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Prevalence of Foot Arch Types of Children and Adolescents in the Eastern of Thailand

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Key words: Foot arch type, flatfoot, arch height, arch flexibility, children

Abstract: Flat foot is the most common which has been found in children and adolescents. Pediatric flatfoot is categorized into flexible flatfoot and rigid flatfoot. The purpose of this study was to compare Arch Height Index (AHI) between sides and gender and to classify the Arch Height Flexibility (AHF) of medial longitudinal arch of foot based on a large foot structure data set from the 6-15 year old children and adolescents in the seven eastern provinces of Thailand. The participants were 2,909 children and adolescentsin the eastern of Thailand. Two thousand five hundred and thirty five individuals were included in the study after erroneous data were eliminated from the data set before analysis. AHI, defined by dorsum height divided by truncated foot length, was measured in three conditions: 10% of weight bearing in sitting, 50 and 90% of weight bearing in standing. AHF was calculated and classified into five categories; very stiff, stiff, neutral, flexible and very flexible. Independent t-test was used to determine the differences between gender and Paired t-test was used to determine differences between sides. The results revealed significant difference of all AHI values between boys and girls in both feet and Lt.foot was significantly lower than that of Rt. foot. For AHF, the medial arch flexibility in children was flexible to very flexible in the high percentage. This would provide a cross-sectional data which need to be considered the prevention of injuries or any consequences.

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INTRODUCTION

Foot, a complex structure with 26 bones linked together has been working on both supporting body weight and contributing the propulsion during movements. The foot is regarded as the terminal segment of the body that adapts to uneven terrain and supports the body during single limb and double stance. The bones of foot form significant structures, the arches of foot. Medial Longitudinal Arch (MLA) is formed by the first metatarsal bone, the medial cuneiform, the narvicular and the talus[1, 2]. It plays a major role in shock attenuation during early and mid-stance, energy transfer and rigid lever during late stance[3]. Foot has been categorized by foot structure as normal, pes planus or flatfoot and pes cavus or high arch. Flatfoot, the flattened Medial Longitudinal Arch (MLA), is not only the static abnormal alignment but the dynamic functional abnormality of back and lower extremities as well[4]. The true incidence of flatfoot is unknown. However, several research suggested that there were several predisposing factors which led to increase incidences of flatfoot such as sex[5], age, body weight[6], structural laxity and types of footwear[7]. Among foot problems, flat foot is the most common which has been found in children and adolescents. Pediatric flatfoot is categorized into flexible flatfoot; a normal arch during non-weight bearing and flattening on stance and rigid flatfoot; a stiff and flattened arch both in weight or non-weight bearing[8]. The children are born with flexible flat foot, then, develop the mature MLA after 6 until 10 years of age[9]. Shoe wearing before the age of 6 is one of the concern in several research[10]. This might cause the deformity and musculoskeletal problems in adulthood with flexible flatfoot. The changes in MLA can alter the foot biomechanics to control the forces which transfer from the foot to lower leg and back[8, 11]. In addition, the biomechanical alterations of the foot might influence postural stability, both static standing and dynamic activities[5].

There are a number of methods of measuring the medial longitudinal arch such as foot shape index %[12], navicular height[5], Arch index[13], Chippaux-Smirak index[14], Staheli arch index[15] and arch height index[16]. The arch height index measurement has gained popular attention recently with high reliable between testers. In addition, several studies have considered both arch height and arch flexibility to be a defining characteristic of foot structure and a descriptor between foot structure and foot function[17]. Therefore, the purpose of this study was to compare AHI between sides and between gender and to classify the AHF of medial longitudinal arch of foot based on a large footstructure data set from the 6-15 years old children and a dolescents in the seven Eastern provinces of Thailand.

MATERIALS AND METHODS

Participants: The seven provinces in the Eastern of Thailand were selected as the location of the study according to geographical determination by the government. After taking the list of public schools in the Eastern, the candidate schools were randomly selected from the list. The participants in this study, drawn by stratified random sampling were 2.909 healthy children and adolescents with age between 6-15 years old. Inclusion criteria required no history of injury about lower extremities, no report of pain and symptoms in the foot or lower extremities and no systematic disease that mightinfluence the lower extremities. All of their parents were asked to read and sign the consent form which all the procedures had been reviewed and approved by the Burapha University Ethical Committee (Approval No. 78/2557). Erroneous data were eliminated from the data set before analysis including missing information or negative values for the change in arch height from sitting to standing. About 2.535 individuals (1, 180 boys and 1, 355 girls) were included in the study after removal of erroneous data.

