ASSESSMENT OF POSTURAL STABILITY IN PATIENTS WITH A TRANSTIBIAL AMPUTATION WITH VARIOUS TIMES OF PROSTHESIS USE

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Postural confidence is an initial precondition for all activities within the activity of daily living. Subjects with lower limb amputation have, due to somatosensory loss of information from the lower limb, more difficult conditions for maintaining postural stability in comparison with healthy subjects. Early prosthetic fitting with a prosthesis (with regard to amputation level, health state, financial claims, etc.) is crucial for amputee reintegration into daily life.

The aim of this study was to assess the selected biomechanical parameters of standing stability in patients with a transtibial lower limb amputation with various times of prosthesis use. The next aim was to assess how the waiting time for the prosthesis fitting influences standing stability in different situations.

The tested group was made up of 21 patients (the average age was 64.4 ± 9.18 years) with a unilateral transtibial amputation. The reason for amputation was in the case of 12 tested patients a vascular disease, in 8 patients trauma and in one it was a tumor. The average length of prosthesis use was 156.4 ± 359.6 days. A right side transtibial amputation had been performed on 10 patients and on the left side in 11 patients. To define the basic parameters of postural stability, two force plates of the Kistler (type 9286AA) were used. Stability was tested for 30 seconds in 4 standing positions (natural bipedal stand, bipedal stand with a narrow base, natural bipedal stand with closed eyes and standing on foam). For an influence assessment of the period of prosthesis use on the level of postural stability, correlation analysis was used. The difference between each standing modification was analysed by ANOVA for repeated measurements and LSD post hoc test.

In all tested situations, the loading of the sound limb is greater compared to the prosthetic limb in patients with a transtibial amputation (from 17.8% to 22.8%). This is also valid for COP sways in a mediolateral direction and for COP movement velocity in both anteroposterior and mediolateral directions ($p < 0.01$, $p < 0.05$). We did not find differences between all the tested standing modifications (except for the natural bipedal standing position) in sways and COP velocity movements. With a prolonged period of waiting for a prosthesis fitting we can observe an enlarged asymmetry of body weight distribution between the legs and also a higher range of COP sway and velocity.

In all measurements in patients with a transtibial amputation, our results show a greater loading on the sound limb compared to the prosthetic one. Faster prosthesis fitting decreases asymmetry from body weight distribution between both of the legs. The basic goal of achieving full value life in patients after lower limb amputation is a tendency towards early prosthesis fitting.

Keywords: Balance, lower limb amputation, posturography, weight bearing symmetry.

INTRODUCTION

It is necessary to perform most activities of daily living to keep one's postural stability. Central and peripheral diseases could lead to the impairment of postural control. Postural stability is influenced by body weight distribution. In the case of side affected disorders in the area of regulation, an abnormal asymmetry of weight distribution between both legs occurs. Symmetrical standing in healthy subjects provides maximal stability (Winter et al., 1996; Winter et al., 1998). The exact relationship between body weight distribution and postural stability is not known.

For everyday stability control the participation of sensory, visual, vestibular and cognitive systems as well as the motor control system are necessary. In the case of the deficiency of some of those systems, then the human organism is forced to adapt to these conditions and to compensate this deficiency with a different system (Meyer, Oddson, & De Luca, 2004).

An example of a somatosensory information loss from a lower limb is an amputation. Subjects with a lower limb amputation have difficulties with maintaining postural stability as a consequence of biomechanical changes caused by the absence of muscles, bones and joints and altered afferent and efferent projections as results (Vlahov, Myers, & Al-Ibrahim, 1990). These patients are forced to create a new control strategy of postural stability, and, eventually, to adapt commonly used strategies (Aruin, Nicholas, & Latash, 1997; Buckley, O'Driscoll, & Bennett, 2002; Viton et al., 2000).

Despite today's huge progress in medicine and mainly in prosthetics, lower limb amputation remains a big physical and psychological encumberment for a patient. The ratio of transfemoral and transtibial amputations incidents has been changing within the last few years. When deciding the level of amputation, in the case of the surgery of transtibial amputation, it is important to appreciate a higher risk of reamputation, a worse prognosis of wound healing, and the possibility of prolonged hospitalization. On the other hand, transtibial amputation has a significantly lower preoperative mortality compared to the transfemoral level of amputation (Bowker, 2004). Further advantages are a better rehabilitation perspective, a higher percentage of prosthesis fitted patients, lowering the cost of the prosthesis and an independent way of life with almost unlimited movement.

