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PLANTAR PRESSURE DISTRIBUTION DURING STAIR ASCENT AND DESCENT

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1 INTRODUCTION

Given the prevalence of stairs in everyday environments, stair ascent and descent impose increased biomechanical demands on the lower extremities [2,3]. During ascent, muscle energy is converted to gravitational energy, whereas during descent, muscles must absorb this energy [4], . Understanding plantar pressure distribution during these activities is important for assessing specific foot-ankle function and comprehend foot rollover mechanism for optimizing training protocols. This study aims to compare plantar pressure and its distribution across ten anatomical regions of the foot during stair ascent and descent in healthy adults.

2 METHODS

This cross-sectional study involved 10 healthy adults (4 female, 6 males; age: 29.6±3.6 years old; height: 1.70±0.09 m; mass: 73.80±16.09 kg) with no previous musculoskeletal injuries in the last six months. All provided informed consent prior to data collection and the study was approved by the local ethics committee. Each participant completed three repetitions of stair ascent and descent. The staircase consisted of four steps, each with a 17 cm riser, 25 cm run, and a width of 60 cm. The exception was the fourth step, which had a run of 90 cm and served as the ending platform. Participants were instructed to look ahead, perform the condition naturally at a self-selected speed, and start with the non-dominant lower limb to ensure the dominant foot consistently stepped on the second step, which was designated for analysis. Plantar pressure data were collected using the Pedar-X in-shoe pressure measurement system (Novel Corporation, Munich, Germany) and were recorded at a frequency of 100 Hz. The data were processed using Matlab (The MathWorks Inc., USA) and filtered using bidirectional fourth-order Butterworth low-pass filter with a cutoff frequency of 8 Hz. The variables extracted were peak pressure, mean pressure and pressure-time integral for 10 anatomical regions of the foot [1], as described in Figure 1. Statistical analysis was performed using the SPSS version 29 (IBM, USA). A repeated measures analysis of variance (ANOVA) was conducted to analyze mean differences in dependent variables across the two conditions (ascent and descent). Bonferroni correction was applied to the pairwise comparisons, with a significance level set at $\alpha=0.05$ for all statistical tests. Effect sizes were evaluated using eta squared (η^2), where $\eta^2<0.01$ indicates a small effect, $0.01\leq\eta^2< 0.06$ represents a medium effect, and $\eta^2\geq0.06$ signifies a large effect.

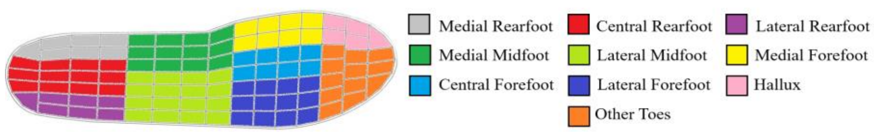

Figure 1- Representation of the ten anatomical regions used for foot segmentation.

3 RESULTS AND DISCUSSION

Table 1. Mean and standard deviation obtained for each foot region during stair ascent and descent.

		MedRF	CentRF	LatRF	MedMF	LatMF	MedFF	CentFF	LatFF	Hallux	OT	*P* value	η²
Peak pressure (kPa)	ASC	61.5 (22.3)	94.6 (26.4)	56.8 (20.5)	1.0 (1.7)	43.1 (21.4)	102.0 (53.7)	113.0 (32.0)	122.0 (32.3)	123.0 (49.8)	34.1 (9.2)	0.006*	0.583
	DES	73.9 (35.5)	105.0 (31.7)	51.0 (18.9)	0.8 (1.0)	45.0 (21.6)	145.0 (58.8)	119.0 (39.2)	119.0 (28.0)	150.0 (89.8)	38.3 (11.1)		
Mean pressure (kPa)	ASC	23.8 (11.4)	42.4 (15.5)	24.3 (9.7)	0.2 (0.4)	18.9 (11.3)	44.1 (26.1)	43.5 (14.1)	48.8 (15.5)	38.2 (26.2)	8.4 (4.6)	0.003*	0.640
	DES	24.9 (16.9)	34.8 (16.8)	14.8 (6.4)	0.1 (0.2)	13.0 (7.7)	62.7 (30.7)	57.7 (22.1)	52.9 (19.4)	46.1 (29.2)	11.8 (5.0)		
Pressure-time Integral (kPa·s)	ASC	24.7 (12.2)	43.9 (17.6)	25.2 (10.8)	0.3 (0.5)	19.1 (11.3)	44.9 (27.3)	43.8 (12.7)	49.4 (15.1)	39.3 (28.2)	8.5 (4.4)	0.899	0.002
	DES	24.2 (19.5)	33.2 (19.1)	13.8 (6.2)	0.1 (0.1)	12.0 (6.7)	58.7 (29.4)	52.5 (16.4)	48.3 (14.9)	44.0 (32.4)	11.0 (4.5)		

kPa: Kilopascal; kPa·s: Kilopascal-second; MedRF: Medial Rearfoot; CentRF: Central Rearfoot; LatRF: Lateral Rearfoot; MedMF: Medial Midfoot; LatMF: Lateral Midfoot; MedFF: Medial Forefoot; CentFF: Central Forefoot; LatFF: Lateral Forefoot; Hallux: Hallux; OT: Other Toes; η²: Partial Eta Squared; *: Indicates a statistically significant difference at $p < 0.05$.

The ANOVA analysis indicated no significant differences in contact time between the ascent and descent conditions. Specifically, the total contact time was 1.01±0.07 s during ascent and 0.93±0.15 s during descent ($p=0.069$, $\eta^2=0.322$). The mean and standard deviation of the pressure variables are presented in Table 1. The analysis of peak pressure in different regions of the foot during ascent and descent conditions revealed differences in load distribution. The MedFF exhibited higher peak pressure ($p=0.018$, $\eta^2=0.481$) and mean pressure during the descent ($p=0.030$, $\eta^2 =0.423$) during descent, indicating a greater mechanical effort in this region, compatible with a prevalent pronation when loading to foot into the step. The analysis of mean pressure revealed that LatRF ($p<0.001$, $\eta^2=0.790$) and LatMF (k=0.027, $\eta^2=0.436$) exhibited higher values during the ascent. Additionally, both the LatMF and OT presented higher values during descent ($p=0.002$, $\eta^2=0.665$; $p=0.004$, $\eta^2=0.617$), suggesting different mechanism of the foot rollover during ascent and descent. More specifically, while ascending steps, the foot rollover loads the plantar are more laterally, which is compatible with a more supinated position of the foot-ankle complex. The pressure-time integral revealed no differences between the ascent and descent, indicating that the overall load remained relatively constant in both conditions. These findings may imply that adaptations in load distribution occur as a subtle process, or that other variables may influence it.

4 CONCLUSIONS

This study elucidates the distribution of plantar pressure in healthy individuals during stair ascent and descent conditions. Notably, the peak pressure in the MedFF region significantly increased during descent, indicating a higher mechanical effort crucial for maintaining stability and balance. Furthermore, the analysis revealed significant increases in peak pressure in the CentMF and LatMF during descent, suggesting a more laterally-oriented foot support in response to the condition.

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