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Effect of Body Mass Index on Plantar Pressure Distribution in Children During Standing

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***Abstract*---Background**: Standing plantar pressure measurement can help in tracing the correlation between plantar pressure distribution and lower-extremity posture, altogether with its relationship with BMI in children. The goal of this study is to figure out if BMI affects peak and average plantar pressure distribution in children when standing or not. **Study Design**: The current study is a primary, observational, cross-sectional one conducted in the Egyptian elementary schools in Talhka City, Dakahlia Governorate. **Subjects & Methods**: Ninety children; 47 girls and 43 boys with ages ranging between 6 to 12 years old were engaged in this study. The BMI of the study group highlighted the idea that 40% of the children were of normal weight (36 participants), 16.7% were overweight (15 participants), (7.8%) were obese (7 participants), and 35.6% were underweight (32 participants). All statistical measures were carried out using the statistical program for social sciences (SPSS) with version 22 for Windows (IBM SPSS, Chicago, IL, USA). **Results**: The current research suggests that there was substantial variance in both peak and average plantar pressure of both the right and left feet when standing in various cases with a spectrum of BMIs.

***Keywords*---**BMI, children, left foot, normal weight, obese, overweight, plantar pressure distribution, right foot, standing, underweight.

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Introduction

According to current research, there is only a moderate association between BMI and plantar pressures, but a strong correlation shows that pressure data should be corrected. Only 32.5 percent of the variance in peak plantar pressure values under the third metatarsal head and midfoot was explained by non-obese children's relative body weight (weight/foot length) and obese children's BMI (Hennig et al., 1994). To categorize the youngsters, the BMI was plotted on a gender-specific BMI graph. A healthy BMI for a child is between the 5th and 85th percentile, whereas a BMI between the 85th and 95th percentile is considered overweight, and a BMI above the 95th percentile is deemed obese (Elliott, 2007).

Each child's BMI was calculated using the slandered formula, which divides a person's weight in kilograms by the square of their height in meters (Barlow & Expert Committee, 2007). The distribution of foot pressure is influenced by several factors. The accuracy of BMI as a measure of adiposity varies substantially depending on the degree of body fatness. Structure (bony prominence), function (limited range of motion), footwear (pointed shoes), and body weight are all conceivable characteristics. BMI is a reliable indicator of excess adiposity in relatively overweight children; however, disparities in BMI in relatively thin children (such as the BMI for age 85th CDC percentile) are mostly related to variances in fat-free mass. A BMI for age at the 95th CDC percentile has moderately high (70–80 percent) sensitivity and positive predictive value, as well as high specificity (95 percent) for identifying children with excess body fatness if appropriate cut-points for both BMI and body fatness are chosen, the prevalence of high levels of each characteristic are roughly equal.

Although their risks are lessened, overweight children (CDC percentiles 85–94) are more likely than thinner children to have high levels of various risk variables and grow up to be obese adults (Freedman & Sherry, 2009). Growth and maturation may impact changes in foot pattern and foot loading produced by obesity in children and adolescents. The anatomy of a child's feet (such as relative foot width and flatfoot type) is well documented to alter with age and to differ between males and girls (Echarri & Forriol, 2003; Mueller et al., 2016). Variations in obesity-related foot morphology have been discovered between normal-weight and obese children, with obese children having a higher Chippaux-Smirak Index, which indicates a narrower longitudinal foot arch (Riddiford-Harland et al., 2000).

A podoscope is straightforward diagnostic equipment that allows you to examine your footprint. A methacrylate hodoscope is a gadget having a fluorescent light incorporated into it. The weight-bearing position when the medial arch was absent or the medial border of the foot was convex was used to diagnose flatfoot (9) Due to variances in muscle and skeletal size, very young children may have distinct pressure patterns features than adults. Furthermore, no normative data on a person's foot function, which could aid in the identification of "normal" pressure patterns, has been supplied. When walking, plantar pressure has mostly been studied in adults (Bennett & Duplock, 1993). The anatomy of a child's foot differs from that of an adult's, with flexibility being the most important factor. Around the age of one, when children begin to walk, the foot skeleton consists of multiple partially ossified regions linked by soft tissue. Another distinguishing aspect of a toddler's feet is the lack of a noticeable longitudinal foot arch. The bone structures of the longitudinal arch develop about a year after birth when toddlers have learned to stand and walk freely. They proceed with the development process until they reach the age of seven (Fritz & Mauch, 2013).

