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Assessment of standing balance in patients after ankle fractures

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Purpose: The objective of the study is to evaluate the degree of balance disorders in patients with surgical treatment of ankle fractures with the use of stabilometric examinations.

Methods: The subjects in the study were 21 patients with ankle fractures treated surgically, within one year of the procedure. The control group comprised 20 healthy subjects. The balance was evaluated with the use of force platform in standing posture in both single and double limb stance. The parameters analysed were the transition area of the centre of feet pressure (COP), the length of the COP path and the COP velocity. The range of movement in the ankle joint and the intensification of pain were also measured.

Results: In the balance evaluation in double limb stance, there were no statistically significant differences. A significant difference was found in the attempts of single limb-stance. An average value of COP transition area in the study group was 261.2 mm^2 in single stance (on the right operated limb) and in the control group – 93.2 mm^2, so the difference was statistically significant ($p = 0.0096$). The presence of pain, the presence or the removal of anastomosis had no significant influence on the balance of the subjects under study. Also a significant correlation between the balance of the subjects and their age was found.

Conclusions: The balance in single limb stance after an instable ankle fracture within one year of the surgical procedure is significantly poorer in comparison with healthy subjects. Elderly persons have significantly poorer balance control.

Key words: *ankle fractures, operative treatment, balance*

1. Introduction

The ankle joint is a joint whose traumas belong to the most frequent traumas of the motor organ. One of the most severe forms of the ankle joint traumas are fractures of lower leg bones, frequently with an accompanying joint subluxation or luxation and the damage of the fibula-tibia syndesmosis [1]–[5]. The ankle fractures amount to 10 % of all types of fractures and they rank second with regard to the frequency of occurrence. It is generally assumed that the number of fractures increases in particular among elderly people [6], [7]. Among children, these traumas amount to 7% of all fractures, which makes them rank fourth after the fractures of the distal part of the forearm, the fractures of the clavicle and fingers [8]. The most frequent causes of lower leg fractures are the falls of one's own height, transportation accidents and falls from various heights. The frequency of fractures depends on the age and sex with a tendency to increase in a group of women over 60 years of age [9]–[10].

The pathological mechanism of ankle traumas is most frequently indirect and their genesis is varied. They can be caused by vertical, vertical and rotational, abductive and adductive forces acting on the foot placed either in pronation or in supination [11], [12]. Their action leads to stretching and then tearing the ligaments and articular capsule, tearing ligaments with the bone attachments and bone fractures, frequently with an accompanying luxation or subluxation of the

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talus bone and the damage of the distal tibia-fibula syndesmosis [13].

The objective of the treatment of the ankle fractures is the restoration of the joint function made as complete as possible. This is gained by means of as fast as possible setting the fracture, a precise restoration of the joint line congruency and joint density, effective stabilisation, possibly short period of immobilisation and, as fast as possible, initiation of the movement of the damaged joint [14]–[16]. Stable fractures without translocation or those in which translocation is only small and in which the length of the broken bone did not change much with the tarsal bone well positioned in relation to the particular surface of the tibia are treated conservatively. The treatment of ankle fractures, in particular of the medial bone with an accompanying tear of deltoid ligament and additional fracture of the lateral bone with the syndesmosis requires surgical treatment in order to reposition and stabilise the fractures [17], [18].

The damage of the internal and external articular structures occurring during the fracture leads to a significant disorder of the gait, decrease in activity in the patient's participation in various spheres of life. The time span of disability frequently lasts much longer than the period of healing and rebuilding of the bone and connective tissue structures. As a result of the fracture, and also within the course of the healing period, there are limitations of the joint mobility, decrease of muscle strength and proprioception, which leads to the impairment of the gait pattern with disorders of the body balance and stability. This, in turn, might increase a sense of uncertainly and fear while walking.

The control of the body balance in a standing position is a complex process. It is connected with a correct function and synergism of the central nervous system, organ of movement and sensory organs responsible for balance control and also with the planning and learning processes [19], [20].

Ankle fractures and their surgical treatment may significantly affect the stability of the entire human posture. The treatment of the damaged joint, first of all, aims at the restoration of its function in the highest possible scope. Postoperative rehabilitation consists in supporting the healing processes within bones and soft tissues, restoration of the range of mobility of the joint, work on muscular strength of the limb and correct co-ordination of their action. A very important role is played by balance and proprioception training, as the restoration of these two abilities has a significant influence on the clinical outcome of treatment and the patient's quality of life.

