with +/- lengthening with the Ilizarov method, without derotation, within the distal epiphysis of the femur or the proximal part of the lower leg during treatment. The other criteria for inclusion and exclusion criteria was the same like for study group.

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. The study was approved by the local Bioethics Commission on 5.01.2012 – decision number KB - 724/2011.

The study group was divided into the following study sub-groups : based on the rate of derotation : acute, gradual ; depending on the level of derotation : thigh, lower leg ; depending on the type of torsion : external, internal ; depending on the size of derotation : $< 30°$, $> 30°$; depending on the strategy of treatment : one-step, two-step, multi-step ; depending on the etiology of torsion : post-traumatic, post-inflammatory, congenital.

Patient's physical activity was assessed using : GRIMBY's scale, presented in 1986 by Grimby (*16*), LOWER LIMB Activity scale, presented by Saleh in 2005 (*41*), UCLA activity scale, introduced by Amstutz in 1984 (*1*), and VAS ACTIVITY scale, introduced by Zahiri in 1998 (*50*).

We assessed the statistical significance of differences between mean scores before and after treatment with regards the scales of activity and compared the results with those obtained in the control group.

To verify whether the average value of the variables varied significantly depending on the level of correction, rate of correction, type of correction, and size of correction, the Mann-Whitney U test and Student's t-test were used. To analyze the significance of differences between mean values of data variables in the study and control groups we used the U Mann-Whitney and Student's t-test. To analyze whether the differences between the average data values of the variables were statistically significant, depending on the strategy or etiology of treatment, Kruskal-Wallis test was employed. Where the use of test data required fulfillment of assumptions about normality, the Shapiro-Wilk test and Kolmogorov-Smirnov test was used to verify the hypothesis of normality. All factors were tested for their statistical relationships based on the tests available within the used statistical software. All analyses were performed on the assumed level of significance $\alpha = 0.05$ using Statistica 10.0.

RESULTS

In the study group, the mean age at the beginning of the treatment was 19 years and 10 months (ranged from 4 years and 8 months to 58 years). In the control group, the mean age at the beginning of the treatment was 19 years and 7 months (ranged from 5 years and 11 months to 64 years and 11 months). The differences in age at the beginning of the treatment between the study group and control group were not statistically significant. Mean follow-up of the study group was found to be five years and six months (ranged from 2 years and 1 month to 15 years and 6 months). Average follow-up for the control group was 5 years and 11 months (ranged from 2 years and 2 months to 23 years and 6 months). Differences in the duration of the follow-up for the study and control groups were not statistically significant. There were 27 women and 29 men in the study group. There were 27 women and 27 men in the control group. Of the 56 patients in the study group, the etiology was congenital in 28 cases, post-traumatic in 12, and post-inflammatory in 16. Of the 54 patients in the control group, the etiology was congenital in 29 cases, post-traumatic in 11, and post-inflammatory in 14. A total of 87 operations, an average of 1.55 operations per patient were performed in 56 patients. In the study group one-step treatment was performed in 41 patients, 10 patients underwent two-stage treatment, and five patients had multi-stage treatment (3-5 surgeries). In the control group one-step treatment was performed in 40 patients, 10 patients underwent two-stage treatment, and 4 patients had multi-stage treatment (3-5 surgeries). Correction of torsional distortion was performed at the level of the femur in 32 patients and at the level of the lower leg in 24 patients. In the control group corticotomy was performed at the level of the femur in 30 patients and at the level of the lower leg in 24 patients. External torsion was corrected in 42 patients, while internal torsion was corrected in 14 patients. Gradual derotation was performed in 32 patients and 24 individuals had acute correction of torsional deformation. The size of the derotation was below 30° in 37 patients and in 19 subjects was above 30°. In the study group, the mean lengthening was 2.8 cm (od 0 cm do 8 cm). The mean remaining shortening after treatment was 0.2 cm (od 0 cm do 5 cm). In the control group, the mean lengthening was 3.2 cm (od 0 cm do 8 cm). The mean remaining shortening after treatment was 0.5 cm (od 0 cm do 9.9 cm). The differences in mean lengthening and remaining shortening after treatment between the study group and control group were not statistically significant. In the study group, the mean value of the corrected deformities was 23.32° (from 6° to 90°) :

