Northwestern Med J. 2023;3(2):81-87
doi: 10.54307/NWMJ.2023.84856

Original Article

The relationship between body mass index and pronation response of the foot in healthy young individuals*

Sağlıklı genç bireylerde vücut kitle indeksi ile ayağın pronasyon cevabı arasındaki ilişkinin değerlendirilmesi

Gamze Taşkın Şenol, İbrahim Kürtül, Abdullah Ray, Gülçin Ahmetoğlu

Atıf/Cite as: Taşkın Şenol G, Kürtül İ, Ray A, Ahmetoğlu G. The relationship between body mass index and pronation response of the foot in healthy young individuals. Northwestern Med J. 2023;3(2):81-87.

ABSTRACT

Aim: This study aims to evaluate the relationship between body mass index and navicular drop in healthy young individuals by considering gender differences. In addition, it is to support the literature for a better understanding of the effect of the foot on the balance mechanisms and to contribute to the development of new approaches in addition to the existing treatment approaches.
Methods: A hundred medical school students between the ages of 18-25 were included in our study. The participants' age, height, and weight information were recorded, and body mass index (BMI) was calculated. The navicular drop test was performed to measure the pronation response of the foot.
Results: The mean±SD values of the determined parameters in men and women were as follows respectively: Age: 20 and 20; Height (cm): 179±12.7 and 163±0.05, Weight (kg): 78.8±5.3 and 54.5; BMI (kg/m2): 24.4±3.5 and 20.2, right navicular tubercle height in a sitting position (SNTR): 43.7±4.8 and 38.7±5.1; right navicular tubercle height in a standing position (StNTR): 36.4±4.2 and 24.9±4.8; the navicular drop rate of the right foot (NDRR): 7.2±4.2 and 7.2±5.3; left navicular tubercle height in a sitting position (SNTL): 37.2±3.5 and 32.3±5.3; left navicular tubercle height in a standing position (StNTL): 30±4.7 and 31.5±5.2; the navicular drop rate of the left foot (NDRL): 7.2±4.7 and 7.4±4.6.
Conclusion: As a result of our study, it is seen that an insignificant change in the rate of navicular drop as the body mass index increases in men and women.

Keywords: Body mass index, foot, navicular, pronation response

ÖZ

Amaç: Bu çalışmanın amacı, sağlıklı genç bireylerde vücut kitle indeksi ile navikular düşme miktarı arasındaki ilişkiyi cinsiyet farkı gözetilerek değerlendirmektir. Ayrıca ayağın denge mekanizmalarındaki etkisinin daha iyi anlaşılması için literatüre destek olmak ve mevcut tedavi yaklaşımlarına katkı sağlamaktır.
Yöntem: Çalışmamıza 18-25 yaş arası 100 tıp fakültesi öğrencisi dahil edildi. Katılımcıların yaş, boy ve kilo bilgileri kaydedildi ve vücut kitle indeksi (VKİ) hesaplandı. Ayağın pronasyon cevabını ölçmek için navikular düşme testi uygulandı.
Bulgular: Belirlenen parametrelerin erkeklerde ve kadınlarda sırasıyla ortalama±ss değerleri; yaş; 20 ve 20, boy (cm); 179±12,7 ve 163±0,05, ağırlık (kg); 78,8±5,3 ve 54,5, VKİ (kg/m2) 24,4±3,5 ve 20,2, oturur pozisyonda sağ navikular tüberkül yüksekliği (ONTSa); 43,7±4,8 ve 38,7±5,1, ayakta sağ navikular tüberkül yüksekliği (ANTSa); 36,4±4,2 ve 24,9±4,8, sağ ayağın navikular düşme oranı (ANDSa); 7,2±4,2ve 7,2±5,3, oturur pozisyonda sol navikular tüberkül yüksekliği (ONTSo); 37,2±3,5 ve 32,3±5,3, ayakta sol navikular tüberkül yüksekliği (ANTSo); 30±4,7 ve 31,5±5,2, sol ayak navikular düşme oranı (ANDSo); 7,2±4,7 ve 7,4±4,6 olarak ölçülmüştür.
Sonuç: Çalışmamız sonucunda kadın ve erkeklerde vücut kitle indeksi arttıkça naviküler düşme oranında anlamlı bir değişimin olmadığı görülmüştür.

