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Short communication

Childhood obesity is associated with altered plantar pressure distribution during running

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ABSTRACT

Background: Obesity is associated with higher foot loading during walking. The impact of this condition on running, however, has yet to be elucidated.
Research question: The purpose of this study was to examine the association between childhood obesity and plantar pressure distribution during running.
Methods: Forty-two volunteers aged 5–10 years took part in this cross-sectional study. Body mass index (BMI) was assessed for obesity classification. Peak plantar pressure was evaluated during running at self-selected speed using an Emed AT-4 pressure platform.
Results and significance: BMI was correlated to peak pressure at whole foot ($r = 0.340$; $p = .027$), midfoot ($r = 0.550$; $p < .001$) and forefoot ($r = 0.454$; $p = .003$). Regarding other baropodometric parameters, obese children generated more forces during running compared to their leaner counterparts (all $p < .050$), except at the hallux. Also, obese children had a larger contact area under all the foot regions (all $p < .050$). These findings provide evidence that childhood obesity is associated with increased plantar pressure during running at self-selected speeds and support the concept that obese children are at higher risk of developing foot discomfort and pain.

1. Introduction

Obesity is associated with higher foot loading during walking [1–3], increasing the risk of foot pain and discomfort [4,5]. Running is a common mode of physical activity for children and generates higher loads on the musculoskeletal system than walking [6,7]. According to a deep literature review, the study by Song-hua et al. [8] was the only to examine the effects of childhood obesity on running plantar pressure pattern, and demonstrated that obese children generated significantly greater peak pressure at the midfoot, forefoot and hallux. Analyses of other baropodometric parameters, however, have yet to be investigated. Therefore, the aim of this study was to examine the association between childhood obesity and plantar pressure distribution during running.

2. Methods

2.1. Design and participants

This cross-sectional study included children aged 5 to 10 years, who were recruited from a local elementary school. All parents of potential participants completed a questionnaire to verify children eligibility prior to enrolment. Exclusion criteria included pre-term births, musculoskeletal and neurological disorders, and non-rearfoot striking runners. After exclusion criteria were applied, a total of 121 children were included in the research. From this sample, 9 volunteers were identified as obese, 14 as overweight, and 98 as normal weight. Given the fact that unequal sample sizes could affect the homogeneity of variance assumption and power of the statistical analysis [9], 19 volunteers were randomly selected from the normal weight group to be included in the analyses. Therefore, 9 obese, 14 overweight and 19 normal weight children composed the study sample. Verbal assent from participants and written informed consent from their parents were obtained, and the experimental protocol was approved by the University Ethics

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2.2. Study measures

In order to classify participants, age-specific cut-off values of body mass index (BMI) was adopted [10]. Barefoot plantar pressure data were collected using an Emed AT-4 pressure platform (Novel GmbH, Munich, GE; 50 Hz; 4 sensors/cm^2; 415 × 255 mm), which was calibrated according to manufacturer's specifications and was positioned on a 3.7 m dense foam walkway especially designed to provide a stable running surface. Children were allowed a period of 5–10 min for practicing running over the platform. Each participant was evaluated at self-selected speed using the midgait protocol [11]. To assess plantar pressure, 5 successful trials were recorded for both feet [12], with the mean value of each foot used for analyses. The EMED/R – Database Light 23.3.43 software was used to construct feet masks for each participant. The masks were developed to produce 6 anatomical regions: whole foot, rearfoot, midfoot, forefoot, hallux and lesser toes. Peak pressure, maximal force (absolute and normalized to body mass), and contact area were assessed at each anatomical region. Measurements of right foot were used for subsequent analyses as there were no significant differences between right and left foot in all variables.

2.3. Statistical analysis

Data were expressed as mean and standard error. To verify data distribution, the Shapiro-Wilk test was performed. Between-groups comparisons were conducted using ANOVA one-way test with Gabriel's post-hoc, or using Kruskal-Wallis test associated with Mann-Whitney test and Bonferroni correction (when variables did not fill all the assumptions for parametric statistics). Chi-square test was conducted to compare categorical variables. Correlations between BMI and plantar pressure distribution were assessed using Pearson's or Spearman's correlation coefficient. Statistical significance was set at $p < .05$. All statistical analyses were conducted with Statistical Package for Social Sciences software version 22.0 (SPSS Inc., Chicago, USA).