Measurements: Each participant's height and mass were measured and Body Mass Index (BMI) was calculated using body mass divided by height squared (kg m^{-2}). Arch Height Index (AHI) was measured using a custom-built arch height index measurement system, the validity and reliabilityof which has been previously established by Butler *et al*.[16]. It was taken in three conditions: 10% of weight bearing in sitting, 50% and 90% of weight bearing in standing. These measurements were as follow; the dorsum height is measured from the floor to the top of the foot at 50% of foot length, the foot length is measured from the posterior portion of the calcaneous to the end of the end of longest toe and the truncated foot length is measured from the posterior portion of the calcaneous to the center of the 1st metatarso phalangeal joint based on bony landmarks[18]. Arch Height Index (AHI) was calculated according to the following equation:

$$\text{AHI} = \text{Dorsal Height at 50\% foot length/trucated foot length}$$

The AHI includes a normal arch height which is truncated by foot length of approximately 0.34±0.03 mm[16]. Arch Height Flexibility (AHF) was defined as the change in archheight (distance from the dorsal surface to theground) from sitting to standing due to the changein load borne by the archduring these activities. Thechange in load was based on an assumed change inbody weight from sitting to standing. Thestandingcondition assumes the weight on the foot to be 50% ofthe body weight on each foot and the sittingcondition assumes the weight on the foot to be 10% of the body weight. Therefore, there was an assumed 40% change in load from standing to sitting[17]. The final equation used to calculate arch flexibility was:

$$\text{Arch height flexbility} = \left[\text{AHI}_{\text{sitting}}\text{-AHI}_{\text{standing}} / \begin{pmatrix} 0.4\times\text{BW}\times \\ 100[\text{m/kN}] \end{pmatrix}\right]$$

Table 1: The classification scheme based on quintiles of proposed Cut off values for arch flexibility Categories[2]

AHF category	Quintile (%)	Cutoff value, mm/kN
Very stiff	0-20	AHF<9.91
Stiff	20-40	9.91<AHF<13.54
Neutral	40-60	13.54<AHF<16.00
Flexible	60-80	16.00<AHF<20.54
Very flexible	80-100	AHF>20.54

The AHF type was based on the classification system proposed herein and the arch height category was based on previous clinically based cutoff values for high arch, neutral and flatfoot proposed by Zifchock *et al*.[17] in Table 1.

Statistical analysis: Means and standard deviations of general anthropometric data such as age, body height, body weight, BMI, AHI and AHF of Lt. and Rt. feet were calculated. Independent t-test was used to determine if there was significantly different between genderof each AHI category and Paired t-test was used to determine if there was significantly different between Lt. and Rt. sidesof each AHI category (p<0.05).

RESULTS AND DISCUSSION

The purpose of this study was to compare AHI between sides and gender, and to classify the arch height and flexibility of medial longitudinal arch of foot based on a large foot structure data set from the 6-15 year-old children and adolescents in the seven east coast provinces of Thailand. The descriptive anthropometric data of the 2,535 participants were presented in Table 2; male (n = 1180) and female (n = 1355).It revealed that the anthropometric means did not differ between gender, except body height.

In addition, the children and adolescents were classified by their BMI as shown in Table 3. The underweight children and adolescents were 50.53% (53.14% for male and 48.27% in female), normal weight was 37.83% (35.51% for male and 39.85% in female), overweight was 7.81% (7.63% for male and 7.97% in female) and obesity was only 3.83% (3.73% for male and 393.91% in female).

The AHI values of 10, 50 and 90% weight bearing were measured, the AHF were calculated and presented in Table 4. The independent t-test revealed significant differences of AHI values between male and female (p = 0.000) but no significant difference had been found in AHF.

Table 5 showed the frequency of AHI in three categories; low, neutral and high arch when bearing body weight. The results indicated that the amount of foot with low arch gradually increased when bearing more body weight. The amount of low arch increased up to 43.9 and 37.9% on Lt. and Rt. feet in boys and 55.9 and 53.8% on Lt. and Rt. feet in girls, respectively. On single leg standing, the amount of low arch in girls was higher to 71.1 and 64.1 on Lt. and Rt. feet respectively. The paired t-test revealed significant differences of all AHI values between Lt. and Rt. sides (p<0.01). The AHI of Lt. foot was significantly lower than that of Rt. foot in both boys and girls but there was no significant difference of AHF according to gender.

