Apunts Med Esport. 2010;**45(165)**:8-15

apunts
MEDICINA DE L'ESPORT
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ORIGINAL

Does overweight affect the footprint and balance of school-aged children?

María Laguna Nieto, Luis M. Alegre, Susana Aznar Laín, Javier Abián Vicén, Laura Martín Casado and Xavier Aguado Jódar*

Faculty of Sports Science, University of Castile and La Mancha, Toledo, Spain

Received November 25, 2008; accepted February 29, 2009

KEYWORDS
Body mass index;
Childhood;
Center of pressure;
Arch Index

Abstract
Purposes: This study aimed to analyze the differences in the footprint and balance performance in school-aged children, with and without overweight.
Material and methods: Twenty six school aged children (age = 11.6±0.5 years), 15 girls and 11 boys participated in the study. Their footprints, average plantar pressures and their balance performance were analyzed with photograph developer, fixer, photo paper and a force platform.
Results: The girls with overweight showed greater Arch Index (p = 0.06, effect size (ES) = 1) and footprint areas than their normal weight counterparts. The area covered by the center of pressure during the single-leg balance test was greater in the overweight groups (overweight boys = 225.71 mm^2; normal weight boys = 163.77 mm^2; overweight girls = 157.74 mm^2; normal weight girls = 83.52 mm^2; ES = 0.86 and 0.74, respectively). There were no differences between overweight and normalweight subjects in the postural sway test.
Conclusions: Overweight girls showed flatter feet than the normal weight ones. In the balance tests, only appeared statistically significant differences between boys and girls, although the practical significance of the differences between over weight and normal weight groups point to a lower balance performance in overweight children.

*Address for correspondence.
E-mail: Xavier.Aguado@uclm.es (Xavier Aguado Jódar).

PALABRAS CLAVE
Índice de masa corporal;
Población infantil;
Centro de presiones;
Arch Index

¿Afecta el sobrepeso a la huella plantar y al equilibrio de niños en edad escolar?

Resumen
Objetivos: El propósito de este estudio ha sido analizar en escolares de primaria las posibles diferencias en la capacidad de equilibrio y en la huella plantar según el sexo y el nivel de sobrepeso.
Material y métodos: Se estudiaron 26 escolares (edad = 11,6±0,5 años),15 niñas y 11 niños de 6.º curso de primaria. Se analizaron las áreas de sus huellas plantares, las presiones plantares medias y el equilibrio. Se empleó revelador, fijador, papel fotográfico y una plataforma de fuerzas.
Resultados: Dentro del grupo de las niñas, al comparar los subgrupos con sobrepeso y sin sobrepeso, se observaron mayores Arch Index (p = 0,06; tamaño del efecto [ES] = 1) y áreas de la huella plantar en las que tenían sobrepeso. En el área barrida en el test de apoyo monopodal, los subgrupos con sobrepeso obtuvieron mayores recorridos, sin significación estadística pero con ES grandes (niños con sobrepeso = 225,71 mm^2 y sin sobrepeso = 163,77 mm^2; niñas con sobrepeso = 157,74 mm^2 y sin sobrepeso = 83,52 mm^2; ES = 0,86 y 0,74, respectivamente). No se encontraron diferencias en el test de ajuste postural entre sujetos con y sin sobrepeso.
Conclusiones: Las niñas con sobrepeso han mostrado alteraciones en la huella plantar, tendiendo a tener pies planos. En los test de equilibrio sólo se encontraron diferencias significativas entre los grupos niños y niñas, aunque la significación práctica de las diferencias entre los grupos con y sin sobrepeso apuntan a un peor rendimiento en niños y niñas con sobrepeso.

Introduction

In many developed and developing countries there is great concern that overweight and obesity is a problem that is reaching epidemic proportions[1-3]. There has been a worldwide increase in obesity at all ages[4,5]. According to the World Health Organisation (WHO)[6] approximately 10% of the world's school-aged children (5-17 years) are overweight (3% are obese). In America, the figure is around 33% (8% obese) and in Europe it is 20% (4% obese). Childhood obesity is now recognised as one of the main health problems in Europe, especially in Italy, Greece and Spain[7]. According to Lobstein and Frelut[8], countries in southern Europe have higher levels of overweight children. In a study in Aragon in Spain, Body Mass Index (BMI) results showed that more than a third of children aged 6-7 were overweight, although levels were less for adolescents aged 13-14[9]. In a later study of Spanish children between the ages of 10 and 13, Serra et al[10] reported that the level of obesity and overweight was 31.2% and that obesity was much more prevalent in boys (41.9%) than in girls (20%). On the other hand, Moreno et al[11] have noted that the prevalence of overweight among girls has risen from 20.5% to 25.8% at the age of 13 and from 21.5% to 23.9% at the age of 14.