The objective of the work is to evaluate the balance of the patients after surgical treatment of ankle fractures, to assess the relationship between the balance and the age of the subjects and their range of movement in the ankle joint as well as the type of fracture and the existence of anastomosis.

2. Material

The study was carried out on a group of patients treated at the Traumatology and Orthopaedic Department at District Hospital in Mielec. The subjects qualified for the study were the patients admitted to hospital after the ankle fractures (one and two-bone fractures) treated surgically. The persons qualified for the study were the patients within at least one year of the surgical treatment, able to walk independently, not using any orthopaedic aids, and being able to load the operated limb. Patients with balance disorders on labirynth-related or neurological grounds, patients with a history of brain stroke, with an active alcohol disease, with sciatic neuralgia, damage of other joints and lower limbs, osteoarthritis of hip and knee joints, patients with endoplasties of the joints in lower limbs with prostheses, subjects suffering from pain with the intensity making single limb stance impossible and the persons with the disorders of peripheral circulation were not admitted to the study. The total number of subjects qualified to the study was 43 persons and 21 of them turned up for the examination. The study group comprised 20 healthy subjects with no pain ailments. Average age of the study subjects was 49 years, with mean age in the control group being 48 years.

The parameters studied were: balance which was evaluated in force platform examination, the intensity of pain in visual analogue scale (VAS) and the range of movement in the ankle joint of the operated limb.

The balance study applied the ST 310 force platform produced by Technobody with Stability ver. 2.1. software. The study consisted in the registration of patients in double stance with their eyes open, in double stance with the eyes closed, and in single stance of the healthy and of the operated limb. The time of parameters registration was 30 seconds for each of the positions studied. The following features were used for the analysis of the results: the velocity of the (COP) transition in anterior-posterior and lateral-medial directions (m/s), the length of the COP path (mm) and the area of the ellipsis of COP transition (mm^2). The preparation of the patient for the force

platform examination in double limb stance consisted in the placement of the patient's feet on the platform slightly astride and the pattern provided by the producer was used in the way that the reference line on the platform was aligned with projection of the tip of the lateral ankle on the surface and the feet were at equal distance from the midline of the device. The upper limbs during all the examinations were loosely down along the body. Before the beginning of the examinations, the patients were asked to assume the most correct motionless position with the sight directed straight onto the marker located on the wall (within the distance of 2 metres). After the end of the examination, the patients, with their eyes opened, were asked not to change the body posture and again to assume the most correct body position and to close their eyes. The subjects before the study could have one attempt of standing on one feet on the platform. For the examination in standing on one foot, the foot of the limb examined was placed in the way that the platform midline was aligned with the line going through the second toe and the middle of the heel. During the examination, the limb which was not examined was lifted in the way that the hip and knee joints were slightly bent. The upper limbs were loosely down along the body.

The results were processed in statistical analysis. Descriptive statistics were calculated. The significance of differences in the mean values of variables were evaluated with U Mann–Whitney–Wilcoxon test and with the Wilcoxon signed-rank test. Test result: $p \leq 0.05$ was regarded as statistically significant. The level of correlation was evaluated with the Pearson product-moment correlation coefficient.

3. Results

In the balance evaluation of subjects in double limb stance with open and closed eyes, mean values of specific parameters were higher in the study group than in the control one. The exception is the mean velocity of COP transition in frontal plane, where the mean values were almost the same in both groups. However, the differences between the average values were not statistically significant (Table 1).

Significant differences in mean values of the parameters studied were shown in the attempts of double limb stance. An average value of COP velocity in anterior-posterior direction in single stance on the operated leg was 12.25 mm/s, whilst in the control group, in standing on the left limb, the mean velocity was 7.57 mm/s. The difference was statistically significant (p =0.000451). In single stance on the operated right limb, the study group also had poorer results, which were statically significant (higher values). Mean values of COP velocity in lateral-medial direction, average value of COP transition and mean COP path length were higher for the study group in com-

Table 1. Stabilometric balance evaluation in double limb stance in the study and control groups in the attempts with open and closed eyes