Anahtar kelimeler: Ayak, navikula, pronasyon yanıtı, vücut kitle indeksi

Received: 09.12.2022
Accepted: 16.05.2023
Publication date: 01.06.2023

Corresponding Author:
G. Taşkın Şenol
ORCID: 0000-0001-5587-1055
Bolu Abant İzzet Baysal University, Faculty of Medicine, Department of Anatomy, Bolu, Türkiye
✉ rumeysagamzetaskin@ibu.edu.tr

İ. Kürtül
ORCID: 0000-0002-9218-6468

A. Ray
ORCID: 0000-0002-8124-6402

G. Ahmetoğlu
ORCID: 0000-0002-0417-1806

Bolu Abant İzzet Baysal University, Faculty of Medicine, Department of Anatomy, Bolu, Türkiye

* This study was presented at the International Korkut Ata Scientific Research Conference held in Osmaniye Korkut Ata University, Osmaniye between 28-30 June 2022.

INTRODUCTION

The feet form a support surface for the body by contacting to various floor shapes during daily life activities such as standing and walking, and they transfer the weight to the ground and absorb the reaction force from the ground (1). They are suitably flexible in nature to prevent the absorbed forces from reaching the proximal parts, are dynamic to perform the walking function, and are rigid to carry the body weight (2). In addition to these functions, the fact that 25% of the bones forming the skeleton are in the foot region indicates that the foot has a complex anatomical and biomechanical peculiarities in terms of anatomy and biomechanics (2,3).

Pronation of the foot is provided by eversion of the calcaneus and displacement of the talus medially under static load. In the overload phase, the foot must go into pronation to adapt to the ground (3).

The medial longitudinal arch (MLA) is the main arch that contributes to the morphology of the foot (1,4-6).

The navicular tubercle represents the height of the MLA and functions with various joints and muscles in maintaining the height of the MLA. It is also the insertion site for the tibialis posterior muscle, which plays a primary role in the dynamic stabilization of the MLA.

Pathology of the MLA, which comprises the calcaneus, talus, navicular, cuboid, first three metatarsals, ligaments, and tendinous structures, such as pes planus and pes cavus, affects the muscle and joint function in the lower extremity (1,4,7).

The condition in which the height of MLA is less than normal or MLA completely collapses is defined as pes planus, which cause impaired load distribution while walking, excessive stress on the foot and ankle, and internal rotation in the hip joint. It is also associated with other clinical conditions of the foot (5). Pes planus is generally associated with shortness of the posterior tibialis muscle. Moreover, the gastrocnemius and peroneal muscles are occasionally shortened due to hindfoot pronation. Compensation of pathology causes muscle fatigue and overuse injuries (5).

The navicular drop test is one of the tests used to evaluate hindfoot pronation and provides the height of the navicular, hence the height of the MLA. This test was preferred in the current study because it is inexpensive, practical, and has provided a high degree of accuracy in other studies (8).

Additionally, high BMI values increase the load on the feet, lead to deterioration of the MLA structure, and a decrease in the elasticity of the heel fat pad, resulting in the impairment of the foot posture (8,9).

Therefore, this study aims to evaluate the relationship between the pronation response of the foot and body mass index in healthy young individuals.

MATERIAL and METHOD

The study was conducted at Bolu Abant Izzet Baysal University, Faculty of Medicine, Bolu, Turkey between January 2022-May 2022, which included 100 (50 female and 50 male) medical school students aged between 18-25 years. The ethical approval for the study was obtained from the Clinical Researches Ethics Committee (2021/117). Exclusion criteria were determined as having lower extremity deformity, major trauma and pain in the lower extremity for the last three months, acute foot-ankle problem and acute infection, and normal MLA structure as inclusion criteria. Written informed consent was obtained from all the subjects who met the inclusion criteria. Initially, the demographic data including name, age, gender, height, weight, and BMI were assessed. BMI analysis was performed

Table 1. Body mass index classification according to the World Health Organization.

Body mass index	Classification
18,5	Weak
18,5- 24,9	Normal weight
25- 29,9	Pre-obesity
30- 34,9	Obesity class I
35 – 40	Obesity class II
> 40	Obesity class III / Morbid Obesity

using the formula (body weight (kg) / height (m) squared). The results were analyzed in five groups according to the classification of the World Health Organization (Table 1). Subsequently, the students were assessed for a navicular drop test.

