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Research article

FLAT FEET AND OBESITY AMONG CHILDREN

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Abstract. *Flat feet (pes planus) represents one of the most frequent deformities of the lower extremities which occurs with the collapse of the physiological arches of the feet. The causes of flat feet are numerous. One of the main causes is excessive weight and obesity, problems which this review paper meant to explain by analyzing the works of authors who dealt with this problem from 2000 to 2017. The prevalence of flat feet varies depending on several factors, but all the authors agree that obesity increases the percentage of the prevalence of flat feet among children. The influence of physical activity on any changes to the status of the arches of the feet and a decrease in body weight have been the focus of very few authors. The recommendation is for this problem to be analyzed more because of the positive results that the application of physical activity has on postural status and disorders of the feet. The prevalence of flat feet differs depending on the geographical area, but also depending on age and gender.*

Key words: *flat feet, obesity, postural status, children*

INTRODUCTION

Flat feet (pes planus) is a relatively frequent occurrence and represents one of the most frequent deformities where a collapse of normal physiological arches of the feet is found (Živković, 2013). Flat feet can cause difficulty in walking, can even lead to more serious health issues, and can cause pain in the regions of the feet and waist (Lee et al., 2005). For that reason treatment should start as soon as possible following diagnosis. This deformity is linked to racial characteristics. The prevalence of flat feet is greater among the African-American population than among Caucasians, and it has been proven that flat feet rarely cause disability (Stewart, 1970). There are numerous theories which explain the discovery and development of flat feet: gender, age, excessive weight, obesity (Vergara-Amador,

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Serrano Sánchez, Correa Posada, Molano, & Guevara, 2012). In the case of so-called standing occupations such as those in the service industry, or traders, dentists, surgeons, the function of feet is reduced to a minimum, and can lead to flat feet (Živković & Karaleić, 2014). In addition, among obese adults, it has been confirmed that there is an increased pressure on the soles of the feet (Hills, Hennig, McDonald, & Bar-Or, 2001).

During childhood, obesity causes abnormally high levels of stress on the development of the structure of the feet, which might lead to structural deformities of the feet, limiting the normal way of life of an individual (Sadehqi-Demneh et al., 2016). The prevalence of flat feet among children with normal weight, overweight children or obese children has not been studied sufficiently in the past. Overweight or obese children are at an increased risk of skeletal fractures and muscle-skeletal pain (Taylor et al., 2006). The foot, under the influence of an excess of physical weight during childhood can lead to the occurrence of flat feet in adolescence (Mauch, Grau, Krauss, Maiwald, & Horstmann, 2008).

Research has indicated that flat feet occur much more frequently among overweight or obese children (Pfeiffer, Kotz, Ledl, Hauser, & Sluga, 2006; Chen, Chung, & Wang, 2009) than among children with normal weight, while other studies support the existence of a positive connection between flat feet and overweight children (Halabchi, Mazaheri, Mirshahi, & Abbasian, 2013). However, the question of whether excessive weight might be the cause of flat feet among children is still open. Various studies indicate that flat feet might occur as a result of the collapse of the medial longitudinal arch of the feet after the completion of development (Halabchi et al., 2013), or due to an increase in the fat tissue in the area of the plantum (Mickle, Steele, & Munro, 2006a). Certain authors point out that flat feet occur as a consequence of changed shape of the ankle bone, which becomes vertical (talus verticalis). This deformity might also lead to rickets which causes changes to the bones (Radisavljević, 2001). Flat feet can occur as a result of the less than perfect static-dynamic position of the locomotor apparatus, the lack of adaptation of the body to standing up, and hypokinesis (Živković, 2013).

This review paper had as its aim to identify and sum up the results of the relevant literature on flat feet and obesity among children, as well as to clarify whether there is any connection between them.

METHODS

The sources of data and research strategies

The electronic search of the papers was carried out in the following databases: PubMed, ScienceDirect, SCIndex and Google Scholar. We reviewed papers which were published on the SCI list from 2000 to 2016. In order to find papers related to this topic, our search was limited to the following key words: flat feet, children, obesity, pain, or a combination of the aforementioned key words.

