

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 adolescents in 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 navicular 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 adolescents 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 might influence 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 reliability of 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 calcaneus to the end of the end of longest toe and the truncated foot length is measured from the posterior portion of the calcaneus 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:

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

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 arch height (distance from the dorsal surface to the ground) from sitting to standing due to the change in load borne by the arch during these activities. The change in load was based on an assumed change in body weight from sitting to standing. The standing condition assumes the weight on the foot to be 50% of the body weight on each foot and the sitting condition 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:

$$\text{Arch height flexibility} = \left[\frac{\text{AHI}_{\text{sitting}} - \text{AHI}_{\text{standing}}}{\left(\frac{0.4 \times \text{BW} \times}{100 [\text{m/kN}]} \right)} \right]$$

Table 1: The classification scheme based on quintiles of proposed Cutoff 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 gender of each AHI category and Paired t-test was used to determine if there was significantly different between Lt. and Rt. sides of 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 planus with very flexible foot arch (Lt. 791 feet and Rt. 662 feet), both boys and girls. Whereas the pes planus 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 as 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

Variables	Total (n = 2535)			Male (n = 1180)			Female (n = 1355)			t-values	p-values
	Mean	SD	95% CI	Mean	SD	95% CI	Mean	SD	95% CI		
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

Age	Male					Female				
	Classification according to BMI					Classification according to BMI				
	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

AHI category	Male (n = 1180)				Female (n = 1355)			
	Lt. AHI	Rt. AHI	t-values	p-values	Lt. AHI	Rt. AHI	t-values	p-values
10% BW								
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.

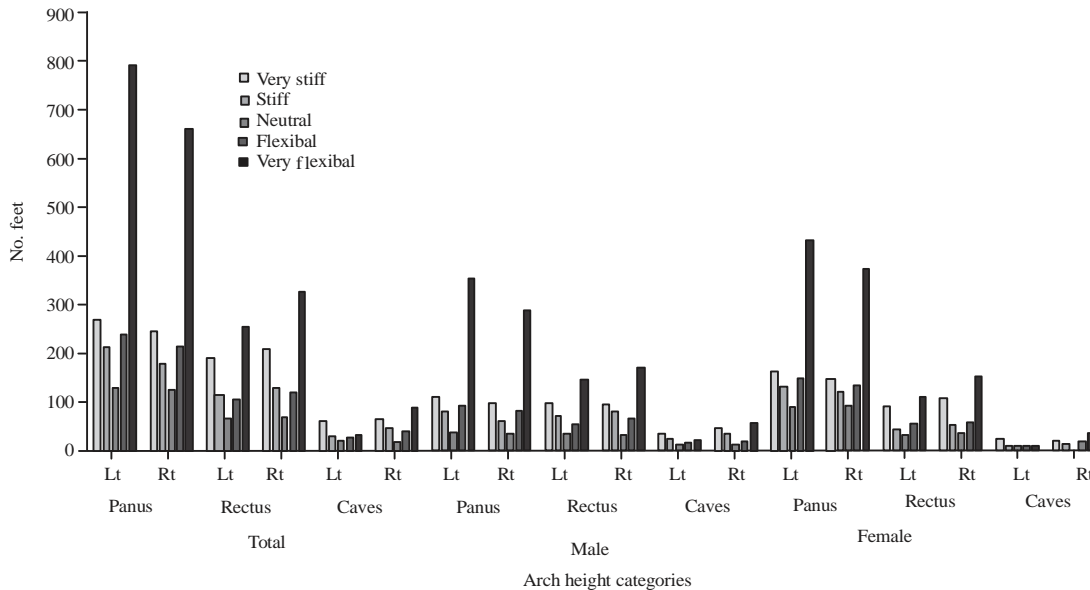


Fig. 1: Distribution of feet in the appropriate arch height and arch flexibility categories

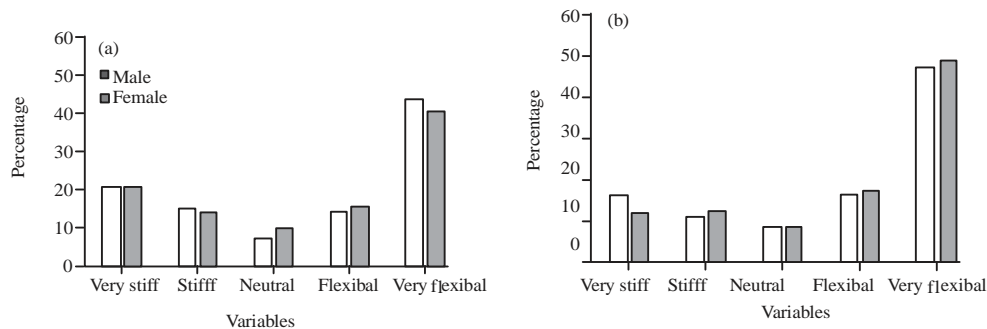


Fig. 2(a, b): The distribution of arch height flexibility of children and adolescents based on quintiles of proposed cutoff values for arch flexibility categories; (A) Lt. foot and (B) Rt. foot

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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