The navicular drop test (NDT): Each student was asked to sit in a relaxed position with the hip and knee flexed at 90 degrees and the foot placed flat on a solid supporting surface. The ankle and subtalar joints are placed in a neutral position. The height of the navicular tuberosity (NT) in this position was marked. The subject was asked to stand with equal weight on both feet and then the new height of the NT was marked. The distance between the two heights was recorded as the navicular drop rate (NDR) (Figure 1). The difference between the marks was measured with a Vernier caliper. Values between 6 and 9 mm were classified as normal MLA, and values greater than 10 mm were classified as pes planus. The students with pes planus were excluded from the study (5).

Evaluated parameters

Right navicular tubercle height in a sitting position (SNTR), left navicular tubercle height in a sitting position (SNTL), right navicular tubercle height in a standing position (StNTR), left navicular tubercle height in a standing position (StNTL) of male and female participants, body mass index (BMI), navicular drop rate right foot (NDRR), navicular drop rate left foot (NDRL).

Statistical analysis

R Project (version 4.1.2) was used for analyzing the data. The normality of the data was tested using the Shapiro-Wilk test. As a result of the analyses, the standard deviation and mean of the parameters that fit the normal distribution and the minimum, maximum and median values of the parameters that did not fit the normal distribution were calculated. The correlation coefficient and p-value are also included. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The distribution of height, weight, BMI, and NDR values (right and left) in the study population was calculated (Table 2).

The distribution of BMI values: 7 participants under 18.5 kg/m², 63 participants between 18.5 and 24.9 kg/m², 24 participants between 25 and 29.9 kg/m², and 5 participants between 30-34.9 kg/m². There is one participant between 35-40

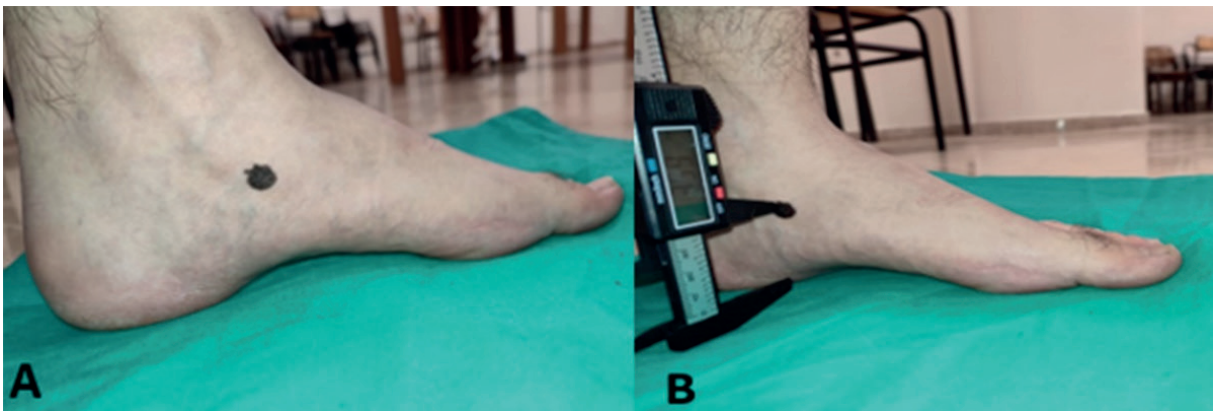

Figure 1. A: Left navicular tubercle in the sitting position B: Measurement of the left navicular tubercle in the sitting position.

Table 2. Distribution of age, height, weight, BMI, SNTR, StNTR, NDRR, SNTL, StNTL, and NDRL* in the study sample.

	Min.		Max.		Median		Mean (±SD)	
	Male	Female	Male	Female	Male	Female	Male	Female
Age	18	19	23	22	20.0	20.0		
Height (cm)	-						179 (±12.7)	163 (±0.05)
Weight (kg)	-	43	-	83		54.5	78.8 (±5.3)	
BMI (kg/m²)	-	16.1	-	31.6		20.2	24.4 (±3.5)	
SNTR							43.7 (±4.8)	38.7 (±5.1)
StNTR							36.4 (±4.2)	24.9 (±4.8)
NDRR							7.2 (±4.2)	7.2 (±5.3)
SNTL							37.2 (±3.5)	32.3 (±5.3)
StNTL							30.0 (±4.7)	31.5 (±5.2)
NDRL							7.2 (±4.7)	7.4 (±4.6)

kg/m² and no participant over 40 kg/m². The distribution of BMI values by gender is shown in Figure 2.

