

THE VARIABILITY ASSESSMENT OF THE DYNAMIC GAIT PARAMETERS OF PERSONS WITH UNILATERAL TRANS-TIBIAL AMPUTATION

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Human gait is a genetically fixed motion model. The use of prosthesis changes the structure of the gait, the distribution of energy increases. The aim of this study was to compare the intra and inter individual variability of the basic dynamic gait parameters of physically active persons with unilateral trans-tibial amputation. A group of 11 males (age 46.1 ± 12.0 years, body weight 82.5 ± 13.9 kg) with unilateral trans-tibial amputation was analysed. The basic dynamic parameters (AMTI) of the gait of each subject with conventional and dynamic prosthetic foot were measured. The inter-individual variability in the group of the evaluated person is higher in comparison with the intraindividual variability. The sizes of the coefficients of reliability are exceeded for measured parameters (time, force, force impulse) in antero-posterior and in vertical direction the value 0.976. The extent of these values depends on the individual properties of evaluated person (for example the instability of the knee etc.).

Keywords: Gait, variability, dynamic, trans-tibial prosthesis.

INTRODUCTION

Human gait is a genetically fixed motion model, which forms due the individual properties during ontogenetic evolution. On one hand it is a movement activity with a lot of similar attributes during the execution by the various sorts of people. On the other hand it is also possible to observe by person different modifications. These differences related with health, mental components, changes in the external conditions etc. Every person chooses meanly the possibility the cadence of the gait, which allows him minimise the energy distribution. Soderberg (1997), Trew and Everett (1997) determines the magnitude of the vertical oscillation of the centre of mass as the criterion of the economy of the gait. For the facility of the quantitative analysis of the gait the maximal restriction of the negative parameters is needful. Very often is the gait of given individual described only on the basis of one attempt (one stride).

The situation is complicated for the persons who used the prosthesis. The changing of the locomotive stereotype may influent the replacement of the limb (segment), which does not related "directly" with the execution of the gait. The afferent information from the periphery is very important for the reflex modification of the movement pattern (Králíček, 1995). But this information disappears by the use of the prosthetics foot. Concurrently the identical input can produce various answers, in dependency on the phase of the gait cycle during that the input is affected (Mayer, 2000). The functional disorders of the motion system are appear-

ing in the diverse muscles activation (Rose & Gamble, 1994). The use of prosthesis changes the structure of the gait, the distribution of energy increases (Torburn et al., 1990; Macfarlane, Nielsen, & Shurr, 1997; Whittle, 1997). The prosthetic foot is less capable of absorbing and generating energy in comparison of the healthy limb. All these factors increase requirements on the stability of the movement. Inter and intrarater reliability of the two minutes walk test in individuals with trans-tibial amputation evaluated Brooks et al. (2002). The various type of the prosthesis influences also the loading of the sound limb (Bateni & Olney, 2002; Janura, Svoboda, & Elfmark, 2005). In doing so we have to start with the presumption that the properties of the prosthetic components of comfort and mobility are the two most important characteristics (Klute, Berge, & Segal, 2004; Van der Linde et al., 2004; May, 2002).

OBJECTIVES

The aim of this study is to compare the intra and inter-individual variability of the basic dynamic gait parameters of physically active persons with unilateral trans-tibial amputation.

The application of the prosthetic foot does not have to be the reason of the differences increasing if we assess the intraindividual variability of the gait parameters. The technique of this movement activity in common conditions can induce by the healthy person the sense of the security. It means to use "stand-by" if the conditions get

worse. The abilities for person with the prosthetic foot are considerably reduced.

MATERIAL AND METHODS

The group of 11 males (age 46.1 ± 12.0 years, body weight 82.5 ± 13.9 kg) with unilateral trans-tibial amputation was analysed. These subjects had been wearing their current prosthesis on average for 13.8 ± 12.5 years. The basic dynamic parameters (AMTI) of three walks of each subject with conventional (SACH) and dynamic (SUREFLEX) foot were measured. The force platforms data were normalised by the gravity force and analysed with the Matlab software.

The conventional prosthetic foot (low activity degree of the user) is stable foot with hardwood keel. Movement in the ankle is realised in the sagittal plane only. Stability in the end of the stance phase is poor. For the dynamic prosthetic foot (middle activity of the user) with the keel from graphite composite a good energy accumulation and subsequent release is typical. It is more expensive but also more comfortable for the active person. In ten subjects, the indication for amputation was traumatic reason whereas cerebral pathology was the indication in one candidate. In three of the subjects amputation was carried out for the right leg, while in the other eight it was the left leg. Six of the subjects had the KBM socket (conventional socket for transfer of load and suspension of the prosthesis, can be also applied with a silicon liner). Five of the amputees had the TSB socket prosthesis (full-fledged stump-socket fit with even pressure distribution, only with silicon liner). All amputees perform ordinary everyday activities, four of them practice active sports.