3. Results

Participants' characteristics are presented in Table 1. Obesity was associated with plantar pressure distribution during running (Fig. 1). Specifically, BMI was correlated to peak pressure at whole foot (r = 0.340; $p = .027$), midfoot (r = 0.550; $p < .001$) and forefoot (r = 0.454; $p = .003$). Regarding other baropodometric parameters, obese children generated more forces during running compared to their leaner counterparts (all $p < .050$), except at the hallux (Table 2); however, when maximum force was normalized to body mass, the values were lower at the whole foot, forefoot and hallux (all $p < .001$). Also, obese children had a larger contact area under all foot regions (all $p < .050$).

4. Discussion

The present study examined the association between childhood obesity and plantar pressure distribution during running. The salient findings indicated that obese children generated more forces compared to their leaner counterparts. These forces were distributed across a greater foot contact area. Nevertheless, it was not sufficient to compensate for the higher forces such that peak plantar pressures were positively associated to obesity, especially at the midfoot and forefoot. In conjunction, these observations provide support for the concept that obesity is linked to altered foot function during running, with potential risk of foot pain and discomfort [4,5].

The present findings are consistent with the results from Song-hua et al. [8], who were pioneers in examining the effects of childhood obesity on plantar pressure distribution during running at slow and fast speeds. It was observed that obesity was associated with higher peak plantar pressure at the midfoot and 4th metatarsal region in both speeds. Moreover, obese children had greater peak plantar pressure at the 4th metatarsal region and hallux in slow speed when compared to the normal weight. Analyses of other baropodometric parameters, however, were not in the scope of the aforementioned study. Of relevant note, in the present study running speed was not controlled, since it may affect the natural standard of each child running [13] and evaluation of running at a self-selected speed is important to reflect forces applied to the feet during daily life activities.

The current study has strengths and limitations. Novelty of the results is a strength. The fact that running speed was not measured might raise the question as to whether our results were not confounded by some degree of speed variation. However, it is well documented that the gait speed is positively related to the maximal force [14]. As the obese participants generated less normalized maximal force during running, the increased plantar pressures observed may not be due to speed but higher body mass. A limitation is the age range of the sample, which is characterized by relevant changes of foot shape and function [15]. Nevertheless, maximal force and contact area values present minor differences after 4.5 years [15]. Therefore, the results should be considered preliminary and further research with a prospective design and a greater sample size comparing different age groups is recommended to confirm the impact of childhood obesity on foot function during running.

5. Conclusion

In conclusion, childhood obesity is associated with altered plantar pressure distribution during running at self-selected speeds. These findings provide further support for the concept that obese children are at higher risk of developing foot discomfort and pain. Future prospective studies are required to elucidate the chronic consequences of these increased plantar loads on the structure and function of obese children's feet.

Conflicts of interest

None.

Table 1
Characteristics of the normal weight, overweight and obese children. Data are presented as relative frequency or mean (standard error).

	Normal weight (n = 19)	Overweight (n = 14)	Obese (n = 9)	*p* ANOVA One-Way/Kruskal-Wallis/Qui-Squared	Gabriel/Mann-Whitney
Gender (males)	47%	64%	44%	.545#	
Age (years)	7.47 (0.36)	7.36 (0.40)	7.22 (0.49)	.851£	
Height (cm)	125.92 (2.09)	128.32 (2.53)	131.77 (2.69)	.284§	
Body mass (kg)	24.25 (0.86)	32.06 (1.86)	40.24 (2.82)	< .001§	a^{**}, b^{*}, c^{*}
BMI (kg/m^2)	15.23 (0.22)	19.21 (0.42)	22.90 (0.70)	< .001§	a^{**}, b^{**}, c^{**}

BMI: Body mass index. § ANOVA One-Way; £ Kruskal-Wallis; # Qui-Squared. Between-group differences: (a) Normal weight – Obese; (b) Normal weight – Overweight; (c) Overweight – Obese. $^{*}p < .05$; $^{**}p < .001$.