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AN EXPLORATION OF THE VERTICAL GROUND REACTION FORCES ON DIFFERENT STEPS DURING STAIR ASCENT AND DESCENT IN HEALTHY ADULTS

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1 INTRODUCTION

Vertical Ground Reaction Forces (VGRF) are an important indicator of the load imposed on the lower limb during a locomotion task and can be a predictor of overloading of the musculoskeletal system[1,2]. Stair walking is a task that is biomechanically challenging for all individuals and many studies have demonstrated the differences between ascending and descending[3]. However, few studies have shown differences in demand on the musculoskeletal system on different steps when ascending and descending. This may offer important information as each step may produce a different demand on the lower limb[2,3] which should be taken into consideration when assessing these tasks. Therefore, the aim of this study is to analyze the VGRF during stair ascent-descent and to compare the forces generated on each step.

2 METHODS

Twenty-one healthy adults (11 female, 10 male), 29±4.7 years old, height of 1.67±0.08 m, and weight of 67.9±12.2 kg participated in this study. This cross-sectional study was approved by the ethics committee of Faculty of Sport from University of Porto, and all volunteers signed the informed consent form. A four-step staircase was constructed with a force platform embedded on each step (two Bertec, OH, USA and two AMTI, MA, USA) operating at 2000 Hz. The steps had a riser height of 17 cm, run of 25 cm, and width of 60 cm. Participants were instructed to perform five repetitions of stair ascent and descent at self-selected pace. Each task began with the participant at rest in front of the first step and ended on the last step (or ground), standing still and looking straight ahead. The movement was initiated with the non-dominant limb. The average of five repetitions of the three middle steps were used for analysis (Figure 1). Data were processed in Visual3D (HAS-Motion, Canada) and a fourth-order Butterworth low pass filter with cut-off frequency of 25 Hz was applied. Further analysis was made in Matlab (The MathWorks Inc., USA) and were analyzed for each task (ascent and descent) and each step (steps 1, 2, 3 for ascending and steps 3, 2, 1 for descending) separately. Data were then normalized to body mass. The variables were F1, F2, F3, where F: peak force, and total contact time (Figure 2).

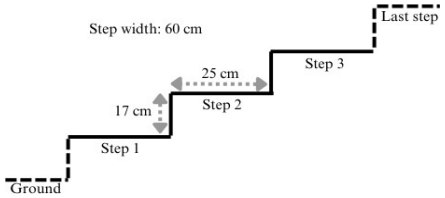

Figure 1. Experimental setup.

Data analysis was performed using SPSS version 29 (IBM, USA). All data were found to be not normally distributed using the Shapiro-Wilk tests. The Friedman test was used to compare the three steps during ascent and descent separately. When p-value was less than 0.05, the Wilcoxon test was used for pairwise comparisons between steps with a significance value of $p<0.05$.

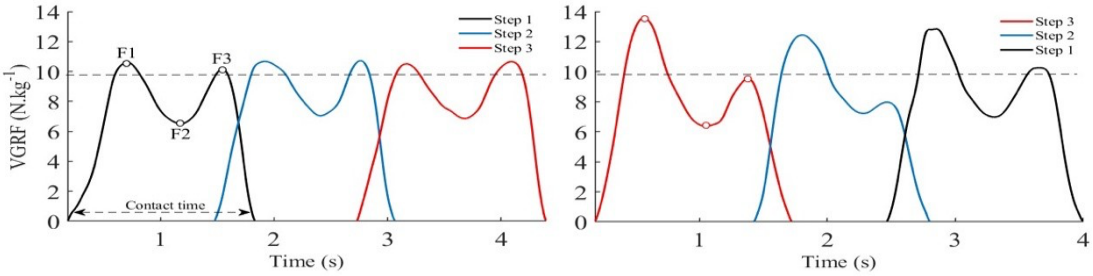

Figure 2. VGRF for the three steps during ascent (right) and descent (left).

3 RESULTS AND DISCUSSION

The results of VGRF for ascent and descent are presented in table 1 and 2, respectively.

Table 1. Median and Interquartile ranges of VGRF during ascent stairs.

	ASCENT			
Variables	STEP 1	STEP 2	STEP 3	P value
F1 (N.kg^{-1})	11.06 (10.88-11.71)	11.19 (10.85-11.63)	11.21 (10.76-11.72)	0.867
F2 (N.kg^{-1})	6.57 (6.13-7.41)	7.01 (6.29-7.41)	6.86 (6.44-7.26)	<.001*
F3 (N.kg^{-1})	9.95 (9.82-10.42)	10.25 (10.03-10.50)	10.28 (9.84-10.60)	0.055
Total time (s)	0.87 (0.81-0.99)	0.84 (0.81-0.93)	0.90 (0.86-0.98)	<.001*

F: peak force; N/Kg^{-1}: Newtons per kilo; s: seconds; *: p<0.05 from Friedman test.

During the ascent, Wilcoxon tests showed F2 was significantly higher in step 2 compared to step 1 (p=0.001) and in step 3 compared to step 1 (p=0.002), and contact time was significantly higher in step 1 comparing to step 2 (p=0.005) and in step 3 compared to step 2 (p<0.001).

Table 2. Median and Interquartile ranges of VGRF during descent stairs.

	DESCENT			
Variables	STEP 3	STEP 2	STEP 1	P value
F1 (N.kg^{-1})	12.79 (12.10-13.70)	13.55 (12.73-14.37)	13.22 (12.69-14.07)	0.010*
F2 (N.kg^{-1})	7.07 (6.79-7.44)	7.33 (6.86-7.45)	7.39 (6.92-7.82)	0.013*
F3 (N.kg^{-1})	9.33 (9.08-9.82)	9.10 (8.68-9.71)	9.35 (8.83-10.04)	0.156
Total time (s)	0.79 (0.76-0.85)	0.77 (0.72-0.80)	0.81 (0.76-0.85)	<.001*

F: peak force; N/Kg^{-1}: Newtons per kilo; s: seconds; *: p<0.05 from Friedman test.

During the descent, Wilcoxon tests showed F1 was higher on step 2 compared to step 3 (p=0.008), and contact time was significantly higher in step 1 compared to step 2 (p<0.001) and in step 3 compared to step 2 (p<0.001). These differences suggest that a variety of movement patterns may be occurring when comparing each step during stair ascent and descent. Exploring these data can provide important information about the body's push-off and propulsion forces at each step and can increase the possibilities for analyses that can be performed on a staircase instrumented with force plates.

4 CONCLUSIONS

The differences between the parameters in VGRF related to each step highlighted that each one is different from each other throughout the ascent or descent cycle, suggesting that each movement phase may be related to a different musculoskeletal demand.

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