– in coronal plane 13.31°
  - from 7° to 30° valgus
  - from 6° to 65° varus
– in horizontal plane 31.94°
  - from 20° to 90° external torsion
  - from 10° to 35° internal torsion
– in sagittal plane 27.67°
  - from 25° to 30° antecurvatum

In the control group, the mean value of the corrected deformities was 11.94° (from 3° to 40°) :

– in coronal plane 10.4 ^{0}
  - from 3° to 22° valgus
  - from 4° to 40° varus
– in sagittal plane 15.4°
  - from 10° to 30° antecurvatum
  - from 7° to 10° recurvatum

The mean value of the corrected deformities in control group was statistically significant lower than in study group (p = 0.03431).

In the study group, the average score of the level of activity measured by the UCLA scale before treatment was 5.75 (from 3 to 10). Mean UCLA activity after treatment was 6.18 (3 to 10). This difference was not statistically significant. The comparison of the mean scores of UCLA activity before and after treatment between the study group and the control group did not reveal statistically significant differences. There were no statistically significant differences between UCLA scale scores of the various sub-groups (Table I).

An increase in the level of activity of the GRIMBY scale was observed after treatment (mean 4.2 ; from 2 to 6) in relation to the before treatment score (mean 3.73 ; from 1 to 6). This difference was statistically significant (p = 0.02). The comparison between the average scores on the GRIMBY scale of the level of activity before and after treatment of the study group and control group revealed no statistically significant differences. There were no statistically significant differences between GRIMBY scale scores of the various subgroups (Table II).

The mean VAS activity before treatment was 5.14 (0 to 9). The mean VAS activity after treatment was 5.98 (2 to 10). This difference was not statistically significant. The comparison between the average scores on the VAS scale of the level of activity before and after treatment of the study group and control group revealed no statistically significant differences. VAS scores for individual study subgroups are shown in Table III. Before treatment, patients with acute derotation scored an average of 5.1 on the VAS scale, which was significantly higher compared to patients with gradual derotation, who had an average score of 5.04 (p = 0.04). After treatment, patients with internal torsion had a mean VAS activity level of 7.67, which was significantly

Table 1. Evaluation of activity on a UCLA scale in the subgroups.

		UCLA before treatment				UCLA after treatment			
		Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Size of derotation	< 30	6.09	6	3	9	6.64	7	4	10
	> 30	5.52	5	3	10	5.7	5	3	10
etiology	Post-traumatic	5	4.5	3	9	5.63	5.5	4	9
	post-inflammatory	6	5.5	3	9	5.75	5.5	3	9
	congenital	5.7	5.5	3	10	6.8	6.5	3	10
Treatment strategy	two-stage	6.22	7	3	9	7	7	4	10
	one-stage	5.67	5	3	10	5.9	6	3	10
	multi-stage	5.4	4	3	9	6.4	6	3	10
Level of derotation	lower leg	6	6	3	10	6.22	6	3	10
	femur	5.68	5	3	9	6.28	6	3	10
Type of derotation	internal torsion	6.5	6	4	9	7	6.5	5	9
	external torsion	5.53	5	3	10	5.78	5.5	3	10
Rate of derotation	acute	4.9	5	3	7	6.2	6	4	9
	gradual	5.6	5	3	10	5.88	5	3	10

Table 2. Evaluation of activity on a GRIMBY scale in the subgroups.

