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Research study

Management

Investigation of plantar pressures in overweight and non-overweight children with a neutral foot posture

A Gatt[1,2], M Spiteri[3], C Formosa[1,2*], N Chockalingam[2,1]

Abstract

Introduction

The aim of the study was to determine differences in dynamic plantar pressure and contact area in a cohort of overweight and non-overweight children. This study also sought to determine whether total foot contact area correlated with average peak plantar pressure measurements.

Materials and methods

A non-experimental matched subject designed was conducted on 20 participants. A plantar pressure mapping system was used to acquire plantar pressures. Assessment included dynamic plantar pressure and contact area of 10 overweight (age 9.6 ± 1.4 years; BMI 26 ± 6) and 10 non-overweight (age 9.6 ± 1.6 years; BMI 16 ± 2) children with a neutral foot type determined by Foot Posture Index. Subjects were matched for age, height and gender.

Results

The study identified a significantly larger foot contact area (p 0.000) and higher peak plantar pressures under the heel (p 0.011), the 2nd – 4th Metatarsophalangeal Joint region (MPJs) (p 0.000) and 1st MPJ (p 0.050) in overweight children when compared to their matched non-overweight participants. A strong positive relationship was reported between peak plantar pressure and foot contact area.

Conclusion

This study has identified significantly higher plantar pressure differences and a larger contact area in overweight children when compared to controls. This increased pressure may be indicative of altered foot function which may later in life lead to musculoskeletal complications and pain. This highlights the importance of increased vigilance coupled with strengthening of existing screening structures with regards to biomechanical assessment of the feet in early childhood in order to reduce the incidence of musculoskeletal abnormalities and pain.

*Corresponding author
Email: Cynthia.formosa@um.edu.mt

[1] University of Malta, Msida, Malta
[2] Staffordshire University, Stoke-on-Trent, United Kingdom
[3] Department of Health, Floriana, Malta

Introduction

Excessive mass has an effect not only on the development and anatomy of the foot but, also on the way the foot and lower limb functions during gait. Although, following WHO guidelines[1], children are being encouraged to develop a more active lifestyle and to increase their physical activities, excessive weight can impose serious consequences on children's feet during their development[2].

As studies have shown a positive correlation between children's BMI and musculoskeletal pain and injuries[3,4], if caution is not exercised when increasing activity in overweight children, detrimental effects on their musculoskeletal system may occur at a time when the child's foot is still very malleable and prone to injury.

Furthermore, foot discomfort and associated structural changes, together with increased forefoot plantar pressures in the obese foot may hinder these children from participating in physical activity[5], making exercise to encourage weight-loss difficult.

A limited number of studies that assess foot plantar pressure distribution in obese children[5,6] imply that the functional and structural limitations imposed by obesity may result in aberrant lower limb mechanics and the potential for musculoskeletal injury. In an investigation of plantar pressure in pre-school children, Mickle et al. reported that overweight/obese children had significantly larger contact areas and larger forces on the plantar surface of their foot[7]. However, this study did not take foot posture into account.

Different protocols for acquiring plantar pressures may produce different outcomes[8], especially if foot posture (i.e. whether the foot is neutral, supinated or pronated) is not taken into consideration. A number of studies that report on the effect of foot posture clearly demonstrate this[9,10]. Hence the effect of foot posture may have a profound effect on foot pressure distribution and thus must be controlled for during any research that investigates plantar foot pressure distribution.

If uncontrolled for, this may confound the acquired data and hence the results of the investigation; i.e. it may be unclear whether alteration in foot pressure distribution is caused by the variable under investigation or foot posture.

A need to understand better the consequences of childhood obesity on the function and development of the musculoskeletal system has emerged, in order to assist in the prevention, treatment and management of the effects of this condition[6,11]. Therefore, it is necessary to understand the main effects of obesity on the biomechanical characteristics of gait, as well as on the movement of the feet, which can contribute to understanding how obesity influences weight-support activities.

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It is becoming increasingly clear that in adults, obesity may have a significant effect on soft-tissues, including tendon, fascia and cartilage[12]. The increasing prevalence of overweight children and with the known fact that overweight children are more susceptible to develop musculoskeletal complications and pain, identified a need for a study to establish whether plantar pressure differs between overweight and non-overweight children, and whether this correlates to the foot contact area, in children with a neutral foot posture.

Materials and methods

A prospective non-experimental quantitative matched-subject study was conducted inside a primary school. This report includes data from a cohort of 20 participants aged 8 to 11 years. This group was chosen for homogeneity and is considered to be old enough in order to follow instructions. This study was approved by the University Ethics Research Committee. Informed parental consent was obtained prior to commencement of study.

Authorisation was also obtained from the Head of School and the Education Department. The reported investigations were carried out in accordance with the principles of the Declaration of Helsinki as revised in 2000[13].

