

STUDY OF FOOT MORPHOLOGICAL CHANGE OF MONGOLIAN CHILDREN

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In modern days, countries around the world vary economically and socially however the footwear designs have become more similar. There are no common standards, principals, and rules yet. The leading footwear manufacturing countries, including Czech, Germany, and Italy are considering footwear designs extensively, which is the daily wear of the human needs, most strategically footwear of children in their growing age. However, Mongolian adult's foot measurement study results show that in Mongolia, children are wearing unfitting shoes from their young age and create distortion to the foot shape.

Therefore, the purpose of the research is to define the Mongolian children's foot growth, morphological change by taking plantogram (foot pattern picture) of 6-18 years old children, and determining foot arch index and angle of bunion in the foot.

Keywords: foot morphology, children, shoe last, footwear, foot length, foot arch, curviness, foot dimensions

Plantogram is a foot pattern picture which is one of the popular method to show important foot dimension parameters including, the shape of the foot, foot axis, angle of bunion in the foot, and foot arch index. Foot dimension parameters are useful variables for determining foot morphological change and foot pattern information. Two types of the arch can be determined, lengthwise and crosswise, from foot pattern.

School-age children's foot pattern results show that number of children with a flat arch is higher than with normal arch in the first five years.

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When age is higher, this number is getting lower, and the number of children with a normal foot arch gets high. The types of foot arches, for instance, per cavus – high arch and pes planus – flat arch, are most known terms in medical science (Figure 1).

Bunion in the foot, in medical terms - hallux valgus, is increasing among young children in recent years (Figure 2). This deformity of foot features tends to increase when children get older. Recent studies show that unfitting shoes are the main cause of bunion in the foot.

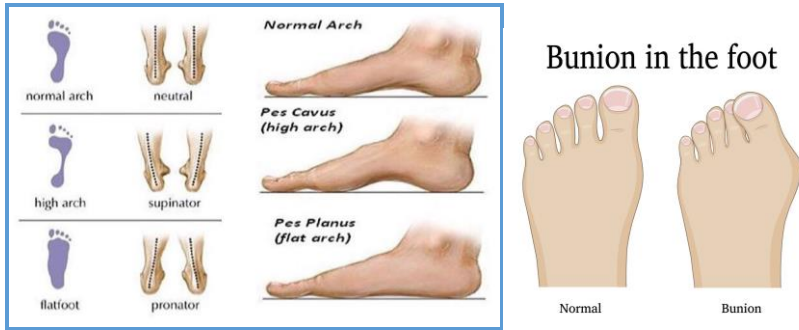


Figure 1 Types of foot arch

Figure 2 Hallux valgus (bunion)

Therefore, this paper aims to determine the distribution of Mongolian children’s foot morphological change and angle of the bunion in the foot during growth age by plantogram (foot pattern picture) of 6-18 years old children.

Sample data is collected from general education school students, both male and female, aged between 6-18 in urban and rural areas by measuring foot morphology and taking plantogram. The sample is divided into three groups by age group (Table 1).

Table 1 - Sample size and age group by gender

Age group	Age	Number of samples		Total sample	Percent-age
		Male	Female		
Elementary school	6-10	432	403	835	41.4%
Secondary School	11-14	349	323	672	33.3%
High School	15-18	236	275	511	25.3%
Total		1017	1001	2018	100%

Bauerfeind AG's equipment was used for taking plantograms, which is qualified all international standards and requirements, and the plantogram pictures were taken by using oil paint.



Figure 3 - Plantogram taking equipment Plantogram picture

Total 2018 plantogram were taken and foot arch index are determined by each picture. The Sztirter-Godunov classification method is used for foot arch index interpretation.

From data processing of total 2018 plantogram, the main three variables, needed for determining angle of bunion, are defined. The three variables are:

1. Foot length
2. Fore foot length
3. Fore foot width

The angle of bunion in the foot is measured from each plantogram. The classification of hallux valgus is classified by Chentsov's method.

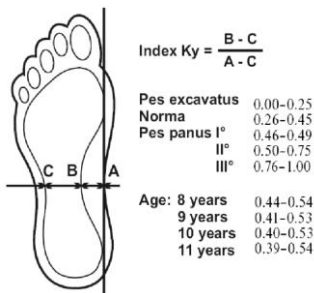


Figure 4 - Method to determine foot arch index



Figure 5 - Measurement method of angle of bunion

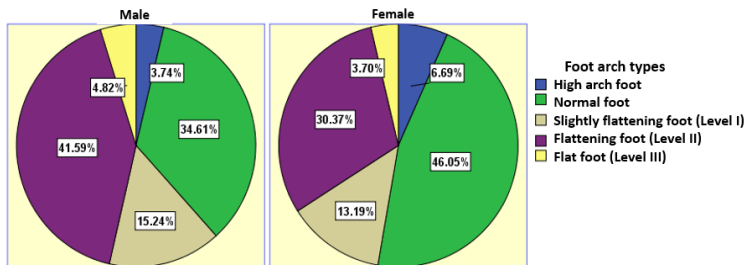
Results

The foot arch index: Two types of foot arch index can be determined, lengthwise and crosswise, and we determined crosswise arch index. The children's foot arch indexes, coefficient /k/, measured from plantogram and the results are classified as: 0,00-0,25 high arch foot (type I), 0,26-0,45 normal foot (type II), 0,45-0,49 slightly flattening foot – Level I (type III), 0,50-0,75 flattening foot –Level II (type IV), and 0,476-1,00 flat foot – Level III (Type V) shown below by Table 2.