Stabilogram	Attempt	x	Mdm	SD	Min	Max	P
V A-P (m/s)	OO B	3.48	3	1.29	2	7	0.189117
	OO K	2.86	3	0.77	2	4	
	OZ B	5.62	5	3.02	3	16	0.27381
	OZ K	4.5	4	0.74	2	8	
V M-L (m/s)	OO B	2.95	3	0.74	2	4	0.879563
	OO K	3	3	0.96	1	5	
	OZ B	4.24	4	1.3	2	7	0.544454
	OZ K	4.07	3.5	1.9	1	9	
DS (mm)	OO B	127.1	125	32.43	75	221	0.411
	OO K	118.14	114.5	29.08	69	164	
	OZ B	199.19	182	78.38	122	450	0.354
	OZ K	171.5	161.5	67.23	56	307	
PP (mm^2)	OO B	50	38	27.99	25	134	0.134
	OO K	40.5	34	29.98	14	134	
	OZ B	89.38	75	50.96	22	220	0.136
	OZ K	64.36	52.5	41.57	12	153	

V A-P – sway velocity of COP in anterior-posterior direction, V M-L – sway velocity of COP in lateral-medial direction, DS – length of COP transition path, PP – area of COP transition, OO B – open eyes attempt study group, OOK – open eyes attempt control group, OZB – closed eyes attempt study group OZK – closed eyes attempt control group.

Table 2. Stabilometric balance evaluation in the study group in single limb stance on the operated limb and in single limb stance on the healthy leg

Stabilogram	Attempt	*x*	Mdm	SD	Min	Max	*P*
V A-P (mm/s)	O kdl	12.25	11.5	3.28	9	18	0.000451
	K kdl	7.57	7	1.99	4	11	
	O kdp	11.69	12	3.17	7	16	0.000062
	K kdp	7	7	1.75	4	10	
V M-L (mm/s)	O kdl	12.75	14	3.92	5	17	0.017937
	K kdl	9.43	10	2.17	5	23	
	O kdp	12.69	13	4.82	6	24	0.010215
	K kdp	8.64	9	2.47	5	22	
DS (mm)	O kdl	513.75	517.5	69.81	387	594	0.000017
	K kdl	332.64	334.5	74.35	320	733	
	O kdp	487.38	485	122.46	292	788	0.000349
	K kdp	306.93	310	31.22	340	751	
PP (mm^2)	O kdl	168.38	162.5	68.9	86	290	0.009681
	K kdl	100.21	91	43.5	41	206	
	O kdp	261.23	148	200.72	83	726	0.000521
	K kdp	93.29	89.5	31.22	53	159	

V A-P – sway velocity of COP in anterior-posterior direction, V M-L – sway velocity of COP in lateral-medical direction, DS – the length of COP transition path, PP – transition area size COP, O kdp – single stance on the right foot in the operated limb, O kdl – single stance on the left foot in the operated limb, K kdl – single stance on the left foot – control group, K kdp – single stance on the left foot – control group.

parison with the control one. The differences were statistically significant (Table 2).

The stabiliometric analysis of the parameters in the operated and non operated limb in the patients with a fracture in history was performed. Mean sway velocity in anterior-posterior direction in single stance on the operated limb is 11.9 mm/s (Mdm = 12 mm/s), for non operated limbs the mean value is 10.9 mm (Mdm = 11 mm/s). The difference was statistically insignificant ($p = 0.09$). The mean velocity of lateral-medial sway in single stance on the operated limb is 12.71 mm/s (Mdm = 13.0 mm/s), and for non-operated limbs these values are as follows: mean velocity is 13.33 mm/s (Mdm = 12.0 mm/s). The difference was insignificant statistically ($p = 0.98$). The mean length of COP transition path in single stance, on the operated legs was 497.43 mm (Mdm = 497 mm), whilst for non-operated legs these values are the following: mean 466.81 mm (Mdm = 442 mm). The difference is not significant statistically ($p = 0.13$). A significant difference was observed between mean values of the surface area COP transition ($p = 0.019872$). The mean size of COP transition area in the operated limb was 225.86 mm^2, and in single stance on non operated limb – 175.86 mm^2.

In the study group, 11 persons reported no pain (VAS 0), and 10 persons reported some pain (group VAS 1) in the ankle joint of the operated limb. The mean value of the COP area in VAS 0 group was 209.55 mm^2 and in VAS 1 group – 243.9 mm^2 ($p = 0.909269$) (Table 3).

With regard to the removal of anastomosis, the subjects were divided into two subgroups: "bZe" – the subjects with removed anastomosis ($n = 7$), "Ze" group – with preserved anastomosis ($n = 14$). The subjects with removed anastomosis obtained higher values (poorer results) in average value of COP velocity in saggital plane and in mean area of COP transition. The mean COP velocity in frontal plane and mean COP length were higher in the group with existing anastomosis. The differences between mean values of the parameters studied were not statistically significant (Table 3).