As a result, regardless of age or gender, persons with a higher body mass might expect higher plantar pressure readings for the entire foot. For differing body masses, the weight distribution across foot areas is likely to be disproportional. Plantar pressure data does not need to be adjusted for body mass, and data from girls and boys would be used for data analysis, according to the authors. As a result, obesity is likely to have a less impact on the shape and function of little children's feet than it is on the shape and function of older children's feet (Mueller et al., 2016). The objective of the current research is to see how different body mass indexes affect peak and average plantar pressure in children with an age range from six to twelve years old when standing. Hopefully, the research findings will show that a high BMI increases the strain on plantar pressure foot loading patterns in children.

Materials and Method

Ethical considerations

The ethical committee of Cairo University's Faculty of Physical Therapy has authorized the current research (No: PT/REC/012-003443). A formal consent has been signed by the participants' parents was also acquired to initiate the study process.

Trial design

Primary, cross-sectional, and observational is the description of the current study that has been conducted at selected public primary and middle schools in Talhka City, Dakahlia Governorate, Egypt. The study's participants were the previously mentioned school students. Expecting a considerable difference in plantar pressure between the three types of the foot arch, sample size calculation has been done through using G*POWER software, version 3.1.9.2; Franz Faul, Universitat Kiel, Germany. It has been found that the needed sample size for this investigation was N=90. =0.05, =0.2, effect size = 0.33. The previously mentioned measures were used in the calculations.

Participants

There are a total of ninety children (47 girls and 43 boys) The current experiment lasted eleven months, from December 2020 to November 2021. Both the children and their caretakers were informed and reassured that their participation in the study was voluntary and confidential, as well as the study technique. The sample was chosen using inclusion and exclusion criteria. Children ranging in their age from 6 to 12 years old, of both sexes, were encompassed in the research, and their BMI was calculated using CDC growth charts (National Center for Health Statistics, 1994). The current study excluded children with recent fractures or procedures, open wounds on the lower limbs, or any fixed deformities in the lower limbs.

The following formula is used to compute the BMI: Anthropometric data were utilized to measure body weight, height, and BMI. A body mass index with a measure below the fifth percentile is considered underweight. The healthy weight spans from the 5th to the 85th percentile. The 85th to 95th percentiles are considered overweight. Moreover, Obese: 95th percentile or higher Himes & Dietz (1994), based on kilograms divided by meters squared (kg/m2). The BMI was then plotted on the Centers for Disease Control and Prevention (CDC) gender-specific BMI graphs and growth charts for girls and boys with ages ranging from 2 to 20 years. The Center for Disease Control and Prevention (CDC) has a body mass index for age chart which is beneficial in the various studies (National Center for Health Statistics, 1994).

On one level, the procedures of determining plantar pressure encompass the use of a pedograph. The procedure for estimating plantar pressure and preparing participants began with each child stepping barefoot on a pressure plate with sensors that transform the mechanical pressure of the foot into electrical signals that were transmitted to the computer system. Furthermore, the program which is known as "eclipse software" has been adopted in the current study as it is utilized to get calculations for pressure values based on the pressure placed on the plate. It also uses pre-programmed colors to indicate the pressures acting on the plantar surface of the foot in a variety of colors. Maximum pressure was represented graphically by the red and yellow colors, while the lowest reassure levels were represented by the green and blue colors. Foot Surface Area, Maximum Plantar Pressure, Average Plantar Pressure, and Thrust are all included in each scan for each child's left and right foot. The child stands relaxed, arms beside his body, and is told not to move for one minute. The measurement's repeatability necessitated three trials. The computed area relates to the extent of surface contact in terms of foot plantar surface and the sensors. Measurement will be taken in a static environment; the device will need to be calibrated by the child standing barefoot on the platform.