The distribution of feet in the appropriate arch height and arch flexibility categories presented in Fig. 1. It revealed that most of the children were pes panus with very flexible foot arch (Lt. 791 feet and Rt. 662 feet), both boys and girls. Whereas the pes panus with very stiff foot arch was in the second (Lt. 270 feet and Rt. 246 feet).

Figure 2 showed the frequency of the AHF in boys and girls which found that medial arch flexibility in children was flexible to very flexible in the amount of 57.3% of Lt. foot and 65.4 of Rt. foot and presented in form of bar graph in Fig. 1. When considering with age, the stiffness of the foot tended to increase a s shown in Fig. 2.

The aim of the study was to compare AHI between sides and gender and to classify the AHF of medial longitudinal arch of foot based on a large foot structure data set from the 6-15 year-old children and adolescents in the seven east coast provinces of Thailand. As mentioned previously, foot is the complex segment which forms a stable support to the body weight distribution in static standing and acts as a rigid level to propel the body during moving with shock absorption enabling by MLA. The deformation of MLA is essential for transferring and absorbing shock especially in impact movements such as jumping, sprinting. It has been noted that the flatness of arch was often accompanied by back and lower limb pain[11], degenerative joint disease[8], balance and functional disability[19] and gait abnormalities[20] in the future. It is a common problem among school-age children which can lead to foot abnormality, pain and poor function. Therefore, there have been several studies concerning about flatfoot and reported the prevalence ranging from 17-58.7%[15, 21]. Our study found that the AHI of low arch type was between 37.9-55.9% when bearing 50% of body weight. It showed that most of the children and adolescents were likely to have low arched foot or flat foot corresponding to those of the previous studies. When the AHF were calculated, our study reported that the very flexible category was the highest percentage according to the results of AHF when gradually bearing body weight and also indicated that the very flexible to flexible categories of AHF had gradually resolved with increase of age. Several evidences have indicated that flatfoot is a physiological phenomenon in early decade of life and

Table 2: Mean and SD of general information and comparison between gender

	Total (n = 2535)			Male (n = 1180)			Female (n = 1355)				
Variables	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	t-values	p-values
Age (years)	11.75	2.66	11.62-11.82	11.65	2.63	11.48-11.77	11.84	2.68	11.66-11.94	-1.728	0.095
Body weight (kg.)	43.93	16.71	43.28-44.58	44.42	17.95	43.39-45.44	43.51	15.54	42.68-44.34	1.348	0.178
Height (cm.)	147.99	16.26	147.36-148.62	148.80	17.96	147.77-149.82	147.29	14.59	146.51-148.07	2.293*	0.022
BMI(kg m^{-2})	19.38	4.71	19.20-19.57	19.30	4.76	19.03-19.57	19.46	4.67	19.21-19.71	-0.854	0.393

Table 3: BMI categories subdivided into age groups of the participants

	Male					Female				
	Classification according to BMI					Classification according to BMI				
Age	Underweight	Normal	Overweight	Obesity	Total	Underweight	Normal	Overweight	Obesity	Total
6	39(3.31%)	0	0	0	39(3.31%)	39(2.88%)	3(0.22%)	0	0	42(3.10%)
7	57(4.83%)	14(1.19%)	0	0	71(6.02%)	61(4.50%)	9(0.66%)	0	0	70(5.16%)
8	46(3.90%)	13(1.10%)	3(0.25%)	3(0.25%)	65(5.50%)	65(4.80%)	15(1.11%)	7(0.52%)	0	87(6.43%)
9	75(6.36%)	24(2.03%)	6(0.51%)	0	105(8.90%)	96(7.08%)	35(2.58%)	9(0.66%)	3(0.22%)	143(10.54%)
10	58(4.91%)	33(2.80%)	8(0.68%)	2(0.17%)	101(8.56%)	48(3.54%)	17(1.25%)	6(0.44%)	1(0.07%)	72(5.30%)
11	50(4.24%)	32(2.71%)	9(0.76%)	3(0.25%)	94(7.96%)	42(3.10%)	21(1.55%)	8(0.59%)	2(0.15%)	73(5.39%)
12	90(7.63%)	50(4.24%)	9(0.76%)	9(0.76%)	158(13.39%)	96(7.08%)	76(5.61%)	17(1.25%)	6(0.44%)	195(14.38%)
13	92(7.80%)	92(7.80%)	24(2.03%)	10(0.85%)	218(18.48%)	90(6.64%)	106(7.82%)	25(1.85%)	15(1.11%)	236(17.42%)
14	77(6.53%)	88(7.46%)	12(1.02%)	10(0.85%)	187(15.86%)	65(4.80%)	131(9.67%)	17(1.25%)	12(0.89%)	225(16.61%)
15	43(3.64%)	73(6.19%)	19(1.61%)	7(0.59%)	142(12.03%)	52(3.84%)	127(9.37%)	19(1.40%)	14(1.03%)	212(15.64%)

