Original Article

Laterality of lower limb and plantar pressure symmetry while walking in young adults

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ABSTRACT

The aim of this study is to discover whether the lateral preference of the lower limbs influences the selected dynamical parameters of the gait and to discover whether the data of the healthy limb can be used as reference ones in patients after lower limb injuries. 51young adults (age 22 ± 2 years, height 1.72 ± 0.1 m, body weight: 70 ± 16 kg) took part in the measurement. Foot preference for 5 different motion tasks (kicking a ball, stepping down from a stool, single leg stance, picking up marbles, hopping on one leg) was observed repetitively and dynamographic records of participants' gait using force plate (Emed®-c50, Novel, De) were performed. The average values of the maximum vertical force relativized to body weight (RF_{max}), maximal Peak Pressure (P.P), Force Time Integral (FTI) and Contact Time (C.T.) were analysed and the symmetrical indices (SI) were calculated. No statistically significant differences were measured in selected dynamic parameters between the preferred and non-preferred foot. The study of laterality in symmetrical gait in a group of young adults has proven that lateral preference of lower extremities does not significantly influence the selected dynamic parameters and that the gait in a group of young adults can be considered as symmetrical from this point of view. In a group of patients after lower limb injuries it is not necessary to take laterality before injury into consideration during walking at normal speed. **Keywords:** Dynamography; Foot preference; Gait; Injury; Motion tasks.

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INTRODUCTION

Walking is a fundamental means of human locomotion. Extensive specialist discussions are held about whether human gait is symmetric or not. Herzog et al. (1989) define gait symmetry as a perfect concordance between the activities of lower limbs. Other authors [2, 3] perceive the term of gait symmetry as walking where in the monitored parameters measured bilaterally there are no statistically significant differences. Sadeghi et al. (1997) speak of gait symmetry in the moment when both lower limbs behave identically.

Next to the hypothesis of gait symmetry, asymmetry is manifested primarily in patients after injuries of lower limbs (Devita et al., 1991; Griffin et al., 1995; Jandova et al., 2016). In the event that asymmetry is recorded in healthy individuals (Devita et al., 1991; Herzog et al., 1989), it is often associated with laterality of lower limbs (Maupas et al., 2002; Sadeghi et al., 1997; Strike and Taylor, 2009).

Lateral preference can be defined as a priority in the selection and use of paired limbs during specific activities. Implementation of physical activities usually requires the dominance of either the left or right hemisphere, while the left hemisphere controls the operation of the right side of the body and vice versa. Among the general population, preference to the right leg prevails in 76-86% of people (Bell and Gabbard, 2000; Dahmen and Fagard, 2005).

In literature there are many studies performed in patients after different lower limb injuries (e.g. Devita et al., 1991; Griffin et al., 1995; Jandova et al., 2016) or in those with various dysfunctions (Kalabova, 2015). When comparing quantitative parameters between a healthy and an injured leg, laterality is not usually taken into account. The question of whether this is correct or not it is still discussed (Vagenas and Hoshizaki, 1992) because a variety of factors related to the number of physical tasks carried out by the left leg, the number of tasks carried out with the right leg (Brown et al., 2006; Kalaycioglu et al., 2008).

This study is closely related to other conducted research focused on asymmetric dynamic gait parameters in patients after fracture of the calcaneus, where the reference data are those of a healthy limb. Patients during the rehabilitation process very often argued that they had already been walking asymmetrical before their foot was injured, that cannot be estimated. From this point of view it is very important to know, whether plantar pressure distribution in healthy people is symmetrical or it is influenced by laterality. In case of correlation between plantar pressure distribution and lower limb preference in a group of healthy young adults, the data in a group of patients after lower leg injuries from the healthy leg could not be taken as reference data.

The opinions regarding symmetry of kinetic data on walking of able-bodied subjects are not uniform in literature. Number of studies supports the hypothesis of asymmetry in kinetic data (Herzog, 1989) that is often explained by the laterality of lower extremities. According to some authors (Menard et al., 1992), the differences in the reaction forces between the left and right lower limb on the level of interaction with the ground during walking are not statistically significant. Inconsistency of researchers´ views led to the realization of this study.