There was no statistically significant difference between body mass index and right and left navicular drop rates in men and women. A weak negative correlation was found between body mass index and right and left navicular drop rates in men, and a weak positive correlation was found between right and left navicular drop rates in women (Table 3).

Table 3. Correlation coefficients and p-values between body mass index and right and left navicular drop rates.

	Body Mass Index- Navicular Drop Rate			
	Right		Left	
	p	r	p	r
Male	0.1	-0.1	0.2	-0.1
Female	0.1	0.2	0.7	0.04

DISCUSSION

It is well known that being overweight leads to pathologies causing more deaths than malnutrition. It is a fast-growing vital health problem worldwide, resulting in degenerative changes and various movement dysfunctions, including foot pain (10). With that in mind, this study has aimed to reveal in detail the effect of the foot on the balance mechanism in young individuals by evaluating the relationship between BMI and NDR. The results have indicated an insignificant change in the rate of navicular drop with increasing body mass index increases in men and women.

It is natural that with increasing age, deformation occurs gradually in the foot structures and the healthy arch structure of the foot under static load

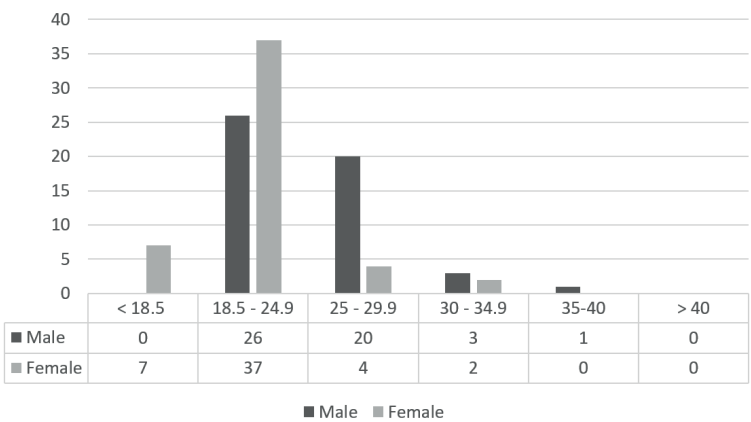

Figure 2. Distribution of body mass index values in males and females.

deteriorates in time. Even though there are studies in the literature on the gender- and age-related morphometric parameters and morphological features of the foot, they are generally conducted in children (11), and the number of studies examining the relationship between BMI and NDR in healthy young individuals is limited. Therefore, this research was limited to individuals between the ages of 18-25. The results have indicated that the increase in BMI in men and women does not change NDR. A weak negative correlation was found between body mass index and right and left navicular drop rates in men, and a weak positive correlation between right and left navicular drop rates in women. The reason for this difference is the deterioration of the foot integrity and biomechanics as a result of the increase in BMI. It is thought that the gender difference in the results is due to the mean BMI values and foot lengths of men being different from those of women. Muscle strength, which also affects NDR, subcutaneous connective tissue thickness, and shoe habits (especially factors such as high heels) should also be evaluated. Another point is that even after the skeletal development is completed in healthy individuals, the MLA continues to progress, albeit partially, and this developmental process is completed later in men than in women, which also contributes to the formation of the arch structure (12).

In an epidemiological study conducted on 825.964 (467.412 men, 358.552 women) participants aged 16-19 years and examining the relationship between navicular drop rate and BMI, it was shown that there was a positive and significant relationship between flexible pes planus (FPP) and BMI (13). In addition, the prevalence of FPP was found to be higher in men compared to women. In terms of BMI values, 78% of the participants in the study were classified as normal weight, while 63% of the participants in our study were classified as normal weight (13).

In a study investigating the effects of weight and obesity on MLA in three different age groups of women, it was determined that 31% of children, 4.7% of young adults, and 77% of the elderly were overweight or obese (10). This study determined that excess body weight contributed to the deterioration of MLA structure more than age (10).

In a study conducted on 227 women and 172 men to evaluate the relationship between foot postural characteristics and BMI, it was emphasized that BMI and foot arch index showed a positive correlation (14). They also stated that the increase in the foot arch index also increased the foot structure deformation (14).