		GRIMBY before treatment				GRIMBY after treatment			
		Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Size of derotation	< 30	3.73	4	2	5	4.27	4	3	6
	> 30	3.63	4	1	6	4.04	4	2	6
etiology	Post-traumatic	3.75	4	2	5	4	4	3	5
	post-inflammatory	3.67	3	2	5	3.75	3.5	2	6
	congenital	3.75	4	1	6	4.55	5	2	6
Treatment strategy	two-stage	3.78	4	3	5	4.56	4	3	6
	one-stage	3.67	4	1	6	4	4	2	6
	multi-stage	4	3	3	6	4.8	5	3	6
Level of derotation	lower leg	3.78	4	2	6	4.22	4	3	6
	femur	3.8	4	2	6	4.28	4	2	6
Type of derotation	internal torsion	3.33	3	2	5	4.5	4.5	3	6
	external torsion	3.72	4	1	6	4.03	4	2	6
Rate of derotation	acute	3.3	3.5	2	4	4.4	4.5	3	6
	gradual	3.76	4	1	6	4.12	4	2	6

Table 3. Evaluation of activity on a VAS ACTIVITY scale in the subgroups.

		VAS ACTIVITY scale before treatment				VAS ACTIVITY scale after treatment			
		Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Size of derotation	< 30	4.45	4	2	8	5.18	5	2	9
	> 30	5.37	6	0	9	6.19	6	2	10
etiology	Post-traumatic	4	4	0	8	5.63	5	3	9
	post-inflammatory	5.75	6	2	9	5.67	5.5	2	9
	congenital	5.2	5	2	9	6.25	7	2	10
Treatment strategy	two-stage	5	5	3	7	6.89	7	4	10
	one-stage	5.23	5	0	9	5.83	5	2	10
	multi-stage	4.8	6	2	7	5.2	6	2	8
Level of derotation	lower leg	5.44	5	2	9	5.94	6	2	10
	femur	5.04	5	0	9	6.04	6	2	10
Type of derotation	internal torsion	6.5	6.5	5	8	7.67*	8.5	5	10
	external torsion	4.84	4	0	9	5.56*	5	2	9
Rate of derotation	acute	5.10*	5	2	8	6.7	7	2	10
	gradual	5.04*	4	0	9	5.6	5	2	9

* : $p < 0.05$.

higher ($p = 0.03$) compared to patients with outer torsion, who had a mean score of 5.56.

The results of the study showed an increase in the level of activity of the lower limb after treatment (mean 11.84 ; from 6 to 17) compared to the results before the treatment (mean 11.45 ; from 3 to 17). This difference was not statistically significant. The comparison between the mean scores of the level of activity of the lower limb before and after treatment of the study group and control group revealed no statistically significant differences. Lower limb activity level scores of various study subgroups did not reveal statistically significant differences (Table IV).

DISCUSSION

Treatment outcome is influenced by patients' expectations for limb elongation ; Ganel divided them into realistic and unrealistic (*14*) ; therefore, it is important to provide a plan and the nature of the treatment with the Ilizarov method prior to surgery. Currently, in comparison to the past, patients' expectations with regards to the possibility of a quick return to employment or self-care are rising (*12*). At the present time, there has been an increase in the level of physical and sport activity in the society ; more sports are enjoyed, also by the elderly and those in poor health. Contemporary patients have high expectations regarding returning or starting sport activity after treatment (*12*).

The Ilizarov method allows mobility with partial weight bearing on the operated limb in the first day after surgery ; also, it is minimally invasive and causes minimal scarring, which is an advantage over other methods of axis correction (*11,17,19*). Early mobilization after surgery reduces the risk of muscle atrophy, articular contractures, articular cartilage atrophy, deep vein thrombosis, and trophic changes. Weight bearing during distraction osteogenesis stimulates angiogenesis, providing a higher density and volume of the blood vessels. Cyclic weight bearing increases collagen production and proliferation of osteoblasts (*32*). However, the long term maintenance of the external fixator increases the risk of complications (*22*). Physiotherapy may limit muscle contractures, pain, muscle atrophy, edema, slow rate of regenerate creation, and also allows for a faster return to effective functioning (*44*). Muscular strength of the limb with Ilizarov

Table 4. Evaluation of activity on a LOWER LIMB Activity scale in the subgroups.