Prior to the measurement itself, each subject underwent adjustment and setting of the dynamic prosthetic foot by three prosthetic technicians. After testing the movement activity and after completion of three trial runs for this study, the dynamic foot was substituted by a conventional prosthetic foot and the entire procedure was repeated.

The statistical analysis of the examined data the programme Statistica 6.0 (ANOVA, coefficient of reliability) was used.

RESULTS AND DISCUSSION

The values of the coefficient of reliability for separated group of parameters are given in TABLE 1.

TABLE 1

The range of the coefficient of reliability of measured parameters on sound and prosthetic limb

	Prosthetics limb		Sound limb	
	SACH	Sureflex	SACH	Sureflex
Time parameters – step	>0.976	>0.982	>0.991	>0.991
Time parameters – stride	0.997–0.999			
Force parameters – step	>0.994	>0.989	>0.994	>0.994
Impulsion of force – step	>0.990	>0.976	>0.983	>0.993

Notice

In TABLE 1 are introduced the values of the parameters measured in antero-posterior (AP) and in vertical (V) direction. For medio-lateral (ML) direction we notice a considerable accrual of the intraindividual variability of the force variables.

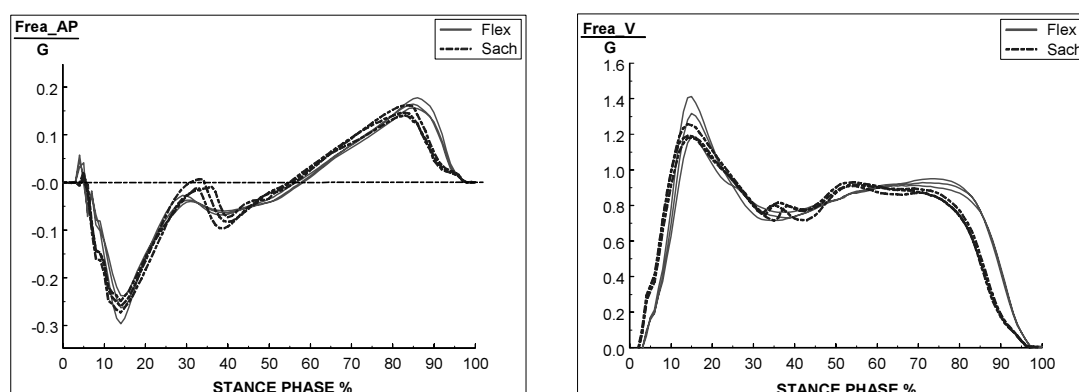
INTRAINDIVIDUAL VARIABILITY

The graphical depiction of the force-time dependency on the prosthetic limb in AP and in vertical direction by the selected person is on the Fig. 1. Even though they exist differences between these individual attempts it is possible to find similar characteristics. They are typical for the gait with given type (sometimes also with both types) of the prosthetic foot.

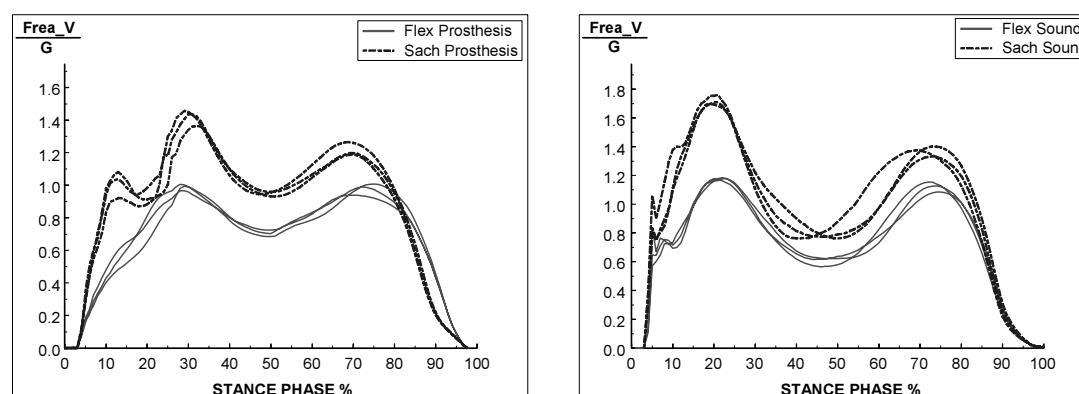
On the Fig. 2 is the comparison of the reaction force curve in vertical direction on the sound and disable limbs, various types of the prosthetic foot are used. The shape of the curves for three attempts with given type of prosthesis is similar. The magnitude of the maximum force in the acceleration and braking phase differs. Tendencies of the changes between sound and prosthetic limbs are similar. The values in the walking with the classic prosthetic foot are bigger for both (disable and sound) limbs.