In an experimental study conducted on a total of 10 volunteers, normal, overweight, obese, and morbidly obese groups were formed by placing weights on the volunteers in a controlled laboratory environment (15). The relationship between peak plantar foot pressure and BMI in volunteers was evaluated. As the weights worn by the volunteers increased, the BMI values were also increased, resulting in higher pressure on the foot (15). In another study conducted according to osteoarthritis index scoring, it was determined that 24 patients with foot pain showed improvement in terms of pain, stiffness, and function after weight loss (16). Another research focusing on the patients who underwent bariatric surgery for musculoskeletal disorders reported that only 1% of patients with foot pain continued to have pain after weight loss (17). However, a systematic review found that there was a decrease in MLA height as BMI values approached normal limits (18). Mostly similar to the results of our study, the literature cited above has highlighted that the foot structure of women improves as BMI approaches normal values.

Contrary to the data mentioned above, a study that has measured the prevalence of gender-

based normative values with 500 participants aged 18-21 years in India found that there is a correlation between the right NDR and height and weight. On the left, the height, weight, and BMI values have not changed NDR. In addition, there was no statistically significant gender difference in terms of NDR (19).

There are also a few studies conducted in Turkey on the topic of this study (9,20). In a study performed on 93 sedentary but healthy individuals aged 45-55 years in Turkey, a significant relationship between MLA and BMI was found (20). In addition, it has been stated that the changes in the foot arch structure that occur as a result of the increase in BMI will be the main cause of lower-extremity orthopedic problems in the long term (20).

In another study of the Turkish population, it has been shown that even if it is not within the limits of obesity, excess weight negatively affects the arch structure of the foot (9). A similar result was obtained in our study.

A research examining the medial and lateral longitudinal arches together stated that it is difficult to determine the normal values of the navicular drop ratio because it is affected by various factors such as foot length, age, gender, and BMI (21).

From a clinical point of view, it has been reported in the literature that low BMI values increase the risk of injury, fracture, scoliosis, and the development of systemic musculoskeletal diseases due to low muscle mass, as well as the incidence of morbidity and mortality (22,23). It is known that disorders of the foot arch structure have a negative effect on flexibility and balance (24).

In future studies, we think that the evaluation of balance and muscle parameters in addition to the parameters in this study will be beneficial. In addition, it would be beneficial to perform further detailed studies specified in different age groups and to include the morbidly obese group in the study.

Ethics Committee Approval: The study protocol was approved by the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee (22.06.2021 / 2021/117).

Conflict of Interest: The authors have declared that they have no conflict of interest.

Funding: The authors have declared that they have not received any financial support.

REFERENCES

1. Demircan A. Ayakta farklı duruş pozisyonlarının pedobarografik verilerinin karşılaştırılması ve güvenilirliklerinin incelenmesi [master's thesis]. İstanbul: İstanbul Medipol University; 2021.
2. Solgun S. Pes Planuslu bireylerde ayak kas kuvveti [master's thesis]. Malatya: İnönü University; 2019.
3. Doğruyol G, Çimen M. Medial ve lateral ark açıları ile ayak uzunluğunun yaş, cinsiyet ve taraf farklılığı açısından radyolojik olarak incelenmesi. Turkish J Sci Heal. 2020; 2(1): 76-83.
4. Akıl S. Üniversite öğrencilerinde ayak medial longitudinal ark durumunun denge ve esneklikle ilişkisi [master's thesis]. İstanbul: İstanbul Medipol University; 2019.
5. Ünver B, Suner Keklik S, Yildirim Şahan T, Bek N. An investigation of the effects of pes planus on distal and proximal lower extremity biomechanical parameters and low back pain. Turkish J Physiother Rehabil. 2019; 30(2): 119-25.
6. Celso RS, Xavier A, Ignacio H-A, Eduardo A. The relation of foot morphology to performance in three vertical jumping tasks. Int J Morphol. 2020; 38(3): 545-51. https://doi.org/10.4067/S0717-95022020000300545
7. Torun Bİ, Çay N. Relationship between the angle of the foot arch and the length of the foot. Kafkas J Med Sci. 2018; 8(3): 172-7. https://doi.org/10.5505/kjms.2018.81557
8. Selçuk H, Keklicek H. Farklı vücut kütle indeksi düzeyinde olan bireylerde statik yük altındaki ayağın pronasyon cevabının incelenmesi. Gümüşhane Üniversitesi Sağlık Bilim Derg. 2018; 7(4): 38-45.
9. Eser T, Ünver B, Alarçin G, Bayraktaroğlu T. Obeziteli olgularda statik ve dinamik plantar basınçlardaki farklılıkların saptanması. Turkish J Diabetes Obes. 2019; 3(3): 165-209.