In the study group the mean value of mobility in the ankle joint was 15° for the movement in dorsal flexion and 30° for flexion in plantar movement. There was almost only very slight negative correlation between the range of movement of dorsal flexion in ankle joint and the following properties: the sway velocity in saggital plane ($r = –0.11329$), sway velocity in frontal plane ($r = –0.17364$), COP path length ($r = –0.09586$), the area of the COP path ($r = –0.20629$). A poor correlation was observed between the scope of plantar flexion and sway velocity in saggital plane ($r = –0.41414$) and the scope of flexion in talocrural joint and COP path length ($r = –0.38778$). The correlation between the scope of plantar flexion in talocrural joint of the operated limb and the fol-

lowing properties: sway velocity of COP in frontal plane was $r = -0.18823$, and with the path area of COP $r = -0.28080$.

The analysis of the correlation between the balance and the age of the subjects was carried out taking into consideration single stance on the operated limb and on non operated limb. Mean values of the parameters studied obtained in a single stance on non operated limb correlated to a low and moderate degree with the age of the subjects (sway velocity of COP in saggital plane $r = 0.34019$; sway velocity of COP in frontal plane: $r = 0.30601$; the path length of COP: $r = 0.42980$; transition area of COP: $r = 0.45094$). In the examination of standing on the operated leg, mean values of the parameters studied displayed a good, positive correlation with the age of the subjects (sway velocity of COP in saggital plane $r = 0.47735$; sway velocity of COP in frontal plane: $r = 0.56642$; COP path length: $r = 0.67097$; transition area of COP: $r = 0.65022$).

The subjects were also divided into a group with the fracture of one bone ($n = 8$) and the group with the fractures of two or three bones ($n = 13$). The mean sway velocity in anterior-posterior direction in single stance on the operated leg in a group of subjects with the fractures of one bone is 13.13 ± 3.18 mm/s (Mdm 12 mm/s), and for the subjects with the fractures of two or three bones, these values are: mean 10.77 ± 3.06 mm/s (Mdm 9 mm/s). The value of the test of the significance of differences is $p = 0.11$. The mean sway velocity in medial-lateral direction in single stance on the operated leg in a group of patients with fractures of one bone is 14.13 ± 4.32 mm/s (Mdm 13.5 mm/s), and for the subjects with fractures of two or three bones these values are: mean 12.77 ± 4.06 mm/s (Mdm 13 mm/s). The value of the test of the significance of differences is $p = 0.94$. Mean value of COP path single stance on the operated leg in patients with the fractures of one bone is 548.13 ± 114.97 mm (Mdm 540.5 mm), and in patients with fractures of two or three bones, these values are: mean 468.69 ± 116.55 mm (Mdm 485 mm). The value of the test of differences significance is $p = 0.14$.

4.Discussion

The objective of the study was to evaluate balance in subjects with surgical treatment of ankle fractures and to find out whether in the period of more than a year after the fracture, the balance differs in comparison with healthy subjects. The influence of some selected factors on the balance of the subjects was also studied.

Table 3. Descriptive statistics and the results of statistical tests studied, taking into consideration the existence of pain in the ankle joint of the operated limb and the existence of anastomosis

Stabilogram	Study group	*x*	Mdm	SD	Min	Max	*p*
V A-P (m/s)	VAS 0	11.45	10	3.7	7	18	0.834942
	VAS 1	11.9	11.5	2.85	8	16	
	Ze	11.28	10.5	3.1	7	16	0.210069
	bZe	13.14	12	3.08	9	18	
V M-L (m/s)	VAS 0	13.55	14	2.84	8	17	0.782231
	VAS 1	13	12.5	5.33	6	24	
	Ze	13.43	14	4.97	5	24	0.304051
	bZe	11.29	12	2.69	8	15	
DS. (mm)	VAS 0	492.36	507	89.56	295	604	0.839385
	VAS 1	506.2	505.5	151.14	292	788	
	Ze	498.07	486	135.93	292	788	0.973323
	bZe	496.14	510	88.54	339	604	
PP (mm^2)	VAS 0	209.55	161	138.21	86	527	0.909269
	VAS 1	243.9	150	200.58	83	726	
	Ze	211.64	154.5	176.15	83	726	0.594805
	bZe	254.29	163	156.81	132	527	

V A-P – sway velocity of COP in anterior-posterior direction, V M-L – sway velocity of COP in lateral-medical direction, DS – the length of COP transition path, PP – transition area size COP, VAS 0 –study subgroup without pain in the anklel joint, VAS 1 – study subgroup with pain in the ankle joint, Ze – study subgroup with existing anastomosis, bZe – study subgroup with removed anastomosis.