Table 4: Mean and standard deviation of AHI when bearing 10%, 50% and 90% body weight, AHF and comparison of all variables between gender

	Total (n = 2535)			Male (n =1180)			Female (n=1355)				
Variables	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI	t-values	p-value
AHI Lt. foot (BW%)											
10	0.343	0.029	0.342-0.344	0.348	0.029	0.346-0.350	0.339	0.028	0.337-0.340	8.062*	0.000
50	0.310	0.028	0.309-0.311	0.314	0.029	0.313-0.316	0.306	0.027	0.305-0.308	7.067*	0.000
90	0.299	0.027	0.298-0.300	0.304	0.028	0.302-0.305	0.295	0.026	0.294-0.297	7.869*	0.000
AHI Rt. foot (BW%)											
10	0.348	0.029	0.347-0.349	0.354	0.029	0.352-0.355	0.343	0.028	0.342-0.345	8.959*	0.000
50	0.313	0.028	0.312-0.314	0.319	0.029	0.317-0.320	0.308	0.027	0.306-0.309	9.610*	0.000
90	0.306	0.027	0.305-0.307	0.312	0.028	0.310-0.313	0.301	0.026	0.300-0.302	9.847*	0.000
AHF (foot)											
Lt.	21.944	15.894	21.325-22.563	22.557	16.345	21.613-23.480	21.419	15.478	20.594-22.244	1.777	0.076
Rt.	23.765	16.038	23.140-24.390	24.053	17.122	23.076-25.031	23.514	15.033	22.713-24.315	0.838	0.402

*p<0.05 comparing between gender

Table 5: The frequency of AHI in each category and comparison of AHI category between Lt. and Rt. sides

	Male (n =1180)				Female (n =1355)			
AHI category	Lt. AHI	Rt. AHI	t-values	p-values	Lt. AHI	Rt. AHI	t-values	p-values
10% BW	**0**							
Low	114(9.7%)	75 (6.4%)	-7.717*	0.000	185(13.7%)	158(11.7%)	-6.919*	0.000
Neutral	340(28.8%)	296 (25.1%)			538(39.7%)	468(34.5%)		
High	726(61.5%)	809 (68.6%)			632(46.6%)	729(53.8%)		
50% BW								
Low	518(43.9%)	447 (37.9%)	-5.923**	0.000	757(55.9%)	729(53.8%)	-2.188*	0.029
Neutral	439(37.2%)	456 (38.6%)			449(33.1%)	462(34.1%)		
High	223(18.9%)	277 (23.5%)			149(11%)	164(12.1%)		
90% BW								
Low	677(57.4%)	563 (47.7%)	-12.072*	0.000	964 (71.1%)	868(64.1%)	-9.513*	0.000
Neutral	393(33.3%)	447 (37.9%)			336 (24.8%)	404(29.8%)		
High	110(9.3%)	170 (14.4%)			55 (4.1%)	83(6.1%)		

will be corrected with the maturation of intrinsic and extrinsic muscles and ligaments surroundings[22]. In addition, the gender difference is one of 3 factors that influences the prevalence of flatfoot. The previous studies revealed that females have a more flexible foot than males during dynamic and static weight bearing[23]. Our study also showed that girls tended to have more flexible foot than boys.