To analyze the obtained data we applied a descriptive method. All the titles and abstracts were reviewed for studies which could potentially be included in the systematic overview. In addition, the list of references of the previously analyzed papers and original research were also reviewed. The relevant studies were obtained following a detailed overview, if they met the criteria for inclusion.

The search strategy was modified and adapted to suit every database and search, where possible, with the aim of improving the sensitivity of the research. The systematic analysis of the papers was carried out according to methodological guidelines and in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – PRISMA (Moher, Liberati, Tetzlaff, & Altman, 2009).

Inclusion criteria

The type of study: controlled randomized and non-randomized studies were reviewed and included in further analysis, while non-controlled studies were excluded. Papers published in English and Serbian were included in the study.

The sample of participants: boys and girls, irrespectively of their lifestyle (active/sedentary), Body Mass Index-BMI (obese/normal weight), over the age of 3.

The type of obtained results: the primary result obtained for the needs of a systematic overview was flat feet. Studies were included in the review if the options of correction and treatment of flat feet were taken into consideration. Secondary results, which were mostly related to the systematic overview of the papers, included studies in which the validity of the clinical techniques for the evaluation of flat feet were used, or if they determined the effects of flat feet on the biomechanics of movement, walking and running.

Exclusion criteria

Exclusion criteria are given as follows: studies written in any other language except English or Serbian; studies focused on innate flat feet; studies which evaluate flat feet, the biological structure of feet, irrespective of weight, or focus only on treating flat feet among adults; studies focusing on all the deformities of the lower extremities; duplicates; studies including participants under the age of 3.

RESULTS

Following a general database search, 670 potential studies were identified, along with nine additional ones based on their references. Once the duplicates were excluded (n=465) and papers eliminated based on their titles and abstracts (n=156), 81 studies remained. The remaining studies were analyzed in detail. Based on the criteria for inclusion, an additional 63 papers did not meet the criteria for further processing. Finally, 18 studies satisfied the predefined criteria and were included in the systematic overview.

All of the studies which analyzed the connection between body weight and flat feet and were compiled from reviewed scientific journals, and were mainly of a transversal character. The studies were carried out in European countries: Austria, Germany, Spain, Turkey and some studies were carried out in Taiwan, and Iran. There were no studies carried out on the African continent or North America, where obesity and flat feet have a very high prevalence. A detailed overview of the selection of papers and their inclusion can be found in Figure 1.