The main objective of this study is to determine whether the plantar pressure distribution in walking in healthy young adults is symmetrical and to determine how this symmetry or/and asymmetry is potentially affected by laterality of lower limbs. Thus the question of whether it is possible to get the data from the healthy limb as a reference regardless of footedness (preference of a lower limb) will be answered.

In healthy young adults, preference of lower limbs for various motion tasks can be expected. Since walking is considered a symmetrical bipedal human activity learned from an early age, it can be assumed that the plantar pressure distribution when walking in healthy population will be symmetrical. Based on this, we hypothesise that in healthy young adults' gait there will not be any statistically significant differences in the plantar pressure distribution between the preferred and non-preferred leg. Due the laterality vertical forces and contact time with the ground on the left and right leg can slightly differ, but not significantly.

MATERIAL AND METHODS

The test group for measuring consisted of 51 young adults (21 males and 30 females, age 22 ± 2 years, height 1.72 ± 0.1 m, weight: 70 ± 16 kg). In each of them, preferences of the lower limbs for kicking a ball and hopping (Sadeghi et al., 1997) were determined. The participants had not been familiarized with the aim of monitoring in order that the selection of a preferred lower limb was spontaneous. Besides these two tests, dynamographic records of all participants´ gait at a normal speed (v = 5 km.h^{-1}) using force plates (Emed®-c50, Novel, Munich, Germany) were performed. During their walk, every third step in the sequence was measured. In each participant, a total of 10 steps (5 left, 5 right) were analysed, from which the average values of the maximum vertical force were further relativized to body weight (RF_{max}), maximal Peak Pressure (*P.P*), Force Time Integral (*FTI*) and Contact Time (*C.T.*). Based on measured variables the symmetrical indices (SI = left/right feet) were calculated. To verify the formulated hypothesis, a statistical analysis ($\chi 2$ test, Wilcoxon test) was performed by using a custom Matlab programme (Mathworks, Inc., Natick, MA, USA). The values were considered significantly different when $p < 0.05$.

All experiments were performed with the approval granted by the institutional Review Board. The experimental work conforms to the highest standards of safety and ethics, with respect to the Declaration of Helsinki and to the national laws. The informed consent of all people participating in the research has been obtained.

RESULTS

In a group of tested students, participants with right foot preference prevailed (right foot preference: 78.9 %, left foot preference: 6.7 %, ambidextrous: 14.4 %). Differences in plantar pressure distribution under the left and right feet are shown in Table 1. During healthy individuals' walk, no statistically significant differences were measured in *C.T.* or *FTI* between the preferred and non-preferred foot at any of the two tests performed (hopping, kicking a ball). Based on the calculation of the symmetry index, gait can be considered as symmetric from the perspective of selected dynamic parameters. In the RF_{max} case, there were statistically significant differences between the preferred and non-preferred foot for hopping and kicking a ball.

In healthy young individuals it was possible to observe an almost perfect symmetry at the level of interaction of the foot and the ground also in the case of trajectory of COP and pressure distribution (Fig. 1). In both the left and the right foot, trajectory of COP begins in the area below the calcaneus, continues through the middle part of the foot, III. metatarsal heads up to the big toe. In both the left and right foot, the maximal peak pressure is in the area under the heel and then under the metatarsal heads.

Table 1. Differences between measured variables of the left and right lower limb and symmetry indices

Variable		mean	SD	DIF	SI	Wilcoxon p-values hopping	Wilcoxon p-values kicking a ball
RF_{max}	left	1.235	0.081			0.5	0.25
	right	1.25	0.084	0.015	1.012	0.012*	0.016*
C.T.	left [ms]	772	82			0.867	-
	right [ms]	766	78	6	0.993	0.099	0.06
FTI	left [Nm]	466	144			0.5	0.75
	right [Nm]	465	140	1	1.001	0.682	0.664

*Legend: SI – symmetry indices (SI = left/right feet), DIF – difference between left and right feet, RFmax – relative maximal vertical [force/bodyweight/g], C.T. – contact time, FTI – force time integral; * p < 0.05.*