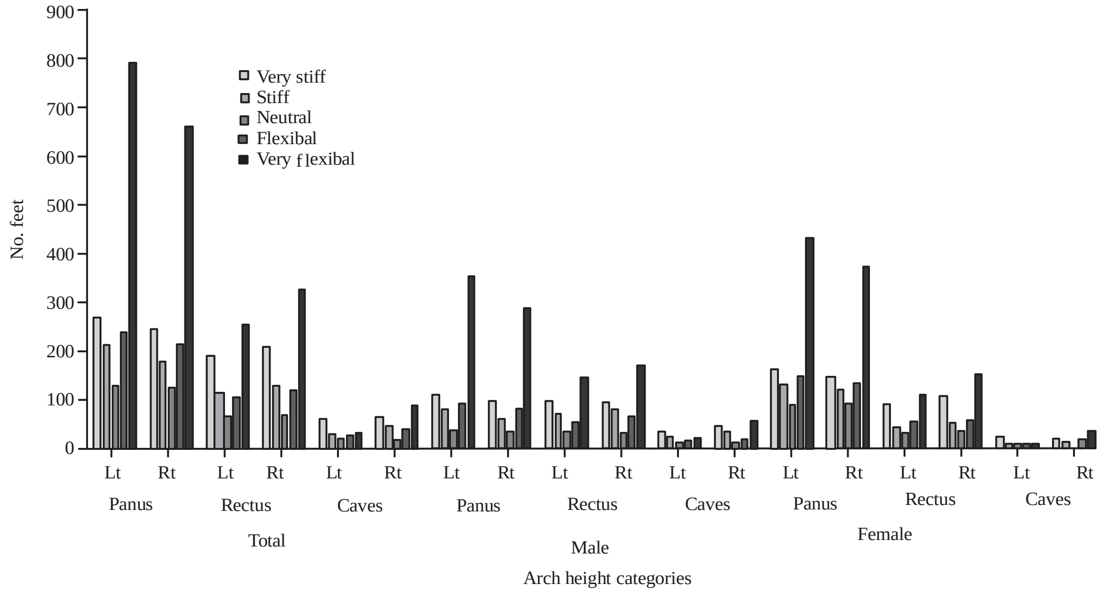

Fig. 1: Distribution of feet in the appropriate arch height and arch flexibility categories

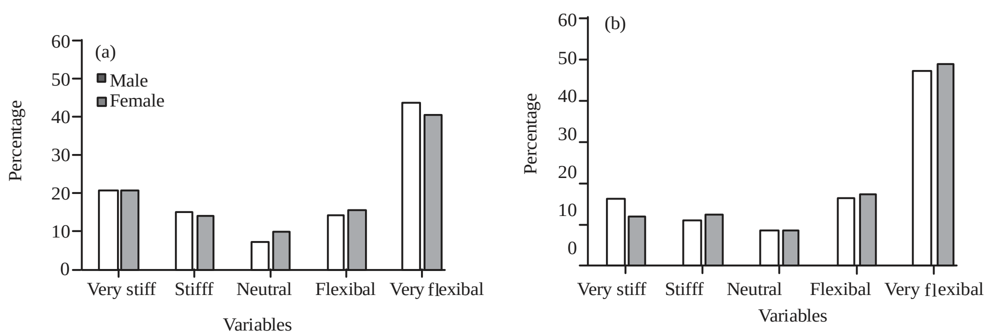

Fig. 2(a, b): The distribution of arch height flexibility of children and adolescents based on quintiles of proposed cutoff values for arch flexibility categories; (A) Lt. foot and (B) Rt. foot

CONCLUSION

In conclusion, the prevalence of flat foot in a population of the 6-12 year-old children and adolescents in the seven east coast provinces of Thailand was 43.9% and 37.9% on Lt. and Rt. feet in boys and 55.9% and 53.8% on Lt. and Rt. feet in girls, respectively when baring 50% of body weight.

There were significant differences of all AHI values between boys and girls in both feet and the AHI of Lt. foot was significantly lower than that of Rt. Foot but there was no significant difference of AHF according to gender. This would provide a cross-sectional data which need to be considered the prevention of injuries or any consequences.

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REFERENCES

01. Fukano, M. and T. Fukubayashi, 2008. Motion characteristics of the medial and lateral longitudinal arch during landing. Eur. J. Applied Physiol., 105: 387-392.
02. Oatis, C.A. and P.F. Beattie, 2009. Kinesiology: The Mechanics and Pathomechanics of Human Movement. 2nd Edn., Lippincott Williams & Wilkins, Pennsylvania, USA.,.