Statistical analysis

The key features of the current study's individuals were summed up using descriptive statistics. Quantitative variables were recapped through the mean and standard deviation, whereas categorical variables were totalized using frequencies and percentages. The Kruskal-Wallis test was utilized to compare the median values of peak and average pressure between different weight categories, and the Mann–Whitney U test was done to see if there was a clear variance between them. The significance level for all statistical examinations was set at p 0.05. All statistical tests were performed using the statistical program for social sciences (SPSS) version 25 for Windows. (Chicago, Illinois, United States of America) IBM SPSS is a statistical program.

Results

General characteristics of the subject

This research group included ninety children (47 girls and 43 boys). Their SD ages, weights, heights, and BMIs were 9.31 ± 2.18 years, 32.87 ± 11.23 kg, 134.57 ± 12.57 cm, and 17.61 ± 3.58 kg/m2, respectively. The study group's weight distribution found that 36 (40%) of cases were of standard weight, 15 (16.7%) were over the standard weight, 7 (7.8%) were obese, and 32 (35.6%) of the children were underweight. (As highlighted in table no.1).

Table 1
Major features of study subjects

	Mean ±SD	Maximum	Minimum
Age (years)	9.31 ± 2.18	12	6
Weight (kg)	32.87 ± 11.23	56	11
Height (cm)	134.57 ± 12.57	158	108
BMI (kg/m^2)	17.61 ± 3.58	27.3	8.3
Sex, n (%)			
Girls	47 (52%)		
Boys	43 (48%)		
Weight status, n (%)			
Normal	36 (40%)		
Overweight	15 (16.7%)		
Obese	7 (7.8%)		
Underweight	32 (35.6%)		

SD: Standard Deviation

Effect of weight status on peak and average pressure

Among different weight groups, there was a clear variance in apex and average pressure on both right and left feet ($p < 0.001$). (As highlighted in table no.2) Obese children had a noticeable higher peak pressure in their right foot than normal children ($p = 0.003$), overweight children ($p = 0.03$), and underweight children ($p = 0.001$). Obese children had a clear higher peak pressure in their left foot compared to normal children ($p = 0.03$) and underweight children ($p = 0.004$). Normal and overweight children had higher peak pressures in their right and left feet than underweight children ($p < 0.01$). Obese children's average right and left foot pressures were substantially higher than those of normal and underweight children ($p < 0.01$). The average pressure of the right foot of normal children, as well as the right and left feet of overweight children, was higher than that of underweight children ($p < 0.01$).

There was no discernible variance in peak and average pressure of the right and left foot between normal and overweight children ($p > 0.05$). Peak left foot pressure and average right and left foot pressure did not differ significantly in overweight and obese cases ($p > 0.05$). Between normal and underweight children, the average pressure on the left foot did not differ significantly ($p > 0.05$). (As highlighted in Table No. 3).

Table 2
Median values of peak and average pressure of the right and left foot of different weight categories

Pressure (g/cm²)	Median (IQR) Normal (N = 36)	Overweight (N = 15)	Obese (N = 7)	Under weight (N = 32)	x^2	p- value
Peak pressure						
Right foot	848.5 (1031.25-726.25)	929 (1080-868)	1100 (1170-1070)	711.5 (798.25-558.5)	26.13	0.001
Left foot	1002 (1326.5-846)	1091 (1576-1018)	1278 (1350-1218)	855 (1008.5-712.25)	17.77	0.001
Average pressure						
Right foot	300 (348.5-263)	332 (411-284)	410 (501-366)	256 (294.25-221)	26.61	0.001
Left foot	320.5 (389.5-273.25)	375 (455-320)	431 (436-426)	311.5 (358.5-244)	15.64	0.001

IQR, interquartile range; x2: Chi-squared value; p-value, level of significance

Table 3
Comparison of peak and average pressure of the right and left foot between different weight categories

	Peak pressure				Average pressure			
	Right foot		Left foot		Right foot		Left foot	
	U-value	p-value	U-value	p-value	U-value	p-value	U-value	p-value
Normal – Overweight	195	0.12	183.5	0.07	183	0.07	175.5	0.051
Normal – Obese	34.5	0.003	60	0.03	30	0.002	50.5	0.01
Normal -Underweight	320.5	0.002	374	0.01	364	0.009	487	0.27
Overweight – Obese	22.5	0.03	35	0.21	25.5	0.057	36	0.24
Overweight -Underweight	93.5	0.001	103	0.002	78.5	0.001	125	0.009
Obese -Underweight	9	0.001	33	0.004	4	0.001	14	0.001