Most research studies, which focus on stability in subjects with lower limb amputation, are concentrated on stability control in quiet standing positions. The results of these works are not explicit. Buckley, O'Driscoll and Bennett (2002), Guerts et al. (1992), Fernie and Holliday (1978), Isakov et al. (1992), Hermodsson et al. (1994) state an increase in postural sways in subjects with lower limb amputation (short and long term prosthesis users) compared to healthy subjects. The standing stability in patients with amputations is altered in the way of postural sway increases and the stability control strategy changes as results (Viton et al., 2000). Other authors (Dornan, Fernie, & Holliday, 1978; Vittas, Larsen, & Jansen, 1986) do not confirm these increased postural sways.

In most of the studies, a one force plate is used to measure postural stability parameters. Studies, which separately analyse the prosthetic and non amputated leg, show a lowering of the load and decrease of the COP (centre of pressure) sway on the prosthetic limb (Guerts et al., 1992; Nadollek, Brauer, & Isles, 2002; Quai, Brauer, & Nitz, 2005).

Research confirms that good intact limb stability for the functional integration of an amputated subject into life is conditional (Schoppen et al., 2003).

The aim of the study was to assess the selected biomechanical parameters of standing stability in persons with transtibial amputation with various lengths of prosthesis use.

METHOD

Research group

The experimental group consists of 21 patients with a unilateral transtibial amputation (16 males, 5 females) from a Rehabilation Centre in Chuchelná. The average age of the patients was 64.4 ± 9.2 years, their average height was 174.3 ± 7.5 cm, and their average weight was 85 ± 16.3 kg, BMI 27.8 ± 4.4 kg/m^2. The reason for the amputation was, in 12 tested subjects, vascular disease, in 8 trauma and in one case it was a tumor. The average length of the prosthesis use was 156.4 ± 359.6 days. The average period from the surgery to the date of measuring was 247.8 ± 365.3 days. The average waiting time for prosthesis fitting was 210.2 ± 315.5 days. Right side transtibial amputation was performed on 10 patients and 11 had left side amputations. All tested subjects had, at the time of measurement, an activity level of 1 to 3 (evaluated by prosthetists). Patients with any health complications (wound, infection, etc.) were excluded.

Methods

To determine the basic biomechanical parameters of the postural stability in the observed subjects, two force plates Kistler (type 9286AA, Kistler Instrumente AG, Winterthur, Switzerland), with a scanning frequency of 200 Hz were used.

The process and organisation of measuring

The task of the observed subjects was to stand with each limb on one force plate, to adopt the required position and to keep this position for 30 seconds with the aim of minimizing body sways. During the recording of data, the tested subjects had their shoes on. Their stability was tested in four different modifications – a natural bipedal stand with opened eyes, a bipedal stand with a narrow base, a natural bipedal stand with closed eyes and standing on foam with a width of 5 cm. The patients were tested without any supporting devices.

Measured parameters and data analysis

For our study purposes from real values of vertical ground reaction force on the affected (P) and non affected (S) lower limb, the relative size of each leg loading (%) was derived in respect of the total force in a vertical direction. The assessment of stability was carried out with the use of a standard deviation of the COP position in both a mediolateral (Sway X) and an anteroposterior direction (Sway Y) and the COP velocity movement in both a mediolateral (Vx) and an anteroposterior direction (Vy). The measured data was analysed with the help of the software Bioware (version 3.2.6.104, Kistler Group, Winterthur, Switzerland) and was statistically analysed with the help of STATISTICA (version 6.0, StatSoft, Inc., Tulsa, Oklahoma, USA). For evaluating the relationship between the prosthesis use influence period and the lower limb loading, we used regression analysis. For influence assessment of the period of using a prosthesis on the level of postural stability, correlation analysis (Pearson's coefficient, Spearman's coefficient) was used. The difference between each standing modification was analysed by means of the analysis of variability for repeated measurement and the LSD post hoc test.

For documentation and better orientation, the whole process of measuring was recorded on a video camera. The results from the force plates were completed by taking information from medical documentation provided on the basis of an agreement with the tested subjects.

RESULTS

Lower leg loading and postural stability parameters

The average values of the observed parameters indicate the difference in lower leg loading and the process of COP movement deviations in both limbs in patients with transtibial amputation and are presented in TABLE 1. We found significant differences ($p < 0.01$, $p < 0.05$) between the sound and prosthetic leg for most measured parameters in each standing modification. The size of COP deviation in a mediolateral direction is greater on the affected limb and is valid for both parts of the COP velocity movement.