Subject selection

The study randomly selected four classrooms from a primary school. All students from the selected classrooms were invited to participate. In all, 87 consented children accepted to participate. They were examined individually in the school clinic for height and weight to establish the BMI according to the 2000 CDC Growth Charts[14], and for foot posture using the Foot Posture Index, FPI-6[15]. Ten recruited children with a mean BMI of 26.6 ±6 kg/m² were included in the overweight group, while the control group included 10 children, matched for age, height and gender, but with a mean BMI of 16 ±2 kg/m².

Only children with a neutral foot position were included in the sample. Participants were excluded if they had a pronated or supinated foot posture, history of lower extremity problems, surgery and/or acute trauma, biomechanical conditions including leg length discrepancies, neurological or musculoskeletal disorders, were underweight, showed lack of interest in the study or were unable to cooperate due to eye, ear or cognitive disorders.

Foot Assessments

The contact area and dynamic plantar pressure were obtained for the chosen 20 participants using a Tekscan HR Mat™ (Boston, USA) plantar pressure assessment system, which is a platform-based, low profile, high resolution foot pressure mapping system. This system has a target area of 488mm by 442mm and is constructed of a 0.18cm thick flexible printed circuit that detects subject's plantar pressures. This mat is made up of 8352 individual pressure sensels, which are distributed evenly in rows and columns across the sensor surface. The 5.1mm by 3.2mm sensels, providing a sensel spatial resolution of 3.9 sensels/cm², makes the HR Mat an appropriate pressure system for children's feet. Data were collected at 60Hz using the manufacturer recommended calibration method prior to data collection.

During dynamic acquisitions, the participant walked barefoot at a self-selected normal speed[16]. To ensure intrarater reliability measurements were all carried out by the same examiner. The two-step protocol was used to decrease data-collection stress as this method has been validated in children and has been found to be comparable to the midgait method[17]. Each participant was positioned two-step lengths from the pressure mat and was instructed to strike the mat with the right foot on their second step.

Three to four additional steps were taken after striking the mat. Several trials were completed to mark the starting point while providing an opportunity for the subject to become accustomed to the equipment. Five trials were recorded, which has been reported to yield reliable results when using the two-step method[17]. A trial was repeated if the researcher observed an atypical gait cycle or the participant targeted the mat.

The variables under investigation were Peak Plantar Pressure measured in kilopascals (KPa) and contact area (m²). Pressure is determined by dividing the measured force by the known area of the sensor, describing the potential damaging effects in the tissue[18]. This was obtained across five foot segments; Heel, 5th MPJ region, 2nd to 4th MPJ region, 1st MPJ region and Hallux (Figure 1). Segments were constructed by the Research Foot Software (version 5.2.2), based on a subjective identification of areas corresponding to anatomical landmarks of the foot.

Contact area of the whole foot was recorded, which has previously reported an error of less than 3%[19].

Table 1: The characteristics of the sample population

Subjects	Overweight Subjects (n=10)	Control (n=10)
	7 males, 3 females	7 males, 3 females
Age (months)	115 ± 17	115 ± 20
Weight (kg)	50 ± 20	30 ± 8
Height (m)	1.37 ± 0.13	1.35 ± 0.15
BMI (kg/m²)	26 ± 6	16 ± 2
FPI scores	(L) 3.3 (R) 3.5	(L) 3.1 (R) 3.2

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Results

Ten overweight children [7 boys, 3 girls] (mean 115 ±17 months) were selected and matched to 10 children of normal weight for age, height and gender (mean 115 ±20 months) (Table 1). As shown in figure 2, the Peak plantar pressures under the rearfoot and forefoot and the contact area of the overweight participants was generally higher than those of their controls. Statistical analysis utilizing a t-test confirmed that the greatest dynamic plantar pressure difference between the Overweight Group and Control Group was found under the second to fourth MPJs (p = 0.000; 226kPa vs 160kPa), followed by the heel (p = 0.011 242kPa vs 203kPa) and first MPJ (p = 0.050; 105kPa vs 102kPa) (Figure 2). Contrary to the above mentioned areas plantar pressure under the hallux was higher in the non-overweight group rather than in the overweight group (p = 0.423; 237kPa vs 204kPa).

The correlation coefficient test calculated for peak plantar pressure and contact area illustrated a positive relationship between these two variables for the heel (0.432), 5th MPJ (0.268), 2-4th MPJ (0.739) and 1st MPJ (0.284), but not for the hallux (-0.026).

Discussion

The aim of the study was to determine differences in dynamic plantar pressure and total foot contact area in a cohort of overweight and non-overweight primary school age children. All participants were a homogenous group of children with a neutral foot posture, i.e. the foot was neither pronated nor supinated, as determined by the FPI. This study also sought to determine whether foot contact area correlated with plantar pressure measurements.

This research has identified higher plantar pressures in overweight children when compared to non-overweight children. The overweight participants generated higher peak plantar pressures under the rearfoot and forefoot and demonstrated larger foot contact area. Most significant pressure differences resulted under the second to the fourth MPJ's, heel and first MPJ respectively.

These results imply that the additional foot contact area did not compensate for the high pressures in the overweight participants. Since the foot contact area in the overweight group was increased, it was to be expected that peak However, a positive relationship was reported between contact area and peak pressures.