03. Queen, R.M., N.A. Mall, W.M. Hardaker and J.A. Nunley, 2007. Describing the medial longitudinal arch using footprint indices and a clinical grading system. Foot Ankle Int., 28: 456-462.
04. Chen, Y.C., S.Z. Lou, C.Y. Huang and F.C. Su, 2010. Effects of foot orthoses on gait patterns of flat feet patients. Clin. Biomech., 25: 265-270.
05. Chang, J.H., S.H. Wang, C.L. Kuo, H.C. Shen, Y.W. Hong and L.C. Lin, 2009. Prevalence of flexible flatfoot in Taiwanese school-aged children in relation to obesity, gender and age. Eur. J. Pediatrics, 169: 447-452.
06. Evans, A.M. and K. Rome, 2011. A review of the evidence for non-surgical interventions for flexible pediatric flat feet. Eur. J. Phys. Rehabil. Med., 47: 69-89.
07. Abolarin, T., A. Aiyegbusi, A. Tella and S. Akinbo, 2011. Predictive factors for flatfoot: The role of age and footwear in children in urban and rural communities in South West Nigeria. Foot, 21: 188-192.
08. Shibuya, N., D.C. Jupiter, L.J. Ciliberti, V.V. Buren and J. La Fontaine, 2010. Characteristics of adult flatfoot in the United States. J. Foot Ankle Surg., 49: 363-368.
09. Onodera, A.N., I.C.N. Sacco, E.H. Morioka, P.S. Souza, M.R. de Sa and A.C. Amadio, 2008. What is the best method for child longitudinal plantar arch assessment and when does arch maturation occur?. Foot, 18: 142-149.
10. Mortazavi, S.J., R. Espandar and T. Baghdadi, 2007. Flatfoot in children: How to approach?. Iranian J. Pediatrics, 17: 163-170.
11. Buldt, A.K., G.S. Murley, P. Butterworth, P. Levinger, H.B. Menz and K.B. Landorf, 2013. The relationship between foot posture and lower limb kinematics during walking: A systematic review. Gait Posture, 38: 363-372.
12. Bosch, K., J. Gerss and D. Rosenbaum, 2006. Preliminary normative values for foot loading parameters of the developing child. Gait Posture, 26: 238-247.
13. Muller, S., A. Carlsohn, J. Muller, H. Baur and F. Mayer, 2011. Static and dynamic foot characteristics in children aged 1-13 years: A cross-sectional study. Gait Posture, 35: 389-394.
14. Gill, S.V., S. Keimig, D. Kelty-Stephen, Y.C. Hung and J.M. DeSilva, 2016. The relationship between foot arch measurements and walking parameters in children. BMC Pediatrics, Vol. 16, 10.1186/s12887-016-0554-5.
15. Sacco, I.C., A.N. Onodera, K. Bosch and D. Rosenbaum, 2015. Comparisons of foot anthropometry and plantar arch indices between German and Brazilian children. BMC Pediatrics, Vol. 15, 10.1186/s12887-015-0321-z
16. Butler, R.J., H. Hillstrom, J. Song, C.J. Richards and I.S. Davis, 2014. Arch height index measurement system: Establishment of reliability and normative values. J. Am. Podiatric Med. Assoc., 98: 102-106.
17. Zifchock, R.A., C. Theriot, H.J. Hillstrom, J. Song and M. Neary, 2017. The Relationship between arch height and arch flexibility: A proposed arch flexibility classification system for the description of multidimensional foot structure. J. Am. Podiatric Med. Assoc., 107: 119-123.
18. McPoil, T.G., M.W. Cornwall, B. Vicenzino, D.S. Teyhen and J.M. Molloy et al., 2008. Effect of using truncated versus total foot length to calculate the arch height ratio. Foot, 18: 220-227.
19. Spink, M.J., M.R. Fotoohabadi, E. Wee, K.D. Hill, S.R. Lord and H.B. Menz, 2010. Foot and ankle strength, range of motion, posture and deformity are associated with balance and functional ability in older adults. Arch. Phys. Med. Rehabil., 92: 68-75.
20. Evans, A.M., K. Rome and L. Peet, 2012. The foot posture index, ankle lunge test, Beighton scale and the lower limb assessment score in healthy children: A reliability study. J. Foot Ankle Res., Vol. 5, 10.1186/1757-1146-5-1
21. Cetin, A., S. Sevil, L. Karaoglu and B. Yucekaya, 2010. Prevalence of flat foot among elementary school students, in rural and urban areas and at suburbs in Anatolia. Eur. J. Orthop. Surg. Traumatology, 21: 327-331.
22. Homayouni, K., H. Karimian, M. Naseri and N. Mohasel, 2015. Prevalence of flexible flatfoot among school-age girls. Shiraz E. Med. J., Vol. 16,
23. Fukano, M. and T. Fukubayashi, 2011. Gender-based differences in the functional deformation of the foot longitudinal arch. Foot, 22: 6-9.