TABLE 1

Values of the observed parameters for assessing lower limb loading and the level of postural stability

	1		2		3		4		Difference
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	S × P
Sway X S	0.702	0.204	0.735	0.232	0.702	0.210	0.675	0.234	1*, 3**, 4**
Sway X P	0.946	0.498	0.956	0.371	0.991	0.532	0.897	0.490	
Sway Y S	1.463	0.431	1.479	0.444	1.664	0.438	1.405	0.444	DNF
Sway Y P	1.477	0.579	1.324	0.375	1.546	0.843	1.590	1.052	
Vx S	1.420	0.605	1.424	0.597	1.395	0.589	1.398	0.694	1*, 2*, 3**
Vx P	2.046	1.173	2.023	0.846	2.081	1.252	1.888	0.972	
Vy S	2.035	0.861	1.849	0.863	1.896	0.879	1.881	0.927	1*, 3**, 4**
Vy P	2.886	1.468	2.496	1.115	3.000	2.099	3.262	3.034	
V S	2.735	1.120	2.575	1.136	2.597	1.133	2.583	1.230	1*, 3**, 4**
V P	3.906	1.969	3.553	1.489	4.022	2.612	4.159	3.135	
Loading %	17.8	17.6	17.8	19.3	21.8	20.8	21.0	20.3	

Legend of TABLE 1, 2, 4:
Sway X – COP movement deviation in a mediolateral [cm]
Sway Y – COP movement deviation in an anteroposterior direction [cm]
Vx – COP velocity movement in a mediolateral direction [$m.s^{-1}$]
Vy – COP velocity movement in an anteroposterior direction [$m.s^{-1}$]
V – total COP velocity movement [$m.s^{-1}$]
Waiting period – time interval between amputation surgery and prosthesis fitting
Amp period – time interval between amputation surgery and our measurement
Fitting period – time interval between prosthesis fitting and our measurement
Loading % – difference between the relative loading on the sound and on the prosthetic limb [%]
S – sound limb
P – prosthetic limb
S × P – significant difference between the sound and the prosthetic limb
S – sound leg
P – prosthetic leg
1 – natural stand
2 – stand with a narrow base
3 – a natural stand with closed eyes
4 – a natural stand on foam
italics – a statistically significant difference $p < 0.05$
bold – a statistically significant difference $p < 0.01$

TABLE 2
Values of correlation coefficients describing relations between time period intervals and parameters in the level of postural stability

Limb		**Sound**					**Prosthetic**					**Loading %**
Parameter	**Stand**	**Sway X**	**Sway Y**	**Vx**	**Vy**	**V**	**Sway X**	**Sway Y**	**Vx**	**Vy**	**V**	
Waiting period	**1**	−0.19	−0.44	−0.11	−0.18	−0.15	*0.59*	**0.68**	*0.57*	*0.59*	**0.62**	**0.72**
	2	−0.43	*−0.55*	−0.38	−0.47	−0.44	0.39	0.27	0.39	0.26	0.32	*0.49*
	3	0.08	−0.01	0.11	0.09	0.11	**0.61**	*0.57*	*0.60*	*0.52*	*0.56*	*0.56*
	4	0.03	−0.22	0.07	−0.02	0.02	**0.61**	**0.76**	0.48	**0.63**	**0.66**	**0.70**
Amp period	**1**	0.05	*−0.46*	0.18	0.01	0.08	0.43	0.43	0.42	0.12	0.25	0.29
	2	−0.42	**−0.56**	−0.36	−0.40	−0.38	0.07	−0.02	0.05	−0.03	0.01	0.42
	3	−0.07	−0.29	−0.02	−0.17	−0.12	0.35	0.31	0.28	0.16	0.18	0.43
	4	−0.13	−0.35	−0.07	−0.11	−0.10	0.09	0.27	0.11	0.08	0.10	0.38
Fitting period	**1**	0.36	−0.03	*0.47*	0.28	0.35	**0.61**	*0.52*	**0.61**	0.38	*0.50*	0.25
	2	0.31	−0.12	0.45	0.33	0.36	0.25	0.30	0.30	0.32	0.32	0.10
	3	0.23	−0.11	0.25	0.38	0.37	0.27	0.27	0.29	0.37	0.38	0.17
	4	0.46	−0.02	0.44	0.20	0.33	0.13	0.23	0.25	0.27	0.27	−0.01

While comparing the observed parameters during various standing modifications (natural stand, stand with a narrow base, natural stand with closed eyes, natural stand on foam) we did not find any statistically significant differences ($p < 0.05$) in patients with a transtibial amputation for lower legs loading and for postural stability parameters on the sound and even on the prosthetic limb.