The authors therefore postulate that the increased body mass may lead to foot structural alterations exhibited by the increased contact pressures would be diminished on account that pressure and area are directly related. Area which may be due to increased midfoot contact, elongation and widening of the foot under the increased load and stress on the plantar soft tissues which may be flattened, thus accounting for this increased contact area.

Midfoot contact may be due to increased sagittal plane movement around the oblique axis of the midtarsal joint. These structural differences and higher plantar pressures in overweight children increase stress which in turn makes the foot vulnerable to bony fatigue and soft tissue damage. This highlights the risk for these children to develop physical limitations, foot discomfort, musculoskeletal pain and injuries in their early stages of childhood.

The findings from his study provide further evidence that overweight and obese children are generating more plantar pressures during their daily activity of simple walking. Whilst physical activity remains one of the

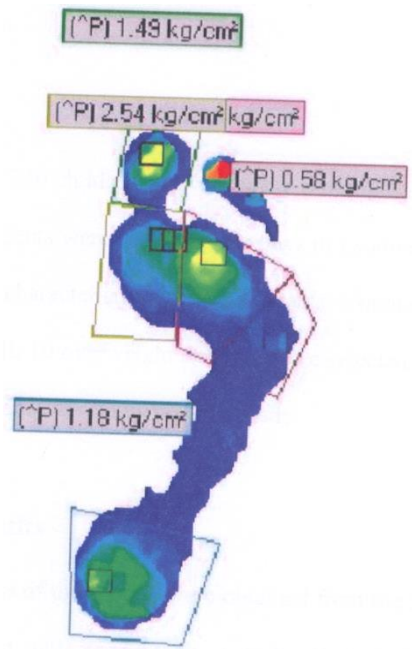

Figure 1: Foot subdivisions for pressure mapping.

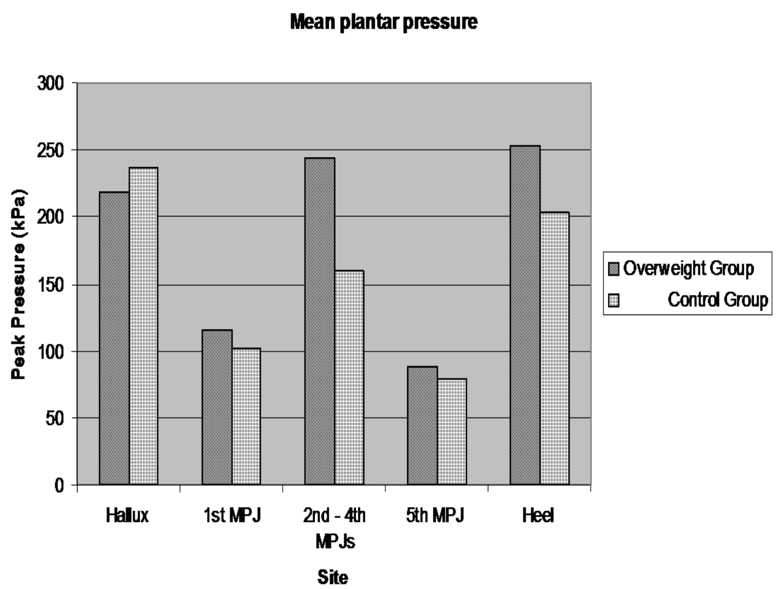

Figure 2: Peak Plantar Pressures in overweight and non-overweight children by site.

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highest priorities in weight management, excessive weight together with the associated high plantar pressures have the potential to lead to musculoskeletal and biomechanical alterations and complications.

Furthermore, foot pain may limit children's participation in physical activity, in turn, perpetuating the cycle of obesity.

The importance of increased vigilance coupled with the introduction of screening programmes in the early years of childhood cannot be emphasised enough with regards to biomechanical assessment of the feet in order to reduce the incidence of musculoskeletal abnormalities and pain.

It has been demonstrated that, once overweight resulted in an increase in contact area, structural alteration to the foot are occurring, possibly resulting in altered biomechanics later on in life. Urgent interventions, appropriate to the structural and functional needs of young overweight children, are required to prevent further weight gain and structural and functional complications to the feet.

However, in the quest for weight-reduction, caution must be exercised during weight-management exercise programmes so as not to inflict musculoskeletal damage to the vulnerable foot.

Early assessments and better management of foot conditions at an early stage in life could prevent or delay long term foot complications and improve quality of life. Although the small sample size could be a possible limitation of this study, results are congruent with those of other studies that have investigated plantar pressures in overweight children but which have not taken foot posture into consideration.

Conversely, future prospective studies should be conducted to investigate the effect of the pronated and supinated foot postures on plantar pressure in overweight children.

Conclusion

This study has identified structural foot alterations related to excessive body weight and higher peak plantar pressures and increased foot contact area in overweight children when compared to non-overweight children.

This research conducted amongst primary school children highlights the importance of increased vigilance during weight management exercise programmes coupled with the introduction of early screening programmes with regards to biomechanical assessment of the feet in order to reduce the incidence of musculoskeletal abnormalities and pain.

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