		LOWER LIMB Activity scale before treatment				LOWER LIMB Activity scale after treatment			
		Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Size of derotation	< 30	12.55	13	7	17	12	13	7	16
	> 30	10.56	9	3	17	11.74	13	6	17
etiology	Post-traumatic	10.13	8.5	3	17	10.88	10.5	7	17
	post-inflammatory	11.33	11	6	17	11.25	10.5	7	17
	congenital	12.15	12	7	17	12.6	13	6	17
Treatment strategy	two-stage	12.33	13	7	17	12.11	13	6	16
	one-stage	11.6	12	3	17	11.8	13	6	17
	multi-stage	9	7	6	16	11.6	13	7	17
Level of derotation	lower leg	12.44	13	7	17	12	13	6	17
	femur	10.92	10	3	17	11.68	13	6	17
Type of derotation	internal torsion	12.5	13.5	9	16	13.17	13	11	17
	external torsion	10.88	10	3	17	11.56	13	6	17
Rate of derotation	acute	11.6	10.5	7	17	12.6	13	6	17
	gradual	10.36	9	3	17	11.36	13	7	16

apparatus is reduced from after surgery to 6 months after removal of the stabilizer. Values close to the preoperative muscle strength are achieved within two years of surgery (*3*).

Impaired limb function makes it difficult or even impossible to engage in sport and physical activity. Inferior functioning of an extremity may be influenced by pain, instability and limitation of joint mobility, reduction of muscular strength, muscular balance disorder, increased weight, and connective tissue scars (*31,37*). According to Jorgensen and Jacobsen, patients with stroke, long immobilization, and limited physical activity had lower bone mineralization, muscle mass, and more body fat. Bone demineralization is a risk factor for osteoporotic fractures (*21,40*). The negative aspects of activity, such as the risk of falls, fractures and other injuries, and overloading of the joints, are less numerous than the many benefits of engaging in sport (*18,36*). The level of activity is dependent on the function of the limb. The return to engaging in sport and physical activity after treatment is one of the most important aspects of the evaluation of treatment for the patients (*41*). Works assessing sport and physical activity in patients treated with the Ilizarov method are scarce, incomplete, and are based on a small number of patients. Catagni reported that following elongation of the leg performed due to a short stature all patients returned to previous sport activities ; however, he does not describe in detail the level of physical activity (*8*). McKee has observed that 64% of patients with correction of post-traumatic distortion with the Ilizarov method could return to activity, but at a reduced level ; this report lacks a detailed description of the types of activity (*29*). Among patients with aplasia of the fibula after treatment with the Ilizarov method, 12.5% had mild limitations in high-energy activities, 62.5% were limited in activities, and 25% had severe limitations in activities (*9*). Jaarsma reported that 48%-67% of patients with post-traumatic torsional deformation were not able to return to the pre-injury sport activity (*20*). In the group of patients after open derotational osteotomy of the lower leg, authors have noted that 17% did not engage in any sport, 25% engaged in sport at a reduced level, and 58% participated in sport at the same level as before the surgery (*13*).

There is a lack of works comparing the scores of sport and physical activity depending on the etiology, treatment strategies, and rate, size, type and level of derotation. We observed no effect of etiology, treatment strategies, and rate, size and level of derotation on the level of sport activity. Only patients with inner torsion had higher VAS activity level after treatment as compared to the group with external torsion.

The implementation of simultaneous correction of torsional distortion and derotation >30° does not lower physical activity. This may be due to the fact that in the early weeks after the osteotomy, the regenerate has the best blood supply and the highest susceptibility to stretch (*2,24*). Younger patients, who dominated the data, are characterized by greater likelihood of muscle tissue proliferation, reducing the risk of articular contractures, dislocations, and subluxations (*42*). Acute correction reduces the time of applying the apparatus, potentially minimizing the risk of complications associated with long-term use of the stabilizer (*10*).