The influence of time period intervals bordered by amputation surgery, prosthesis fitting and the date of measurement on postural stability level

The dependence between the measured parameters and the time period intervals bordered by amputation surgery, prosthesis fitting and posturographic measurement expressed by values of correlation coefficients are shown in TABLE 2.

The time period between the amputation and prosthesis fitting significantly correlates for all types of natural stands with the parameters characterized by COP movement on the prosthetic limb and also with a loading difference between the sound and prosthetic limb.

Patients fitted with prostheses later have a greater COP sway with a faster COP velocity on the prosthetic limb and a greater asymmetry of body weight distribution between the lower legs (TABLE 3). The relationship between the time period of waiting for prosthesis fitting and an asymmetry of loading expressed by linear regression is shown in Fig. 1. The asymmetry of body weight distribution between both legs increases with an extending waiting time period.

We found a statistically significant dependence ($p < 0.01$, $p < 0.05$) on the time period between the time of prosthesis fitting and the date of measurement with the parameters of incident COP movement in a natural standing position. The differences in COP velocity movements and COP deviations increase with a longer period after prosthesis fitting.

TABLE 3
Values of regression coefficients and coefficients of the determination describing the relationship between the waiting period for the prosthesis fitting and the difference in lower legs loading

Stand	**b**	**a**	**r^2**
1	−0.023	0.002	0.519
2	0.000	0.002	0.241
3	0.018	0.002	0.315
4	−0.016	0.002	0.495

Legend:
a, b – quadratic regression coefficient
r^2 – coefficient of determination
1 – natural stand
2 – stand with a narrow base
3 – natural stand with closed eyes
4 – natural stand on foam

Dependence between the parameters characterized by COP sway and COP velocity movement

Parameters characterized by COP movement correlate to the prosthetic limb with COP velocity movement (except for standing on foam) and also with the difference between sound and prosthetic limb loading ($p < 0.01$). The tendency is similar to the sound limb, but only for COP movement in a mediolateral direction (TABLE 4).

Fig. 1
A graphical representation of linear regression describing the relationship between a waiting period for the prosthesis fitting and the difference in lower legs loading

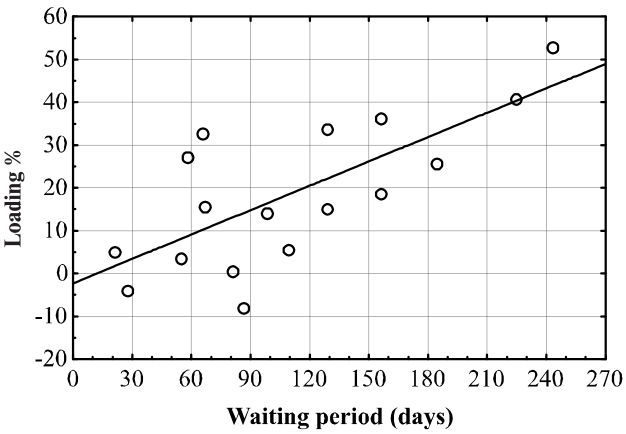

TABLE 4
Values of correlation coefficients describing relationships amongst the size of parameters characterizing a level of postural stability and its velocity changes

Limb	Parameter	Stand	Vx	Vy	V	Loading %
Sound	Sway X	1	**0.91**	**0.71**	**0.81**	−0.26
		2	**0.95**	**0.88**	**0.92**	−0.49
		3	**0.96**	**0.89**	**0.95**	−0.20
		4	**0.93**	**0.87**	**0.94**	−0.13
	Sway Y	1	0.06	0.22	0.16	−0.20
		2	*0.50*	**0.65**	*0.60*	−0.43
		3	0.25	0.24	0.25	−0.10
		4	0.17	*0.51*	0.40	−0.15
Prosthetic	Sway X	1	**0.99**	**0.79**	**0.90**	**0.71**
		2	**0.98**	**0.88**	**0.95**	**0.73**
		3	**0.98**	**0.92**	**0.95**	**0.67**
		4	**0.92**	0.34	0.47	**0.67**
	Sway Y	1	**0.88**	**0.94**	**0.96**	**0.78**
		2	**0.83**	**0.96**	**0.93**	**0.64**
		3	**0.90**	**0.98**	**0.97**	*0.58*
		4	*0.54*	**0.95**	**0.96**	**0.60**

DISCUSSION

Asymmetry of body weight distribution in patients with lower leg amputation

The results of our study show that measuring a group of patients with transtibial amputation while standing in different modifications applies a heavier load to the non affected limb (17.8–21.8%). The boundary value of physiological asymmetry in loading of the limbs is 10% (Véle, 1995). For the elderly, the mean limb load asymmetry while standing with eyes open was 7% (Blaszczyk et al., 2000).