Obesity is seen more and more as a problem of public health[12]. The relationship of overweight and obesity with morbidity and mortality is well established and is the subject of constant revision and review[13]. This is particularly the case with childhood obesity and its long term consequences for health[2,14,15] as it is more probable that overweight children and adolescents will become obese adults[16,17].

Despite the fact that the majority of children do not manifest the negative effects of obesity until some decades later in life[18], there are consequences for the skeletal-muscular system, which include lower-limb alignment problems[19], the risk of fractures and a general lack of mobility that could lead to greater health difficulties for the child or adolesecent[20] (obese children tend to be less active than their peers[21-23]). Obese children may also exhibit reduced flexibility and problems with walking and running[4] caused by changes in the structure of the foot. Younger overweight children may suffer flatfeet due to the development of a midfoot plantar fat pad[24] although as they grow older, the tensile strength of the plantar structure increases and flatfoot disappears. On the other hand, if weight gain continues in the medium or long term, the flattening of the midfoot region is maintained, resulting in flatfot[24-26]. Mickle et al[27] have argued that flatfoot in overweight and obese children is not due to increased plantar pad width but structural changes in the anatomy of the foot, a phenomena that could be aggravated if the overweight continues beyond adolescence.

It has been reported that physical changes associated with childhood obesity can decrease the balance capacity of the individual[28]. Nevertheless, the majority of studies on childhood obesity, to date, have focused on the consequences for the skeletal muscular system and corporal alignment with considerably less interest shown in balance capcity[19]. Berrigan et al[29] suggests that an increase in body fat mass in adults reduces postural stability. Bernard et al[30] used the Romberg test with 13-17 year olds and concluded that postural control of obese adolescents was worse than normal weight subjects of the same age; a condition that intensifies when individuals are subject to postural disturbances and leads to a greater risk of falling[31].

After an extensive bibliographic review and due to the paucity of studies on balance in obese children, it was decided that the objective of this work would be an analysis of differences in balance capacity and footprint in school-age children, in accordance with sex and the level of overweight.

Material and methods

Subjects

The study sample was made up of 26 schoolchildren (11 boys and 15 girls) from the 6th year of Primary School, with no history of neurological disease or visual or vestibular skeletal-muscular disorders. The descriptive characteristics of the subjects are shown in table 1. All the subjects were given an explanation of the objectives and nature of the study and their parents gave signed consent for participation.

Instruments

Cineanthropometric characteristics were ascertained by means of a Seca foot scale (accurate to 100 g), a GPM anthropometer (accurate to 1 mm), a Holtain skinfold calliper (accurate to 0.2 mm) and a Seca stadiometer (accurate to 1 mm). Balance tests were undertaken by means of a Dinascan 600 M extensiometric forces platform with a surface area of 0.60 × 0.37 m, connected to a computer. The tests had a sampling frequency of 50 Hz. Footprints were obtained by using photo fixer and black and white photographic paper.

Protocols

Cineanthropometric measurements used protocols recommended by the Grupo Español de Cineantropometría[32] (Spanish Group of Cineanthropometry). Data was taken in three different sessions: In the first session a photopodogram of the right foot was taken (Figure 1) using the Viladot method[33]; the second session covered cineanthropometric characteristics to collect descriptive data and a 10-minute induction to the balance test which included a demonstration by the researcher and some training in techniques in the balance tests; in the third session the single-leg and balance tests took place, there was an interval of 120 s between the two tests and each subject made three attempts with the best result being chosen.