10. Jankowicz-Szymanska A, Wódka K, Kołpa M, Mikołajczyk E. Foot longitudinal arches in obese, overweight and normal weight females who differ in age. Homo. 2018; 69(1-2): 37-42. https://doi.org/10.1016/j.jchb.2018.03.001
11. Stotz A, Hollander K, Heidt C, Sehner S, Zech A. Clinical assessment of the medial longitudinal arch in children: rater agreement and relationship to objective foot arch measurements. SN Compr Clin Med. 2020; 2(12): 2763-70. https://doi.org/10.1007/s42399-020-00594-5
12. Volpon JB. Footprint analysis during the growth period. J Pediatr Orthop. 1994; 14(1): 83-5. https://doi.org/10.1097/01241398-199401000-00017
13. Tenenbaum S, Hershkovich O, Gordon B, et al. Flexible pes planus in adolescents: body mass index, body height, and gender--an epidemiological study. Foot Ankle Int. 2013; 34(6): 811-7. https://doi.org/10.1177/1071100712472327
14. Aurichio TR, Rebelatto JR, de Castro AP. The relationship between the body mass index (BMI) and foot posture in elderly people. Arch Gerontol Geriatr. 2011; 52(2): e89-92. https://doi.org/10.1016/j.archger.2010.06.014
15. Pirozzi K, McGuire J, Meyr AJ. Effect of variable body mass on plantar foot pressure and off-loading device efficacy. J Foot Ankle Surg. 2014; 53(5): 588-97. https://doi.org/10.1053/j.jfas.2014.02.005
16. Hooper MM, Stellato TA, Hallowell PT, Seitz BA, Moskowitz RW. Musculoskeletal findings in obese subjects before and after weight loss following bariatric surgery. Int J Obes (Lond). 2007; 31(1): 114-20. https://doi.org/10.1038/sj.ijo.0803349
17. McGoey BV, Deitel M, Saplys RJ, Kliman ME. Effect of weight loss on musculoskeletal pain in the morbidly obese. J Bone Joint Surg Br. 1990; 72(2): 322-3. https://doi.org/10.1302/0301-620X.72B2.2138158
18. Butterworth PA, Landorf KB, Smith SE, Menz HB. The association between body mass index and musculoskeletal foot disorders: a systematic review. Obes Rev. 2012; 13(7): 630-42. https://doi.org/10.1111/j.1467-789X.2012.00996.x
19. Aenumulapalli A, Kulkarni MM, Gandotra AR. Prevalence of Flexible Flat Foot in Adults: A Cross-sectional Study. J Clin Diagn Res. 2017; 11(6): AC17-20. https://doi.org/10.7860/JCDR/2017/26566.10059
20. Atak E, Özbek H, Algun C. Sağlıklı sedanter bireylerde vücut ağırlığı artışının ayak postürü ve diz ağrısı üzerine etkisi. J Exerc Ther Rehabil. 2016; 3(2): 66-71.
21. Fukano M, Fukubayashi T. Motion characteristics of the medial and lateral longitudinal arch during landing. Eur J Appl Physiol. 2009; 105(3): 387-92. https://doi.org/10.1007/s00421-008-0915-3
22. Huisman HW, Schutte R, Venter HL, van Rooyen JM. Low BMI is inversely associated with arterial stiffness in Africans. Br J Nutr. 2015; 113(10): 1621-7. https://doi.org/10.1017/S0007114515000975
23. Tarrant RC, Queally JM, Moore DP, Kiely PJ. Prevalence and impact of low body mass index on outcomes in patients with adolescent idiopathic scoliosis: a systematic review. Eur J Clin Nutr. 2018; 72(11): 1463-84. https://doi.org/10.1038/s41430-018-0095-0
24. El-Shamy FF, Ghait AS. Effect of flexible pes planus on postural stability in adolescent females. Int J Sci Res. 2014; 3: 2012-15.