While the advantage of increased healthy lower limb loading is better at control stability, the disadvantage remains the frequent overload and consequential joints arthrosis of this limb (Burke, Roman, & Wright, 1978; Nadollek, Brauer, & Isles, 2002).

Asymmetrical lower limb loading can be explained by listing the following reasons – decreased ankle movement, pain of the stump, discomfort caused by a hard prosthesis socket, etc. (Nadollek, Brauer, & Isles, 2002; Summers, Morrison, & Cochrane, 1988).

Postural stability decreases with the growing asymmetry of body weight distribution. This theory is confirmed by the results of some studies (Blaszczyk et al., 2000; Genthon & Rougier, 2005).

It is necessary to appreciate that this general hypothesis, when we count on a higher stability in biomechanical system symmetry, is not completely valid. The asymmetry while standing upright should be considered to be a part of functional asymmetry, which combines the anatomical human body asymmetry, and also restrictions, which appear together with the pathology and the body's ageing. The lower limbs' asymmetrical loading can, in older subjects, represent a compensatory mechanism of postural stability control (Blaszczyk et al., 2000).

Standing stability in patients after lower limb amputation

The research confirms that the good stability in the intact limb is conditional for the functional involvement of an amputated subject into life (Schoppen et al., 2003).

The standing stability in patients with a lower limb amputation is altered with the result of higher postural sways and changes of control stability strategy thus implied (Viton et al., 2000).

In our work, we learnt that there was an increase in postural deviations in subjects with transtibial amputation in comparison with the control group. Hermodsson et al. (1994) also confirms the increase of postural deviations after lower limb amputation (both short term and long term prosthesis users). Other studies, on the other hand, did not show any difference in healthy subjects (Vittas, Larsen, & Jansen, 1986; Dornan, Fernie, & Holliday, 1978).

Vittas, Larsen and Jansen (1986) came to the conclusions that patients with transtibial amputation have lowered postural sways compared to healthy subjects. However, only one force plate was used for measurement in this study. Studies, which separately analyse the prosthetic and non amputated lower limb, point towards a loading decrease and a decrease in COP deviations on the prosthetic lower limb (Guerts et al., 1992; Nadollek, Brauer, & Isles, 2002; Quai, Brauer, & Nitz, 2005).

Rogers, Hedman and Pai (1993) state that an improvement of bipedal standing stability would mean an improvement of locomotion stability. However, the measuring of static balance does not necessarily characterize the balance during motional activities as a movement from bipedal to monopedal standing or to walking (Mouchnino et al., 1992).

Influence of the waiting time for prosthesis fitting

The time the patient spends waiting for the prosthesis fitting shows itself to be key factor in our research for the symmetrical weight distribution between both lower limbs. It influenced parameters describing COP movement as well as the velocity of the COP movement on the prosthetic lower limb. With the longer waiting time for prosthesis fitting, the asymmetry of body weight distribution increases. The asymmetry of body weight distribution in healthy older subjects is linked with the enlargement of postural sway in an A/P direction (Blaszczyk et al., 2000; Marigold & Eng, 2006).

This fact was also verified in our study about patients with lower limb amputation. With a longer waiting time, the range of COP moves in an A/P direction, both on the healthy and prosthetic lower limb.

Influence of the time of prosthesis use

The duration of prosthesis use had a significant impact on the results of the measurement on a prosthetic limb in a natural bipedal stand. COP movement grows with the length of time the patient has the prosthesis available and the velocity grows and the extent of COP movement increases.

We can explain these facts by the tendency to involve a prosthetic limb more to the postural control of stability and resulting increase of COP movement velocity and COP deviations sways. Patients find confidence in the prosthesis use and begin to rely on it more.

The next question is why we can see this tendency only in the natural stand. This standing position can be less difficult for patients and therefore he/she involves the prosthetic limb in, while in other more difficult standing modifications he or she relies more on the sound limb.

Influence of sight

We did not find any statistical influence of sight and proprioception in the measured parameters of postural stability. These were surprising findings because, according to many studies, whereby disabling the sight control in subjects with amputation increases and COP sway on average in both legs, it manages to increase the non amputated lower limb loading (Guerts et al., 1992; Hermodsson et al., 1994; Isakov et al., 1992; Nadollek, Brauer, & Isles, 2002; Quai, Brauer, & Nitz, 2005). Vrieling et al. (2008) supposes that the influence of visual control intensifies, as a compensation mechanism of somatosensory deficit in patients, after lower limb amputation. In healthy subjects with disabilities of visual control, this difference in the loading of lower limbs was not found (Gauthier-Gagnon et al., 1986), or, respectively, only a very small difference (Guerts et al., 1992; Hermodsson et al., 1994; Isakov et al., 1992).