Taylor stated that internal torsion poses greater problems as compared to the outer torsion (*46*). Tetsworth noted at greater risk of complications in the case of correcting the internal torsion, especially in combination with a substantial shortening (*47*). On the other hand, Jaarsma found that patients with external torsion have more functional problems than those with inner torsion. This probably results from the greater possibility of compensating for the internal torsion. In order to compensate for external torsion, internal rotation is required in the hip joint ; this is more limited in comparison with the external rotation, which is necessary to compensate for the internal torsion (*20*). Better activity level scores in patients with correction of the internal torsion may result from superior soft tissues adaptation and increased possibilities of body compensation in the group with inner torsion.

Gremmo et al. noted restricted mobility of the knee joint in 7% of patients after lower leg elongation, in 20% after elongation of the thigh, and limited mobility of the ankle joint in 50% of patients with lower leg elongation (*15*). However, appropriate physiotherapy allows achieving physical activity similar to or higher than before the surgery in

patients with derotation of the thigh as well as the lower leg.

According to a number of authors, distractive-corrective osteotomy in patients with congenital etiology is associated with a higher risk of complications and higher elongation index as compared to those with post-inflammatory or post-traumatic etiology (*38*). Morasiewicz *et al* have reported that following correction using the Ilizarov method, patients with deformities caused by congenital factors showed higher asymmetry of gait parameters compared to patients treated due to shortening and post-traumatic or developmental distortions. They suggested that patients with congenital deformities introduced compensatory mechanisms and motor stereotypes beginning from birth, which despite the reduction of shortening and correction of axis do not allow for the full symmetry of gait. Individuals with acquired deformities do not have as developed compensatory mechanisms as in the case of congenital defects. Alignment and correction of distortion in patients with acquired etiology allows for normalization of gait in a higher proportion of patients compared to patients with inherited etiology. Achieving equalization and correct limb axis in patients with post-traumatic deformities allows restoring the normal function of the limb. In patients with congenital malformations, elongation and axis correction do not restore the original function of the limb, but provide new biomechanical conditions to achieve normal limb function (*33*). In our study, the etiology had no effect on locomotor activity. This could be due to the fact that in patients with congenital etiology, knowing the potentially higher risk of complications, the rate of correction and distraction was modified with greater care and more attention was paid to reducing potential complications.

Significant shortening and distortion of the lower limbs before treatment in patients treated in multiple stages potentially limited physical activity of patients before treatment. On the other hand, it seems that patients treated with two-stage and multi-stage approach pursued achieving high physical activity with the strongest intention. Following elongation and limb axis correction, it allowed them to engage in activities at a level similar to that of patients treated via single stage.

We have observed improvement in physical and sport activity after derotational osteotomy using the Ilizarov method as compared to the results before treatment. All patients evaluated by us returned to at least the same level of physical activity as before the operation. Scores of physical activity level scales were similar in the treated and control groups. Therefore, performing derotational corticotomy with the Ilizarov method does not affect the locomotor activity after treatment. This may be due to the fact that patients treated with the Ilizarov method engage in various activities within the framework of physiotherapy intended to restore and increase muscle strength and joint mobility. Increased physical activity of patients after derotational osteotomies with the Ilizarov method, in addition to overall patient satisfaction and improved outcomes of treatment, allows increasing muscle mass and bone density, reducing the amount of body fat and the risk of osteoporotic fractures (*15*). Alignment of the shortening and correction of the distortion may allow performing activities which were impossible before treatment, further motivating the patients to engage in them.

Derotational corticotomy using the Ilizarov method allows returning to or increasing physical and sport activity. Scores of physical activity level scales were similar in the treated and control groups. The etiology, treatment strategies, and rate, size and level of derotation did not affect the scores of the activity scales. Patients with internal torsion had a higher VAS activity level after treatment.

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