Single-leg balance test (Figure 2). Barefoot, the subject stands on the platform and places the right foot on previously marked front and back reference lines. The child stands on one leg, without the free foot touching the standing leg or the platform and holds the position, keeping as still as

Table 1 Descriptive characteristics of the study population

	n	Age (years)	Height (cm)	Weight (kg)	BMI (k·m^{-2})	Fat (%)	FFM (kg)	Overweight (n)
Girls	15	11.46 (0.49)	1.49 (0.04)	45.86 (7.58)	20.60 (3.06)	23.34 (3.85)	22.52 (5.48)	6
Boys	11	11.70 (0.50)	1.50 (0.06)	42.69 (6.97)	18.79 (1.90)	20.04 (6.21)	22.65 (4.18)	2
All	26	11.56 (0.50)	1.50 (0.05)	44.52 (7.36)	19.84 (2.74)	21.94 (5.15)	22.58 (4.88)	8

Average (standard deviation).
FFM: fat free mass; BMI: body mass index; n: number of subjects.

Figure 1 Taking the footprint by means of photopodogram.

possible, for 10 s. During the test, arms must be kept at the sides, eyes must be open and fixed on a cross (with the horizontal axis longer than the vertical axis) placed at 1.5 m in front of the platform.

Balance test. Barefoot, the subject stands on the platform and places both feet on the marked lines. At a distance of 1.5 m from the platform, there are four targets that light up at random. The subject moves their centre of pressure (COP), as quickly as possible, with arms at the sides, towards the target and remains at the target until the next target lights up. The test lasts for 40 s.

Figure 2 Single-leg balance test.

Footprints were scanned and digitalised with the Area Calculator 2.61 programme (José Luis López Elvira), to calculate the area and different parameters of the footprint.

Variables

BMI and body fat percentage were calculated. Body fat was calculated using the formula proposed by Lohman et al[34]. Overweight (according to age and sex) was calculated using the BMI tables employed by Cole et al[35]. The Area Calculator 2.61 programme was used to obtain data on the frontfoot, midfoot and backfoot total areas and the Arch Index, following the protocols established by Cavanagh and Rodgers[36]. The Arch Index was obtained by dividing the area of the midfoot by the total area of the footprint and expresses the tendency of flatfoot; higher values indicate a higher level of flatfoot. Total average pressure is calculated by dividing the weight of the subject by the total footprint area. The area covered by the COP was revealed by the single-leg balance test; it is the same as that obtained on projecting the centre of gravity of the subject onto the support base *(plumb)* — a smaller area demonstrates better balance. The balance test results were given as percentage, based on the number of times that the subject was able to project the centre of gravity onto the illuminated target, a higher percentage demonstrates better balance.

Statistics

The SPSS 15.0 programme was utilised. Non-parametric statistical tests were undertaken. Averages, typical deviations, ranges and the Mann-Whitney U test were used to compare groups by sex and level of overweight. Relationships between the anthropometric variables of footprint and balance were analysed with lineal correlations. The statistical significance criteria was $p<0.05$. Effect size (ES) was calculated with the Cohen *d,* in order to take into account the practical significance of the differences.

Results

The results of the studied variables are shown in table 2. Analysis was based on 2 groups (boys and girls) and 2 subgroups (overweight and normal weight).

The biggest differences were found amongst the girls. On comparing overweight and normal weight, a greater Arch Index ($p = 0.06$; ES = 1) and greater significance in footprint areas (total, frontfoot and backfoot) (Figure 3) were observed in the overweight subgroup. In the area covered by the single-leg balance test, both girls and boys in the overweight subgroups obtained higher values (overweight boys = 225.71 ± 81.76 mm^2, normal weight boys = 163.77 ± 60.28 mm^2, p = NS; overweight girls = 157.74 ± 140.54 mm^2, normal weight girls = 83.52 ± 10.40 mm^2, p = NS). In the balance test, overweight girls achieved better results than normal weight girls, whilst in the boys group this situation was reversed though the differences were not significant (overweight girls = $81.54\pm15.41\%$,

Table 2 Results of footprint and balance test variables by sex and BMI

	Boys		Girls	
	With overweight	Without overweight	With overweight	Without overweight
Foot dimensions				
Front foot area (mm²)	3,104.88 (635.43)	3,148.74 (589.96)	3,740.29 (164.63)**	3,180.09 (423.90)
Mid foot area (mm²)	1,534.90 (233.06)	1,633.99 (609.48)	2,213.01 (751.15)*	1,486.75 (516.61)
Back foot area (mm²)	2,279.46 (313.20)	2,082.30 (471.09)	2.485.41 (175.33)**	2,167.53 (226.93)
Total area (mm²)	6,919.24 (715.57)	6,919.24 (715.57)	8,438.70 (973.12)	6,834.37 (996.82)
AI	0.22 (0.06)	0.23 (0.04)	0.26 (0.05) (p = 0.06)	0.21 (0.05)
Total average pressure (kPa)	697.41 (84.56)	611.58 (159.46)	606.94 (94.74)	607.19 (113.70)
Balance tests				
Area of coverage (mm²)	225.71 (81.76)	163.77 (60.28)	157.74 (140.54)	83.52 (10.40)
Accuracy (%)	64.60 (24.75)	72.61 (15.37)	81.54 (15.41)	79.30 (15.47)