The loss of information from missing proprioreceptors of the foot is partly substituted for by an information transfer from the skin receptors, subcutis and also from receptors located in the muscles, ligaments and joints of the residual limb (Isakov et al., 1992).

One of the possible reasons could be the fact, that the skin on the stump becomes more sensitive to pressure at the point of stump and socket contact, which would make the control of the prosthesis easier. The adaptation could be caused also by expansion of afferent input on the intact lower limb. This idea has not been confirmed (Kavounoudias et al., 2005).

Limits of the study

With respect to the fact that we made the effort to simulate everyday life situations as much as possible, at most we did not come to the standardization of the standing position from the point of anteroposterior foot placement. It is necessary to appreciate that the tested persons, often just a few days after prosthesis fitting, are put up to solve difficult situations in keeping postural stability. For this reason we aimed to standardize the standing position only in the frontal plane. Earlier studies show that the foot position in healthy subjects is closer than for subjects with lower limb amputation (Fernie & Holliday, 1978) and that the dependence on visual control is lower for subjects with amputations in the case of a larger supporting base (Gauthier-Gagnon et al., 1986).

We unearthed another limit in that the patients couldn't be observed on a long term basis. Repetitions of measurements in these patients, which would lead to a data gain of changes in lower limb loading and postural stability, are, however, at this time, impossible.

CONCLUSIONS

1. In all types of standing, the modifications to the loading on the sound limb were greater than on the amputated one in persons with a transtibial amputation.
2. The size of the COP sway in the mediolateral direction is greater for the prosthetic limb in all standing modifications. This is valid for the COP velocity movement in both anteroposterior and mediolateral directions.

3. The size of the COP movement sway on the sound limb significantly correlates with the COP velocity movement in all types of standing positions.
4. We did not find any significant differences between each type of standing position (except natural stance) in a range of sway movements and COP velocity movements.
5. With a prolonged time period between surgery and prosthetic fitting, the asymmetry of loading between the amputated and the non amputated leg is bigger. We can find greater degrees of sway and the velocity of COP movement.

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REFERENCES

Aruin, A. S., Nicholas, J. J., & Latash, M. L. (1997). Anticipatory postural adjustment during standing in below the knee amputees. *Clinical Biomechanics, 12(1),* 52–59.

Blaszczyk, J. W., Prince, F., Raiche, M., & Hébert, R. (2000). Effect of ageing and vision on limb load asymmetry during quiet stance. *Journal of Biomechanics, 33(10)*, 1243–1248.

Bowker, J. H. (2004). Transfemoral amputation surgical management. In D. G. Smith, J. W. Michael, & J. H. Bowker (Eds.), *Atlas of Amputations and Limb Deficiencies. Surgical, Prosthetic, and Rehabilitation Principles* (3rd ed.) (pp. 589–619). Rosemont, IL: American Academy of Orthopaedic Surgeons.

Buckley, J. G., O'Driscoll, D., & Bennett, S. J. (2002). Postural sway and active balance performance in highly active lower-limb amputees. *American Journal of Physical Medicine & Rehabilitation, 81(1),* 13–20.

Burke, M. J., Roman, V., & Wright, V. (1978). Bone and joint changes in lower limb amputees. *Annals of the Rheumatic Diseases, 37(3)*, 252–254.

Dornan, J., Fernie, G. R., & Holliday, R. J. (1978). Visual input: Its importance in the control of postural sway. *Archives of Physical Medicine and Rehabilitation, 59(12)*, 586–591.

Fernie, G. R., & Holliday, P. J. (1978). Postural sway in amputees and normal subjects. *The Journal of Bone and Joint Surgery. American volume, 60(7)*, 895–898.

Gauthier-Gagnon, C., St-Pierre, D., Drouin, G., & Riley, E. (1986). Augmented sensory feedback in the early training of standing balance in below the knee amputees. *Physiotherapy Canada, 38(3),* 137–142.

Genthon, N., & Rougier, P. (2005). Influence of an asymmetrical body weight distribution on the control of undisturbed upright stance. *Journal of Biomechanics*, *38(10),* 2037–2049.

Guerts, A. C., Mulder, T. W., Nienhuis, B., & Rijken, R. A. (1992). Postural reorganization following lower limb amputation. Possible motor and sensory determinants of recovery. *Scandinavian Journal of Rehabilitation Medicine, 24(2),* 83–90.