The evaluation of balance in double limb stance with closed and open eyes did not show any statistically significant differences between the study and the control group. The evaluated parameters, the COP transition velocity in anterior-posterior and medial-lateral direction, the path length of COP transition and the area of COP transition did not differ much in significant way, but the majority of the parameters had slightly lower values than in the control group. Once the study is limited only to the evaluation in double limb stance, it may be supposed that one year after the surgery, the balance of the subjects is normal, on the same level as in healthy subjects or that the patients compensate the functions of the operated leg with the healthy one. In single limb stance there are significant differences in all parameters and there are also significant differences between the control and the study limb. Balance disorders illustrated with an increase of the value of the force platform examination parameters in single limb stance on the operated limb, may result from the disorder of the function of static and dynamic joint stabilisers, the limitation of the afferent sensory feedback and psychic factors, such as fear and the need to protect the limb. Weakening the damaged limb and its decreased ability may persist after the fracture for the period from 8 to 24 and more months [21]–[23]. Nilsson, when evaluating the balance with stabilometric examination in a group of 54 patients after the fractures of the distal epiphysis of the lower leg, showed that in a single limb stance, the subjects display a significantly larger sway velocity of COP in anterior-posterior direction whilst in medial-lateral direction no significant difference was found [23]. In the present study, no significant differences were found in mean transition velocity of COP, but it must be stressed that mean velocity in anterior-posterior direction was higher in standing on the operated limb. The area of COP transition was significantly smaller in standing on non-operated leg with very close values of the length of COP path.

Egol carried out the evaluation of the frequency of pain occurrence and intensification in a group of 232 patients after the ankle fractures. He proved that, one year after the fracture, 88% persons feel only some slight pain of the broken limb or no pain at all. Among those who experienced pain, 90% had no limitations in everyday activities [24]. In the study, the intensification of pain in the operated limb was only moderate. No significant influence of pain on the balance of the subjects was proven.

The results obtained by the subjects who had the anastomosis removed and by those who still had the anastomosis during the examination were compared and analysed. No statistically significant differences in the balance of the two groups were found. The objective of the study carried out by Kołodziej was to compare clinical results of the operative treatment of ankle fractures with co-existing damage of fibula-tibia syndesmosis in the group of patients who had the anastomosing screw of the syndesmosis removed with the results of the patients who, for various reasons, did not have the anastomosis of the syndesmosis removed.

The authors studied a group of 33 patients and proved that the removal of anastomosis did not have any influence on the treatment outcome [25]. The deterioration of balance with age is an obvious factor. The subjects of the study were people in the age group ranging between 20 and 65 years. In the non-operated limb, some slight positive correlations between age and balance were found. The correlation strength increases in the examination of the operated limb. A strong positive correlation between the age and COP transition speed in medial-lateral direction, path length and the transition length of COP were found. The outcome suggests that older subjects regain ability after ankle fractures at a slower pace, which makes their age a worsening factor in the prognosis of the functional outcome of the treatment of ankle fractures. This results from a slower pace of regaining the baseline value of muscular strength of the damaged limb after the period of immobilisation. The study which was carried out by Egol and Ekldah showed a significant correlation between the age of the subjects and their physical ability and balance after the fractures. Egol concludes that the return to a good condition is faster among younger people below 40 years of age. Jonsson in turn, emphasises the importance of the decrease of muscle strength with age and its influence on the deterioration of the balance [24], [26].

The present study, in spite of a small group of subjects with surgical treatment of ankle fractures showed significant difference in maintaining balance in comparison with healthy subjects. In particular, the symptoms of balance disorders concern elderly people, which may increase the risk of a fall, and also may be an important indication for intensive rehabilitation, even in a very remote period after the operative treatment of the fracture. On the basis of the patients' histories, it was established that 86% subjects used the rehabilitation at various periods after the operation. The types of these procedures were quite varied, yet it seems that they were mostly insufficient. Rehabilitation and its effects were not the objective of this study and they should be a separate study subject in a group of patients with lower leg bone fractures.

5. Conclusions

In the study group of persons within more than one year of the surgical treatment of the ankle joints, significant balance disorders in single-limb stance on the operated limb were shown. It was also shown that in the study group, balance disorders increased with age, yet they did not depend on the pain within the operated ankle joint. Balance disorders in the stance on the operated limb in the study group occurred irrespective of whether the anastomosis was removed or not within the period of one year of the treatment.

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