

# SYMMETRY AND VARIABILITY OF THE FIRST PART OF THE VERTICAL GROUND REACTION FORCE DURING BAREFOOT WALKING

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## INTRODUCTION

Healthy normal individuals during walking show a vertical ground reaction force pattern with a small variability (Stacoff, Diezi et al. 2005) and a high symmetry, although some degree of variability and asymmetry is observed (Maria Kim and J. Eng 2003; White, Gilchrist et al. 2004; Stacoff, Diezi et al. 2005). The trial to trial variability is determined by the coefficient of variation (Stacoff, Diezi et al. 2005). To evaluate the symmetry between the two lower limbs the symmetry index is used. Both parameters are used to evaluate the gait, the implementation of insoles and/or the recovery after a surgery (Ocaña, Gómez Pellico et al. 1993; Steven and Regina 2003). The purpose of this study is to analyze the influence of barefoot walking at self-selected speed on the symmetry and on the variability of the first part of the vertical ground reaction force.

## MATERIAL AND METHODS

Fourty five firemen took part in the study. It took place at the Human Motion Analysis Research Laboratory in the Basurto's Hospital. Two force platforms were installed flush with the ground in the center of a 10 meters walkway. The subjects undertook several practice to ensure that they were familiar with the laboratory dimensions and the placement of the force platforms. Each subject conducted five barefoot walking trials. Two consecutive steps were recorded in each trial. Subjects were asked to walk at self-selected speed over the force platforms. Trials would be accepted if there were no visible alteration of the stride as the subjects walked across the platforms, the entire right foot landed on the first platform and the left foot on the second platform and the speed showed a consistency between different trials. The vertical ground reaction force was collected at a sampling frequency of 500Hz. Forces were normalized to the subjects' bodyweight. For the analysis of the first part of the vertical ground reaction force three variables for each limb were registered; the heel strike transient (Fz1), the first thrust maximum (Fz2), and the thrust maximum loading rate (LR). The term "heelstrike transient" refers to the impact between the foot and the ground, when a spike of force is superimposed on the upslope of vertical the ground reaction force (Whittle 1999). We considered the presence of the heel strike transient when the spike of force descended 20N before its ascending to the first thrust maximum. The first thrust maximum is the peak force during the weight acceptance phase of stance (Maria Kim and J. Eng 2003; Stacoff, Diezi et al. 2005). The loading rate was calculated by the method proposed by Keller et al. (Keller, Weisberger et al. 1996), dividing the first thrust maximum by the time interval between initial foot contact and the occurrence of the vertical first thrust maximum.

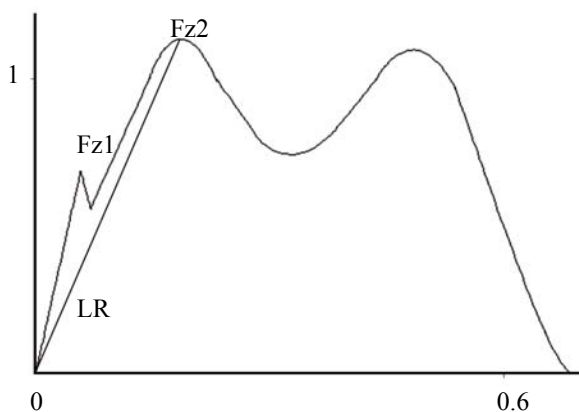


Fig. 1. Measured parameters during walking at self-selected speed.

The symmetry of the first part of the vertical ground reaction force of two consecutive steps was obtained with the absolute symmetry index formula proposed by Stacoff (Stacoff, Diezi et al. 2005).

$$SI = \left| \frac{X_{right} - X_{left}}{(X_{right} + X_{left}) \times 0.5} \right| \times 100$$

The  $X_{right}$  is the variable recorded for the right limb and  $X_{left}$  is the corresponding variable for the left limb. A symmetry index of zero represents perfect symmetry.

To determine the trial to trial variability the formula used by Stacoff (Stacoff, Diezi et al. 2005) was used:

$$CV (\%) = \frac{\text{standard deviation}}{\text{mean}} \times 100 \%$$

## RESULTS

225 trials were analyzed. LR and Fz2 were detected in every trial for both legs. Fz1 for the right limb took place in 191 trials (84.89%) and for the left limb in 205 trials (91.11%).

Table 1. Absolute symmetry indices ( $\pm$  S.D).

	ASI
Fz1 (%)	3.03 $\pm$ 2.39
Fz2 (%)	1.26 $\pm$ 1.06
LR (%)	3.31 $\pm$ 3.80

Table 2. Mean values ( $\pm$  S.D.) of the coefficient of variation for both steps. \* indicates significant difference between groups ( $P < 0.01$ ).

	Mean	
	Right	Left
Fz1 (%)	8 $\pm$ 3.68	7.05 $\pm$ 3.07
Fz2 (%)	2.53* $\pm$ 0.88	2.54* $\pm$ 0.93
LR (%)	6 $\pm$ 3.39	7.24 $\pm$ 3.6

## DISCUSSION AND CONCLUSION

The absolute symmetry index of Fz1, Fz2 and LR presented average values between 1 and 4%. These values supported the results of Stacoff (Stacoff, Diezi et al. 2005) and Giakas and Baltzopoulos (Giakas and Baltzopoulos 1997). The formers found that the absolute symmetry index of Fz2 during walking at self selected speed ranged from 3 to 5%. The latter found similar results during two separated steps. White (White et al. 1999) found higher values in children. Our results are smaller than the 5% that Stacoff (Stacoff, Diezi et al. 2005) considered of normal walking.

The coefficient of variation of Fz2 is significantly smaller than the coefficient of Fz1 and LR. This difference indicates that the first thrust maximum shows a smaller variability than the heel strike transient and the loading rate. Fz1, Fz2 and LR show a coefficient of variation around 2-8% which is below the 12,5% that is considered of normal walking by White (White, Agouris et al. 1999)

The results of this study demonstrated that in healthy normal individuals walking at self-selected speed the first part of the vertical ground reaction force shows a high symmetry and a small variability.

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