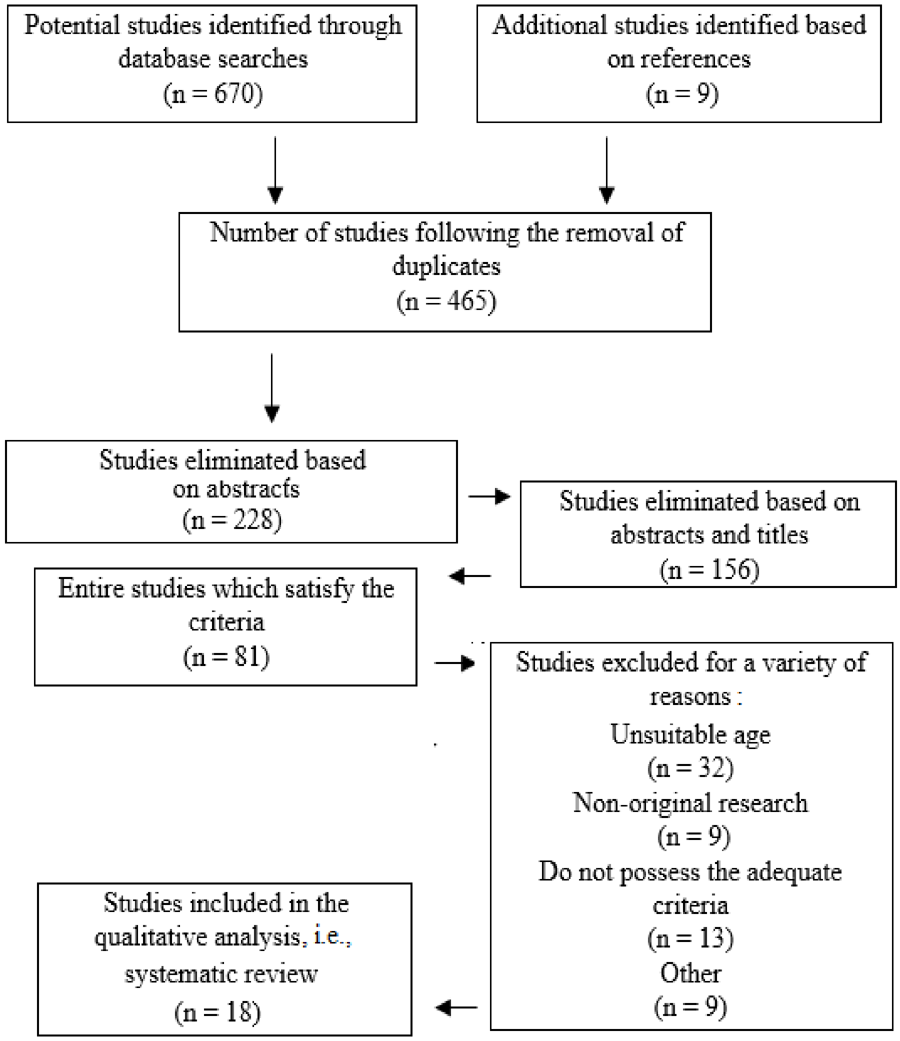

Fig. 1 An overview of the compilation process of appropriate studies based on predetermined criteria

Table 1 An overview of the studies

First author and year of publication	Number of participants	Age of the participants	Body weight status	Status of the feet, measurement technique	Results
Atamturk (2009)	N=516 M-253 F-263	18-83 M-40.5±13.4 F-43.3±14.9	BMI $\leq$30kg/m^2 >30kg/m^2	Pes planu, pes cavus, plantogram	There is no statistical significance of the influence of age, weight and height on the prevalence of the deformities
Adoracion Vilarroya, Manuel Esquivel, Tomas, Buenafe, & Moreno (2008)	N=245	9-16	Normal weight, excessive weight and obesity	Flat feet, plantogram	Increased percentage of collapsed arches of the feet among obese children
Chen et al. (2009)	N=1034 M-549 F-475	5-13	Normal w., excessive weight and obesity	Flat feet, a 3D probe and digital tape	The prevalence of flat feet: among boys 35%, among girls 20%, with normal weight 27%, overweight 31% and obese 56%.
Chen et al. (2011)	N=1598 M-833 F-765	3-6	BMI was calculated	Normal arches of the feet (n-733), unilateral flat foot (n-266), and bilateral flat feet (n-599)	A significant decrease in the prevalence of flat feet among older children (from 54.5% among 3 to 21% among 6 year-olds in the third group) the prevalence of flat feet increases with an increase in weight and is greater among boys
Chang et al. (2010)	N=2083	7-12 Six groups divided based on age	Obese, overweight, normal and decreased weight.	Flat feet among 67% of the boys and 49% of the girls, a plantogram according to Denis	The prevalence of flat feet among obese 75%, overweight 65%, normal weight 57% and reduced weight 48%. Greater prevalence among the boys and decreases among older children
De Sa Pinto, de Barros Holanda, Radu, Villares, & Lima (2006)	N=96 M-53 F-43	M-10.8±2.1 F-10.4±2.3	25 boys and 24 girls were obese, while 28-19 were of normal weight	Flat feet, back pain, osteo-articular changes to the legs, a digital podoscope, ultrasound	The prevalence of the disorder among the obese is 55% while for the others it is 23%