The statistics represent the comparison with and without overweight in the same sex.
AI: Arch Index.
*p < 0.05. **p < 0.01.

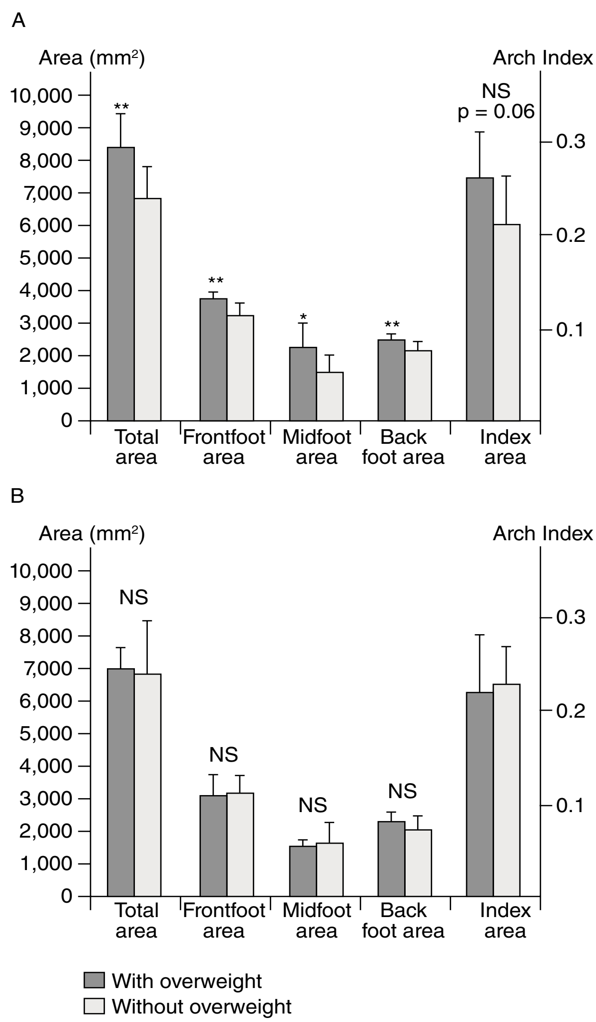

Figure 3 Results of footprint total area, frontfoot, midfoot, back foot and Arch Index by BMI in girls (A) and boys (B). NS = not significant. * = p < 0.05, ** = p < 0.01. The error bars show standard deviation.

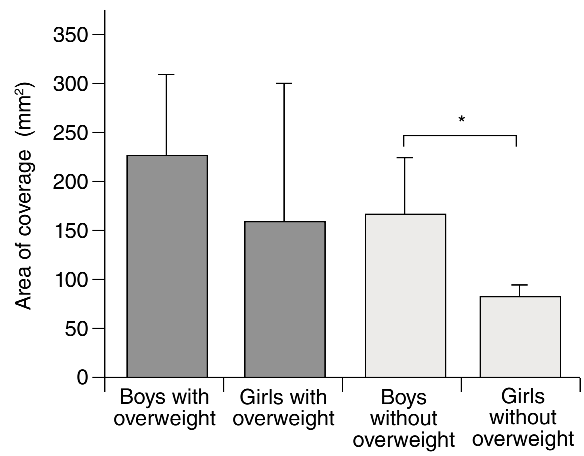

Figure 4 Results of the area covered by the balance tests by sex and BMI. The error bars show standard deviation. *p < 0.05.

normal weight girls = 79.30±15.47%, p = NS; overweight boys = 64.60±24.75%, normal weight boys = 72.61±15.37 %; p = NS). Effect sizes were low (ES = 0.15-0.39).