Fig. 1

The shape of the reaction force curve in antero-posterior and in vertical direction by the use of the various type of the prosthetic foot

**Fig. 2**

The shape of the vertical component of the reaction force in contact phase of the step on the prosthetic (various types of the prosthetic foot) and sound limb



INTERINDIVIDUAL VARIABILITY

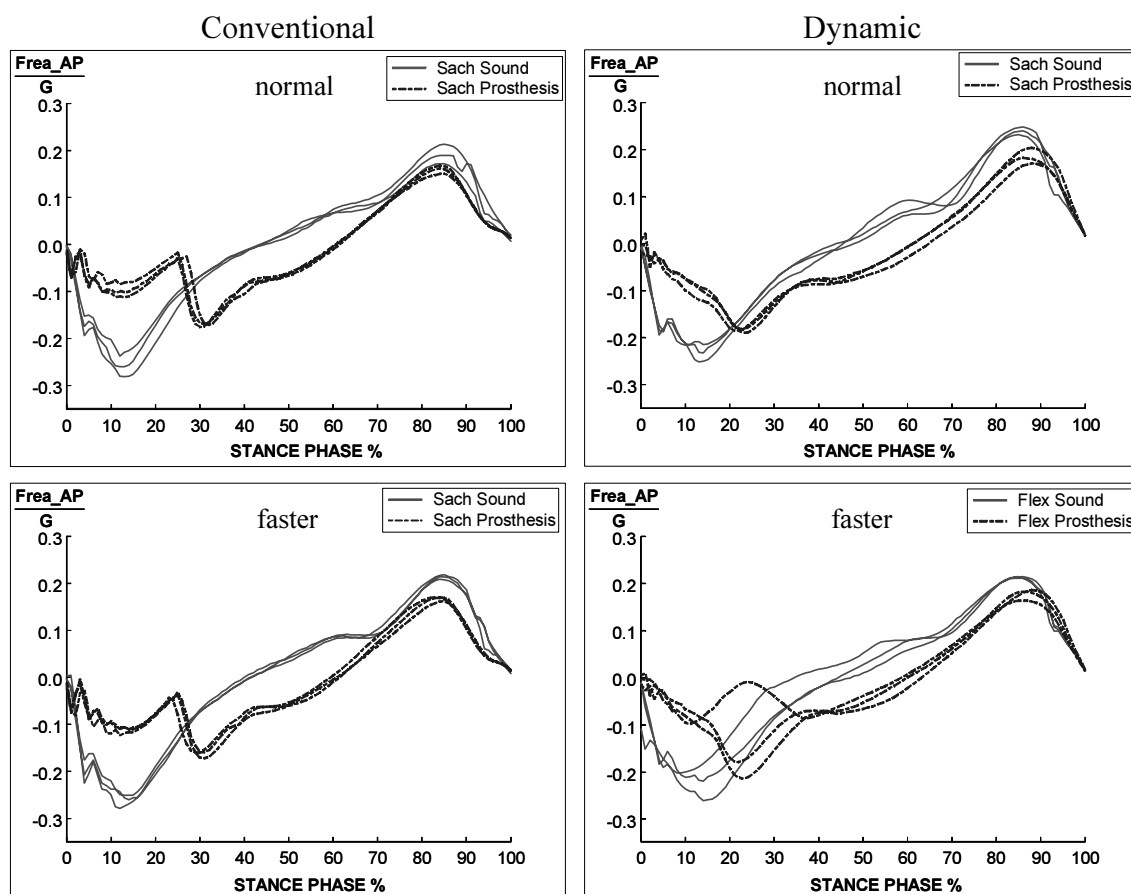
The traits of the selected components of the reaction force differs considerable among measured persons. The magnitude of the force impulse in the acceleration and in the braking phase of the step is changing. The number of the local extreme of the reaction force increases when using the prosthetic foot. The “classic” double apex curve is replaced by the curve with three and more apex. In the end of the braking phase is coming up the additional “deceleration” just before subsequent acceleration of the motion. There exist also differences in the magnitude of the maximal force in the vertical direction in the contact of the foot with the pad like that in the time of

the achievement of this maximum. For some persons we did not find the increasing of the force in the final part of take off. The significant differences among individual subjects we found also during the gait with the dynamic prosthetic foot. The size of these differences is smaller in comparison with the use of the conventional foot.

The magnitude of variability for various gait speeds is related to the overall health state and motion activity level of a given person. For people who execute common daily activities in a limited range, the variability of dynamic variables decreases with the use of a conventional foot (Fig. 3). Therefore the influence of speed accrument is necessarily considered in relation to the properties of the prosthetic foot and the internal variables of the locomotion system of each person.