Echarri & Forriol (2003)	N=1851 M-945 F-906	3-12	Body weight is not treated as a factor of occurrence of flat feet	Flat feet, Chippaux–Smirak index, Staheli's index and Clark's angle, a comparison of the urban and rural environment	The prevalence is highest among the ages of 3-4 and decreases. In the case of boys the prevalence is greater, as it is among children in an urban environment
Hills et al. (2001)	N=70 M-35 F-35	M-42.4±10.8 F-40±12.6	BMI Obese-38.75±6 Normal w-24.28±3 M-67-179kg F-46-150kg	Pressure on the feet on the tension platform while walking and standing	The pressure of the feet on all the measurement points is greater among obese individuals. In a standing position the pressure of the medial arch is greater among obese women.
Mauch et al. (2008)	N=2887 M-1450 F-1437	3-14	Increased, decreased and normal weight, based on BMI	Flat feet, typology of the feet, a 3D scan of the feet	Obese children more often suffer from flat and robust feet, and those with lower weight have thinner and longer feet, while children with normal weight have all types of feet
Mickle, Steele, & Munro (2006a)	N=34	Obese 4,4±08 yrs Norm w. 4.4±07 yrs	Obese and normal weight based on BMI	Pressure of the feet on the tension platform when walking	Significantly increased contact surface and force of pressure on the tension board among obese individuals. The pressure point at the level of the medial arch is increased and indicates a flat foot
Mickle, Steele, & Munro (2006b)	N=38 Normal weight -19 Obese-19	3-6	19 obese children and 19 children with normal weight and based on BMI	Flat feet, ultrasound diagnosis of the fat tissue on the medial arch	The thickness of the fat tissue is not statistically significant, while flat feet are more prevalent among obese and overweight children
Pfeiffer et al. (2006)	N=835 M-424 F-411	3-6	Normal weight, excessive weight and obesity, BMI	Flexible flat foot 44% pathologically flat foot of less than 1%	The prevalence of flat feet significantly decreases with age (3 yrs 54% and 6 yrs 24%). Among boys 52% and among girls 36%
Riddirord-Harland, Steele, & Storlien (2000)	N=124	8.5±05	Obese-62 Normal weight-62	Flat feet, a podograph with the angle of the impression and the Chippaux–Smirak index	Decreased angle of impression and increased index among obese individuals, which assumes the existence of the endangered function of the feet in the future if there is no decrease in body weight

Riddirord-Harland, Steele, & Baur (2011)	N=150 Norm.-75 Obese -75	6-9	Excessive and normal weight, BMI	Flat feet and thickness of the subcutaneous tissue of the medial arch. Podography and ultrasonography	Fat tissue on the medial arch of the foot does not affect the collapse of the arches, and is even thicker in less collapsed arches. Increased weight as the factor of the occurrence of flat feet
Sadeghi-Demneh et al. (2016)	N=667 M-340 F-327	7-14	Normal weight, excessive weight and obesity, BMI	Flat feet, clinical examination and plantogram	Greater prevalence of flat feet, deformity of the ankle and pain in the foot among obese children and overweight children
Tenenbaum et al. (2013)	N=825964 M-467412 F-358552	17	Increased and normal BMI	A flexible flat foot with severe and milder criteria, clinical method	The prevalence of flat feet among men was 12.4% for mild and 3.8% for the severe stage, while among women it was 9.3% and 2.4%. Increased BMI is an important factor of prevalence at the 1.385 and 1.765 level among men and 1.408 and 1.549 among women (overweight and obese in both cases)
Vergara-Amador et al. (2012)	N=940 Bogota 60% Baranquilla 40%	3-10	One of the factors of prevalence of flat feet, but it was not considered	Flat feet in different geographic regions, plantography using the Denis method	General prevalence of 15.74% (20.8 and 7.9%). A general prevalence among children aged 3 to 5 is 30.9 (38.3 and 17.3%) while among children aged 6-7 it was 11.3% (17.2-1.5%). The percentage decreases with age
Chang et al. (2010)	N=44 M-24 F-20	3-6	Measured weight and height without the use of the BMI	Five groups, 3D contour of the foot was measured using a 3D scan, a digital caliper to measure the height of the medial arch	3D laser scan represents an exceptional reference for clinical study, as well as the index for distinguishing between types of deformities

M-male; F-female

DISCUSSION

Many studies extracted from the population of school children indicate a general prevalence of flat feet, by many means of determination and classification. The prevalence of flat feet in the population varies from a high 67% among men and 49% among women (Chang et al. 2010), to the lowest 14.2% and 15% (Tenenbaum et al., 2013; Mauch et al., 2008). Among the studied 44%, less than 1% had the pathological deformity of flat feet (Pfeiffer et al., 2006).