On comparing normal weight boys and girls, there were significant differences in the single-leg balance test, with boys registering higher values (normal weight boys = 163.77±60.28 mm², normal weight girls = 83.52±10.40 mm², p<0.01) (Figure 4).

No important correlations were found between the anthropometric variables of footprint or balance.

Discussion

Plantar footprints

The results obtained with the footprints are consistent with a study by Riddiford-Harland et al[24], which found greater plantar areas in obese subjects (8-9 years) than normal weight subjects. Nevertheless, in our study, results were only significant with girls, though this is probably due to the fact that the girls group was larger in number and there were greater differences in BMI between the overweight and normal weight subjects. This might also explain the lack of significant differences in the boys group, as noted by Mickle et al[27] with respect to boys and adolescents that suffer flatfoot due to an overload mechanism in the long term. This would mean that the link between obesity and flatfoot would be more likely to appear later, during adolescence[24,25,28].

Area of coverage

According to Goulding et al[37], in boys and adolescents between 10 and 21, there is a significant relationship between body weight, BMI, fat percentage and total fat mass and results in balance tests; overweight adolescents have worse balance than their normal weight peers. Bernard et al[30] reported similar results in obese subjects between the ages of 13 and 17, but only when postural capacity was altered by a surface area of foam. In this study, we found that in the single-leg balance test, greater areas were covered by the overweight subgroups, though they were not statistically significant. This might be due to the relatively small sample or the fact that the test did not add any disturbances, such as the use of foam. If the study sample was larger, it is probable that differences would be more significant. In fact, a large effect size was found in the differences in the boys group (ES = 0.86) and a medium-large effect in the girls group (ES = 0.74). It was calculated that the minimum number of subjects required to allow for possible differences in the areas covered between the overweight and normal weight subgroups is 44 for girls and 21 for boys, with a statistical potential of 80%.

Accuracy percentage

The postural sway test showed no differences between the accuracy percentages for overweight and normal weight subjects. This may be due to the fact that the test involves different postural adjustment strategies to the single-leg balance test, such as, for example, the level of proximal and distal muscle activation of the lower limbs[38]. Childhood overweight can substantially affect performance in some motor tests without provoking significant differences in others[39]. It would be interesting to be able to delimit the balances that are most affected by overweight in order to design corrective interventions that could be implemented in the school environment. This would, of course, have to be done without undermining the importance of encouraging physical activity and developing a less sedentary life-style, vital objectives of physical education programmes in schools[40].

Sex differences

Area of coverage results for normal weight subjects were significantly better (smaller areas) in the girls group ($p < 0.05$), confirming the work of Steindl et al[41], which found that boys of 11-12 years obtained worse results than girls of the same age. In the overweight subjects group girls also obtained better results though they were not statistically significant.

As for the accuracy percentage, girls obtained better results than boys but they were not statistically significant.

Limitations of the study

The main limitation of the study was the difficulty of working with sophisticated biomechanical protocols and methodologies within the school environment. It is difficult to reconcile this fact with the minimum number of subjects required for statistically significant results. Despite this limitation, the study obtained high effect size levels on comparing overweight and normal weight subjects.

Future studies should aim for the minimum number of subjects required, perhaps at the cost of simplifying the analysis methodologies. Adolescent subjects should also be studied in order to clarify differences in footprint and some balance types, as the more advanced age of the subjects facilitates the study of larger sample populations.

Conclusions

Overweight girls showed footprint alterations, with a tendency toward flatfoot. In this study, overweight boys did not show this tendency though flatfoot could well appear later in life if excessive weight continues to exert disproportionate pressure on the feet.

Overweight girls and boys obtained worse results (though not significant) in the single-leg static balance test. There were no differences between normal weight and overweight subjects in the balance test. It would seem that overweight affects some types of balance but not others. It would be interesting to be able to delimit the balances that are most affected by overweight in order to design corrective interventions that could be implemented in the school environment.

Girls obtained better results in the balance tests than boys.

Conflict of interest

The authors declare no conflict and no financial interests.

Funding

This study has been funded by the Castile and La Mancha Council of Communities Department of Education and

Science project “Footwear Biomechanics for Children” (Ref. PAI 07-0071-0231).

Acknowledgements

The authors would like to thank the children from the Santa Teresa School, Toledo, for their participation; Esperanza López Pérez, Head Teacher, and Dulce N. Rodríguez Casares, class teacher, for their cooperation and support.

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