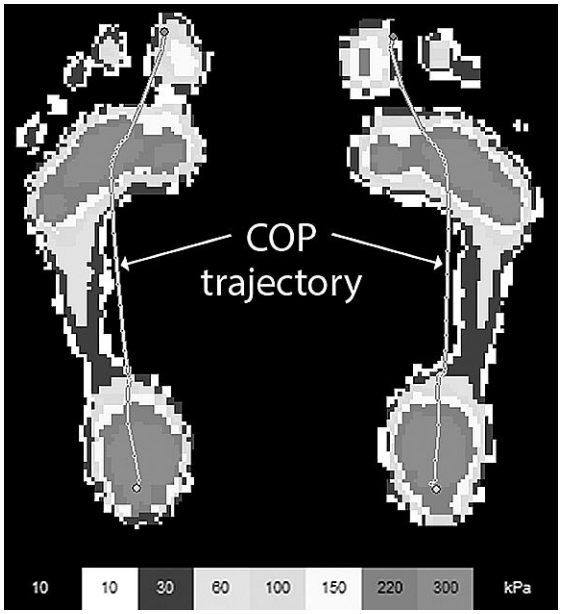

Figure 1. Dynamometrically measured variables during stance phase when walking: pressure distribution and trajectory of COP on the left and right feet

DISCUSSION

Laterality is a general descriptor of behavioural or functional asymmetry that occurs in people with lateral preference. The current trend in research of physical exercise recognizes the theory that people prefer one side over the other when carrying out various tasks (Kalaycioglu et al., 2008).

Based on the presented results, it can be stated that at two selected motion tasks (hopping, kicking a ball) preference of the right leg prevails (78.9 % participants with right foot preference, 6.7 % with left foot preference and 14.4 % ambidextrous), which is consistent with previous studies (Schneiders et al., 2010), according to which 76 – 87 % of people prefer the right lower limb.

In connection with the question whether healthy young adults' gait is symmetrical or whether LL preference affects dynamic gait parameters, it was found out that in the case of *C.T.* and *FTI*, absolute measured values are not entirely identical (Rosenrot, 1980), however the difference between the values of the left and on the right leg is not statistically significant and SI approaches the value 1. On this basis, it is possible to be inclined

to think that healthy young individuals' gait is symmetrical (Gundersen et al., 1989) and is not influenced by any LL preferences in either of the performed motor tests. On the other hand, although in the case of RF_{max} (relative maximal vertical force) there is a relationship between foot preference and the RF_{max}. This can be explained by greater force production on the preferred limb in different variants of jumps (Meylan et al., 2010; Miyaguchi and Demura, 2010).

Based on the conducted measurements and the subsequent statistical processing, the hypothesis that in *C.T.* and *FTI* between the preferred and non-preferred lower limb in a group of healthy young adults there are not statistically significant differences was confirmed. This finding is very important for the evaluation of asymmetry gait in patients where data of the healthy limb are taken as reference ones (Devita et al., 1991; Griffin et al., 1995; Jandova et al., 2016; Titianova and Tarkka, 1995; White et al., 2004). Speculation whether this is correct (Vagenas and Hoshizaki, 1992) would probably survive. However, taking into consideration pre-traumatic status in terms of distribution of ground pressure is not real; moreover - from the viewpoint of laterality of lower limbs - it is not even necessary in young people. Nevertheless, the question remains whether this also applies for other age groups. Furthermore, it is necessary to consider the relationship between walking speed and the differences in dynamic parameters in future research, since the influence of walking speed and the influence of LL laterality on plantar pressure distribution in some physical activities has already been proved (Jandova et al., 2015).

In terms of selected dynamic parameters (contact time, peak pressure and force time integral), healthy young individuals' gait at normal speed can be considered as symmetrical.

The difference in the values of the vertical force component measured on the preferred and nonpreferred LL are statistically significant.

C.T. or *FTI* are not affected by LL preferences for selected motor tasks.

For practical purposes, it can be concluded that when observing the dynamic parameters (plantar pressure distribution) in patients after LL injuries the data of the healthy limb can be used as reference ones; laterality before an injury does not have to be taken into consideration during waking at normal speed.

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CONFLICT OF INTEREST DECLARATION

We, authors, confirm that we do not have any conflict of interest in connexion to the study.

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