All of the studies have indicated an increased prevalence of flat feet among obese children, with a frequency of 48% among children with normal weight, and 75% among obese children (Chang et al., 2010). Studies carried out in Taiwan indicate a low prevalence of flat feet measured in various ways, but they also indicate that the increase in weight reaches an increased prevalence of flat feet (Chen et al., 2009; Chen et al., 2011). The realized studies focused on the possible connection with age, believing that the prevalence of flat feet diminishes with an increase in age (Chang et al., 2010; Chen et al., 2011).

The studies carried out in Iran indicate that there are more significant differences in the prevalence of flat feet among children with normal weight, overweight and obese children. Studies have shown that with an increase in body weight there is a greater prevalence of flat feet, which indicates that obesity in childhood can lead to structural changes of the feet, angular deformities and in turn decreased activity, which can lead to pain (Sadeghi-Demneh et al., 2016).

Case studies indicated the differences in the foot morphology among children with excess weight and obese children, compared to children of normal weight, with specific differences in the general structure of the feet (Riddiford-Harland et al., 2000), and increased fat tissue in the area of the plantum (Riddiford-Harland et al., 2011). The morphological aspects of the abilities of the foot in the studies were obtained by various means of measurement (Riddiford-Harland et al., 2000; Mickle et al., 2006a; Pfeiffer et al., 2006; Adoracion Vilarroya et al., 2008; Mauch et al., 2008; Chen et al., 2009; Riddiford-Harland et al., 2011).

In general, studies indicate low plantar arches and an increase in the thickness of fat tissue of the feet among overweight or obese children. However, one study did not determine any differences in the thickness of fat tissue of the feet among the groups (Mickle et al., 2006b). Certain researchers classify feet into five types, and provide specific findings that overweight children have a greater tendency towards flat and strong feet (Mauch et al., 2008). Only one study indicated the differences between a pathologically flat foot and a flexible flat foot (Pfeiffer et al., 2006), even though individual studies only indicate the frequency of flexibility of flat feet (Tenenbaum et al., 2013).

Among children, flat feet is one of the most frequent deformities of the lower extremities with various factors which determine its occurrence, including type of footwear, obesity, age and gender (McCluskey, 2001; Echarri, & Forriol, 2003). It is considered that most children, and at least 20% of adults have flat feet which are flexible, and which can be corrected (Staheli, Chew, & Corbett, 1987; Vanderwildeet, Staheli, Chew, & Malagon, 1988). These musculo-skeletal problems are a known complication which occurs due to the onset of obesity (de Sa Pinto et al., 2006; Paulis, Silva, Koes, & van Middelkoop, 2014), and so even in this overview there seems to be a positive connection between obesity and flat feet (Atamturk, 2009). If we were to take a look at all the studies of flat feet in relation to obesity, we may conclude that obesity is, generally speaking, a factor of some concern (Kohls-Gatzoulis et al., 2004). In all the studies there is a clear connection between an increase in weight and the prevalence of flat feet. However, there is data which indicate that obese children have stronger legs (Chen et al., 2009). Generally speaking we may say that excess weight and obesity have a negative impact on one's feet.

Despite all these studies, which all reached similar conclusions, it is necessary to establish a positive correlation between a high body mass index and flat feet (Adoracion Vilarroya et al., 2008). Studies also indicate a negative connection between body weight and the longitudinal arch of the foot. In these studies authors used body weight or BMI as a criterion needed to present these interactions (Atamturk, 2009). In the study of Mickle et al. (2006a) the average height of the plantar angle was measured among children of normal weight and obese children and it was found that body weigh in both cases does not confirm the set hypothesis. Low plantar angles occur among children who are overweight and obese preschool children, and can cause structural changes to the foot anatomy. This is a postulate of these structural chagnes, which can negatively influence the functional ability of the feet.

The clinical image and functional ability of the feet have not yet been clarified. The clinical evaluation of a child with flat feet should consist of a more general study of the skeletal-joint system, while the general overview has as its aim to evaluate the torsion and angle parameters of the lower extremities (Stolzman et al., 2015). Flat feet cause pain in the feet and lower legs (Wearing et al., 2007), especially following a long walk or intense bouts of exercise (Hills et al., 2001; Willems et al., 2006).