Hermodsson, Y., Ekdahl, C., Persson, B. M., & Roxendal, G. (1994). Standing balance in trans-tibial amputees following vascular disease or trauma: A comparative study with healthy subjects. *Prosthetics and Orthotics International*, *18(3),* 150–158.

Isakov, E., Mizrahi, J., Ring, H., Suzak, Z., & Hakim, N. (1992). Standing sway and weight bearing distribution in people with below-knee amputation. *Archives of Physical Medicine and Rehabilitation, 73(2),* 174–178.

Kavounoudias, A., Tremblay, C., Gravel, D., Iancu, A., & Forget, R. (2005). Bilateral changes in somatosensory sensibility after unilateral below knee amputation. *Archives of Physical Medicine and Rehabilitation, 86(4),* 633–640.

Marigold, D. S., & Eng, J. J. (2006). The relationship of asymmetric weight bearing with postural sway and visual reliance in stroke. *Gait & Posture, 23(2)*, 249–255.

Meyer, P. F., Oddson, L. I., & De Luca, C. J. (2004). The role of plantar cutaneous sensation in unperturbed stance. *Experimental Brain Research, 156(4)*, 505–512.

Mouchnino, L., Aurenty, R., Massion, J., & Pedotti, A. (1992). Coordination between equilibrium and head trunk orientation during leg raising: A new strategy built up by training. *Journal of Neurophysiology, 67(6)*, 1587–1598.

Nadollek, H., Brauer, S., & Isles, R. (2002). Outcomes after transtibial amputation: The relationship between quiet stance ability, strength of hip abductor muscles and gait. *Physiotherapy Research International, 7(4),* 203–214.

Quai, T. M., Brauer, S., & Nitz, J. C. (2005). Somatosensation, circulation and stance balance in elderly divascular transtibial amputees. *Clinical Rehabilitation, 19(6),* 668–676.

Rogers, M. W., Hedman, L. D., & Pai, Y. C. (1993). Kinetic analysis of dynamic transition in stance support accompanying voluntary leg flexion movements in hemiparetic adults. *Archives of Physical Medicine and Rehabilitation, 74(1)*, 19–25.

Schoppen, T., Boonstra, A. M., Groothoff, J. W., de Vries, J., Göeken, L. N., & Eisma, W. H. (2003).

Physical, mental, and social predictors of functional outcome in unilateral lower limb amputees. *Archives of Physical Medicine and Rehabilitation, 84(6),* 803–811.

Summers, G. D., Morrison, J. D., & Cochrane, G. M. (1988). Amputee walking training: A preliminary study of biomechanical measurements of stance and balance. *International Disability Studies*, *10(1)*, 1–5.

Véle, F. (1995). *Kineziologie posturálního systému*. Praha: Univerzita Karlova.

Viton, J. M., Mouchnino, L., Mille, M. L., Cincera, M., Delarque, A., Pedotti, A., Bardot, A., & Massion, J. (2000). Equilibrium and movement control strategies in transtibial amputees. *Prosthetics and Orthotics International*, *24(2)*, 108–116.

Vittas, D., Larsen, T. K., & Jansen, C. (1986). Body sway in below knee amputees. *Prosthetics and Orthotics International*, *10(3)*, 139–141.

Vlahov, D., Myers, A. H., & Al-Ibrahim, M. S. (1990). Epidemiology of falls among patients in a rehabilitation hospital. *Archives of Physical Medicine and Rehabilitation*, *71(1)*, 8–12.

Vrieling, A. H., Van Keeken, H. G., Schoppen, T., Otten, E., Hof, A. L., Halbertsma, J. P. K., & Postem, K. (2008). Balance control on a moving platform in unilateral lower limb amputees. *Gait & Posture*, *28(2)*, 222–228.

Winter, D. A., Prince, F., Frank, J. S., Powell, C., & Zabjek, K. F. (1996). Unified theory regarding A/P and M/L balance in quiet standing. *Journal of Neurophysiology*, *75(6)*, 2334–2343.

Winter, D. A., Patla, A. E., Prince, F., Ishac, M., & Gielo-Perczak, K. (1998). Stiffness control of balance in quiet standing. *Journal of Neurophysiology*, *80(3)*, 1211–1221.