U- value, Mann-Whitney test value; p-value, level of significance

Discussion

The major objective of the current study is to determine how BMI affected peak plantar pressure and average plantar pressure in children when standing. The data revealed that varied body mass indexes and plantar pressure distribution within a specific posture have a beneficial relationship, especially in children. As for Plantar pressure, it was measured in twenty obese and twenty non-obese cases during both unipedal and bipedal posture. A comparison was drawn between both overweight and underweight individuals, as well as between foot and leg areas. da Rocha et al. (2014), backs up this study's findings that obese children have a larger plantar pressure distribution than their non-obese peers.

Obesity is a significant component that must be considered in the current investigation. Obesity affects prepubescent children's foot form and plantar pressure patterns (Dowling et al., 2001). The above-mentioned result is consistent with the findings of the current investigation. Thirteen obese and thirteen nonobese participants participated in the current investigation. Foot discomfort caused by structural modifications and noticeable forefoot plantar pressure in obese cases' feet would prohibit them from getting involved in various physical workouts or activities and cause other difficulties, according to BMI, foot structure, and plantar pressure calculations. Moreover, cases that are pigeonholed to be overweight or obese had to a great extent considerably higher force-time and pressure-time integrals than their counterparts. This simply implies the idea that obese pre-school children's midfoot area is subjected to increased stress. Subsequently, the complications of bone issues and soft tissue damage are inevitable. More research is needed to see how these noticeable plantar pressure characteristics affect foot complications and physical performance in young obese cases as they grow in the cases of adult people (Mickle et al., 2006).

Weight category impacts plantar load distribution, according to a study published in 2020 Feka et al. (2020), with the obese category varying from the others. Furthermore, the rearfoot had the largest pressure distribution of all the foot regions studied. Furthermore, plantar load distribution is affected by sex in obese boys but not in other groups. In addition, when compared to boys, girls place a vastly greater burden on the backfoot. On one level, a scientific study with specific features to be taken into account has needed 10382 cases with ages ranging between one to twelve years. The criteria that have been calculated in the study; foot contact area, arch-index, peak pressure, and force-time integral in various foot regions. The previously mentioned calculations were done to trace the impact of body mass variances on plantar pressure distribution characteristics in children. Variances in foot loading or contact features were identified between body mass classifications for all cases and in specific age categories.

Overweight and obese cases had a bigger foot contact area, a lower longitudinal foot arch, a higher peak pressure, and a higher force-time integral than normal-weight cases. As a result, overweight children do not correct for their excess weight through passive "foot structure" or active "gait" mechanisms, and these discrepancies appear to grow as they get older. Furthermore, the results for this broad age range give the first conclusive evidence of age-dependent changes in loading patterns, which must be investigated in the context of child foot development (6). Small sample size, human errors, and constraints connected with the set-up location of the foot and weight distribution during a plantar pressure scan are all drawbacks of this study's "odometry system".

Conclusion

The approximate average pressure of the right and left foot of obese children was markedly greater than standard and underweight children, as per the findings of the current study and subsequent discussion. Furthermore, as compared to normal, overweight, and underweight children, obese children showed relatively high pressure in their right foot. Obese children's peak pressure in their left foot was much higher than normal and underweight children's. Normal and overweight children's peak pressure in both feet was substantially higher than those of underweight children.

Obese children had much higher average pressure on their right and left feet than both normal and underweight children. The average pressure of a child's right foot, as well as the right and left feet of children with special needs, has risen exponentially. The right and left foot's peak and average pressures did not differ significantly between normal and overweight children. Furthermore, there were no substantial variations whether in the peak pressure in the left foot or the medium pressure in feet between overweight and other obese cases. As a result, there was no great variation concerning the pressure on the left foot in the cases of both normal and underweight children.

Conflict of interest

There is no conflict of interest to highlight.

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