Fig. 3

The influence of the gait speed on the shape of the force curve in the antero-posterior direction when using both conventional and dynamic prosthetic feet in users with a lower motion activity level



In subjects with amputations it is impossible to individually determine if the usage of prosthetic devices results in a decrease or, conversely, in an enhancement of parameter variability. The character of changes can be a criterion for the quality standard assessment of prosthetic tool setting. The variability of kinetic (GRF) parameters changes with walking speed alteration. From the movement control standpoint, the optimal speed was found to be (5.5–5.8 km.h⁻¹), which applies only for the propulsion control mechanism (Masani, Kouzaki, & Fukunaga, 2002).

Variance in gait speed within sessions is greater in healthy subjects as compared to persons with trans-femoral amputation (Boonstra, Fidler, & Eisma, 1993). Loading asymmetry increases during walking between the artificial limb and healthy limb. In healthy individuals the reaction force difference is under 10% (Hamil et al., 1983 in Nolan et al., 2003; Herzog et al., 1989), in amputees this difference is exceeded by 23% (Engsberg et al., 1993). It is impossible to increase the gait speed in subjects with amputation if this increase results in a loading of the asymmetry growth (Nolan et al., 2003). The variability of gait parameters over 5 days in persons

with trans-femoral amputation is greater than during one day (Dundass, Yao, & Mechefske, 2003). The amount of this variation among trials increases for amputees as compared with healthy subjects (Zahedi et al., 1997).

CONCLUSIONS

The execution of the gait in the group of person with trans-tibial amputation is stable from the point of view of the basic dynamic parameters. The interindividual variability in the group of the evaluated person is bigger in comparison with the intraindividual variability. The sizes of the coefficients of reliability are exceeded for measured parameters (time, force, force impulse) in antero-posterior and in vertical direction the value 0.976. The extent of these values depends on the individual properties of evaluated person (for example the instability of the knee etc.). The similar tendencies were found for the stability of the dynamic parameters on both types of the prosthetic foot as well as on the sound limb. The variability of the measured parameters in medio-lateral direction significantly increases inside the group like that for individual person.

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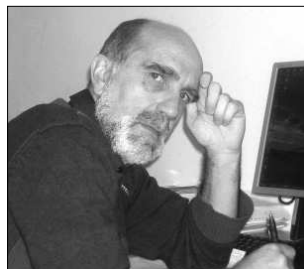
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**HODNOCENÍ VARIABILITY
DYNAMICKÝCH PARAMETRŮ CHŮZE
U OSOB S JEDNOSTRANNOU
TRANS-TIBIÁLNÍ AMPUTACÍ
(Souhrn anglického textu)**

Při analýze pohybové činnosti člověka musíme vždy řešit otázky, které se vztahují k validitě naměřených hodnot. Realizace každého pohybu, tedy i chůze, se vyznačuje určitou mírou variability. Přitom variabilitu v určitém rozsahu nelze považovat jako něco negativního, co může být způsobeno problémy v nervovém nebo kosterně-svalovém systému. „Přirozená“ variabilita (variabilita ve „fyzilogickém“ rozsahu) je součástí zdravých biologických systémů. Reedukace chůze u osob s trans-tibiální amputací se projevuje ve změně variability kinematických a dynamických charakteristik. Pro možnost kvantifikace těchto změn a pro určení vlivu různých typů protetických chodidel (klasické – SACH, dynamické – SUREFLEX) jsme provedli dynamickou analýzu chůze u 11 mužů (věk 46,1 ± 12,0 roku, hmotnost 82,5 ± 13,9 kg) s jednostrannou trans-tibiální amputací. Interindividuální variabilita v rámci dané skupiny je větší v porovnání s intraindividuální variabilitou. Hodnoty koeficientu reliability jsou pro měřené parametry (čas, síla, impuls síly) v antero-posteriorním a ve vertikálním směru větší než 0,976. Jejich velikost souvisí s individuálními vlastnostmi sledovaných osob.

Pro oba typy protetického chodidla, podobně jako pro zdravou končetinu, jsou tendence pro stabilitu dynamických parametrů podobné. Stabilita měřených parametrů v medio-laterálním směru se významně snižuje uvnitř sledované skupiny i pro jednotlivé osoby. Velikost variability při různé rychlosti chůze souvisí se zdravotním stavem a se stupněm pohybové aktivity daného probanda. Pro osoby, které vykonávají běžné denní aktivity v omezeném rozsahu, je variabilita dynamických parametrů chůze nižší při použití klasického chodidla.

Klíčová slova: chůze, variabilita, dynamika, transtibiální protéza.

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