HODNOCENÍ POSTURÁLNÍ STABILITY PACIENTŮ S TRANSTIBIÁLNÍ AMPUTACÍ S RŮZNOU DOBOU POUŽÍVÁNÍ PROTÉZY

(Souhrn anglického textu)

Ztráta somatosenzorické informace z dolní končetiny způsobená amputací se podílí na vzniku potíží při udržení posturální stability, které zvyšují riziko pádu. Snaha o včasné vybavení protézou, při zohlednění všech působících vlivů (typ amputace, zdravotní stav pacienta, finanční náročnost apod.), je nezbytným předpokladem pro návrat osob s amputací do běžného života.

Cílem studie bylo zhodnocení vybraných biomechanických parametrů stability stoje u osob s transtibiální amputací s různou dobou používání protézy. Dále posouzení vlivu doby čekání na vybavení protetickou pomůckou na stabilitu stoje v různých situacích.

Sledovaný soubor tvořilo 21 pacientů (průměrný věk 64,4 ± 9,18 let) s jednostrannou transtibiální amputací. Příčinou amputace bylo u 12 testovaných osob cévní onemocnění, u 8 testovaných osob trauma a u 1 tumor. Průměrná délka používání protézy byla 156,4 ± 359,6 dnů. Pravostrannou transtibiální amputaci mělo 10 pacientů, 11 amputaci levostrannou. K určení základních parametrů posturální stability byly použity dvě silové plošiny Kistler (typ 9286AA). Stabilita byla testována po dobu 30 s ve 4 modifikacích stoje (přirozený bipedální stoj, bipedální stoj s úzkou bázi, přirozený bipedální stoj se zavřenýma očima a stoj na molitanu). Pro určení vlivu doby používání protézy na úroveň posturální stability jsme použili korelační analýzu. Rozdíl mezi jednotlivými modifikacemi stoje byl hodnocen analýzou rozptylu pro opakovaná měření a LSD post hoc testem.

Zatížení na zdravé končetině je u osob s transtibiální amputací ve všech typech stoje větší než na postižené končetině (rozdíl 17,8 až 21,8 % v závislosti na typu stoje). To platí také pro velikost výchylky COP v mediolaterálním směru a pro rychlost pohybu COP v anteroposteriorním a v mediolaterálním směru ($p < 0{,}01$, $p < 0{,}05$). Parametry charakterizující pohyb COP korelují ($p < 0{,}01$) na postižené končetině s rychlostí pohybu COP (s výjimkou stoje na molitanu, $p < 0{,}01$). Na zdravé končetině platí tato závislost pouze pro pohyb COP v mediolaterálním směru. Mezi jednotlivými typy stoje (s výjimkou přirozeného stoje) jsme nenalezli významné rozdíly v rozsahu a v rychlosti pohybu COP.

S rostoucí dobou, která uplyne mezi amputací a vybavením protetickou pomůckou, dochází k nárůstu asymetrie v zatížení amputované a zdravé končetiny, rozsah pohybu COP a jeho rychlost se zvětšují. Pro zmenšení pravděpodobnosti přetěžování zdravé končetiny v bipedálním stoji je nutné využít všechny možnosti pro zkrácení doby při vybavení protézou.

Klíčová slova: balance, amputace dolní končetiny, dynamografie, symetrie zatížení.

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First-line publications

Kozáková, D., Janura, M., & Rosický, J. (2009). Problematika pooperačního pahýlu u pacientů s transtibiální amputací pohledem fyzioterapeuta, biomechanika a protetika. *Rehabilitace a fyzikální lékařství, 3,* 102–108.

Kozáková, D., Svoboda, Z., Janura, M., & Paráková, B. (2008). Hodnocení posturální stability pacientů s transfemorální amputací s různou dobou používání protézy. *Česká kinantropologie, 12(4),* 77–86.

Kozáková, D., Janura, M., & Svoboda, Z. (2007). Hodnocení vlivu protetické fyzioterapie na vybrané biomechanické parametry u osob s transtibiální amputací. In K. Kovář & M. Šefl (Eds.), *Sborník příspěvků studentské vědecké konference Mladí ve vědě na počátku nového tisíciletí* (pp. 49–51). Praha: Univerzita Karlova.

Kozáková, D. (2007). *How can we measure function? Perceptive evaluation* [Educational material from seminar Clinical Considerations During Prosthetic Feet Prescription]. Frýdek Místek: Ossur Academy.

Kozáková, D. (2007). *Hodnocení údajů od uživatelů – jak můžeme měřit funkčnost?* [Výukový materiál ze semináře Klinické aspekty při volbě protetického chodidla]. Frýdek Místek: Ossur Academy.

Kozáková, D. (2007). *Amputee mobility predictor.* Frýdek Místek: Ossur Academy.

Kozáková, D., & Svoboda, Z. (2008). *Biomechanika nohy.* Frýdek Místek: Ossur Academy.