Considering that flat feet are more prevalent among obese children, the deformity will probably affect their functional abilities and the extent to which they can take part in physical activity; however, the recommendation of the experts who deal with the evaluation and treatment of this deformity is not to treat flat feet as a potential problem related to weight (Krebs et al., 2007). Flat feet lead to a decrease in static and dynamic activities, balance, speed of walking, may limit running, dancing, riding a bicycle, and pain can occur in the area of the lower extremities and spine (Rome, Ashford, & Evans, 2010). The guidelines of clinical practice for diagnosing and treating flat feet was initiated by the American College of Foot and Ankle Orthopedics (Powell, Seid, & Szer, 2005).

Healthcare has to make a distinction between the flexible and pathological state of a flat foot. Contemporary literature which deals with the evaluation of flat feet and obesity among children and adolescents has several limitations. None of the studies have indicated that pain occurs, or noted some other complication which can stem from the occurrence of this deformity, which indicates that most children with flat feet do not exhibit any symptoms and might never require treatment (Barlow, 2007). However, the evaluation of pain related to flat feet and obesity has not been explained completely (Wearing et al., 2007). Research has not indicated that pain or disability ensue due to the occurrence of flat feet, but Sadehqi-Demneh et al. (2016) indicate that there might be some pain, if there are changes in the structure of the feet. Stretching exercises and strength exercises of the foot and ankle are usually the initial recommendation for the improved function of the feet, or decrease in pain, if it occurs (Rome et al., 2010).

The measurement techniques and foot scans (a radiogram, a three-dimension measurement system/scanner, ultrasound, clinical measurement tapes, platforms) indicate very different changes on the arches of the feet. The reason for that might be the different quality of the scan technique and measurement technique. It is necessary to carry out a study or several studies which will include all the instruments used to evaluate the status of the feet, with the measurement of a representative sample, and thus lead to a potential unification of the results of the evaluation of foot deformities.

CONCLUSION

A detailed survey of the literature has determined that with the increase in body mass there is an increase in the prevalence of flat feet. The complications related to flat feet among obese children, such as pain, limited activities, have not been explained fully, and require further study. This overview did not lead to any general conclusions that obesity and pain among children might be related to plantar limitations, but it could recommend a combination of scans, measurements and clinical examinations in each evaluation of every case of flat feet, in order to possibly find the cause of the pain, as well as for any planned corrective treatment. We can conclude that a systematic clinical examination of the children is needed, in order to determine the extent to which the arches have collapsed, and to monitor their further evaluation during periods of growth or even better, during corrective treatment. With these positive changes, there is hope that an overweight or obese child might finally be able to increase his participation in physical activity and exercise, to make changes in his weight status and improve his quality of life.

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RAVNO STOPALO I GOJAZNOST KOD DECE

Ravno stopalo (pes planus) predstavlja jedan od najčešćih deformiteta donjih ekstremiteta koji nastaje usled smanjenja ili gubitka fizioloških svodova stopala. Uzroci nastanka ravnog stopala su mnogobrojni. Jedan od glavnih uzroka je prekomerna težina i gojaznost, što ovo pregledno istraživanje pokušava da objasni kroz analizu radova autora koji su se bavili ovom problematikom u periodu od 2000 do 2017 godine. Prevalenca ravnog stopala varira u zavisnosti od mnogo faktora, ali se svi autori slažu da gojaznost povećava procenat prisutnosti ravnog stopala kod dece. Uticajem fizičke aktivnosti na popravljanje statusa svoda stopala i smanjenje telesne težine, bavilo se malo autora. Preporuka je da se taj segment više obrađuje zbog pozitivnih rezultata primene fizičke aktivnosti na posturalni status i poremećaje na stopalu. Prevalenca ravnog stopala se razlikuje u zavisnosti od geografskog područja, ali i u zavisnosti od uzrasta i pola.

Ključne reči: *Ravno stopalo, gojaznost, posturalni status, deca*