Table 2 - Child foot arch types

Foot arch types	Sample Size		Total	Percentage
	Male	Female		
High arch foot, n (%)	38 (3,7)	67 (6,7)	105	5,2%
Normal foot, n (%)	352 (34,6)	461 (46,1)	813	40,3%
Slightly flattening foot /Level I/, n (%)	155 (15,2)	132 (13,2)	287	14,2%
Flattening foot /Level II/, n (%)	423 (41,6)	304 (30,4)	727	36,0%
Flat foot /Level III/, n (%)	49 (4,8)	37 (3,7)	86	4,3%
Total, n (%)	1017	1001	2018	100,0%

3,7% of the boys have high arch foot, 34,61% normal foot, 15,24% slightly flattening foot, and 56,84% have flattening and flat foot. For girls, the indexes are more normal 6,7% have high arch foot, almost half of them, 46,05%, have normal foot, 13,19% have slightly flattening foot, and flattening and flat foot girls are more than 20% lower than boys, 34,07% (figure 6).



FFigure 6 - Foot arch types by gender (n=2018)

Table 3 - Foot arch types by age group and gender

Foot arch types	n	Elementary school (6-10)		Middle school (11-14)		High School (15-18)	
		Male	Female	Male	Female	Male	Female
I High arch foot	105	9 (2,1)	22 (5,5)	18 (5,2)	22 (6,8)	11 (4,7)	23 (8,4)
II Normal foot	813	134 (31,0)	176 (43,7)	133 (38,1)	154 (47,7)	85 (36,0)	131 (47,6)
III Slightly flattening foot	287	53 (12,3)	59 (14,6)	61 (17,5)	38 (11,8)	41 (17,4)	35 (12,7)
IV Flattening foot	727	202 (46,8)	127 (31,5)	128 (36,7)	96 (29,7)	93 (39,4)	81 (29,5)
V Flat foot	86	34 (7,9)	19 (4,7)	9 (2,6)	13 (4,0)	6 (2,5)	5 (1,8)
Total	2018	432	403	349	323	236	275

The plantogram measurement results of 6-18-year-old general education school students, 1017 boys, and 1001 girls, the total percentage of high arch foot and normal footed girls are 52,8%, contrary, the percentage of boys is lower than 14%, 38,2%. From this result, we can say that the deformity issue is higher in boys compared to girls.

6-10 years old girls have the lowest share of the high arch foot, 5,5%, and 15-18 years old girls have the highest share, 8,4%. For boys highest share of a high arch foot is 11-14, 5,2%, and 6-10 has the lowest, 2,1%. In elementary school students, the high arch index is lower and, higher in middle and high school students. For boys, the share of high arch foot and the normal foot is lower than girls' share, which indicates the foot deformity occurs more for boys than girls (Table 3).

Type IV – flattening foot number is higher among boys compared to girls. On the other hand, percentage of normal foot girls are higher boys, in each age group. For both girls and boys, during its growth age, comparison between the high arch foot (type I) and flat foot (type V), the flattening foot (type IV) growth trend observed (figure 7).

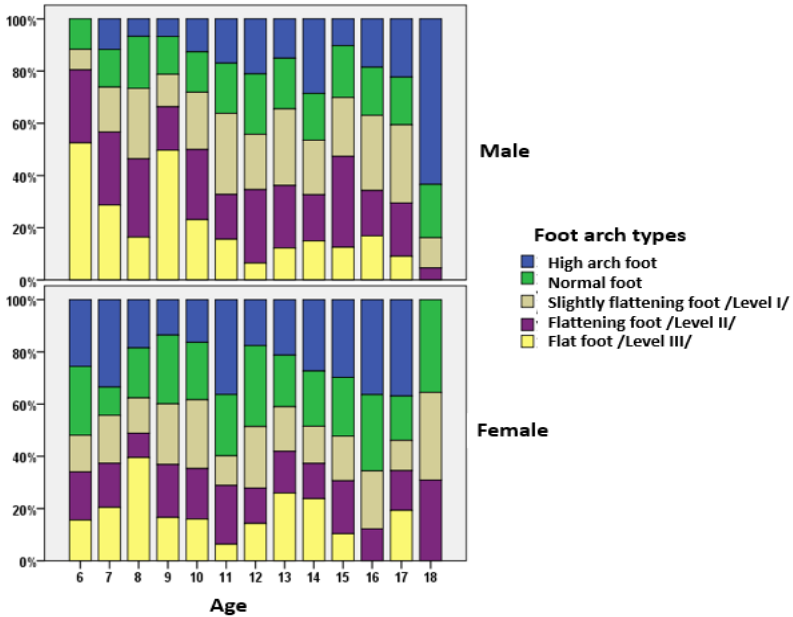


Figure 7 - Foot arch types by gender and age group

Angle of bunion in the foot:

In the table 4, the angle of bunion shown by gender. The result of the research shows that, 16,5% of girls’ bunion angle is medium and 3,5% have high angles. Whereas, 11,1% of boys have medium angle and 2,3% has high angle. We can say that girls’ bunion angles are higher than boys’.

Table 4 - Classification of bunion in the foot angle

Classification	Frequency		Result
	Female, n (%)	Male, n (%)	
Straight or Low angle (-10°...+10°)	801 (80,0)	881 (86,6)	83,3%
Medium angle (-11°...+15°)	165 (16,5)	113 (11,1)	13,8%
Higher angle (+16° <)	35 (3,5)	23 (2,3)	2,9%
Total	1001	1017	100

The bunion angle for girls are increasing as they are growing older. For instance, figure 9 illustrates that average angle degrees are:

- Elementary school girls – 5.65°
- Secondary schools - 6.74°
- High school girls - 7.53°

Comparing same age group girls and boys bunion angle, girls have medium angle bunion is much higher from boys (besides only 6 years old).

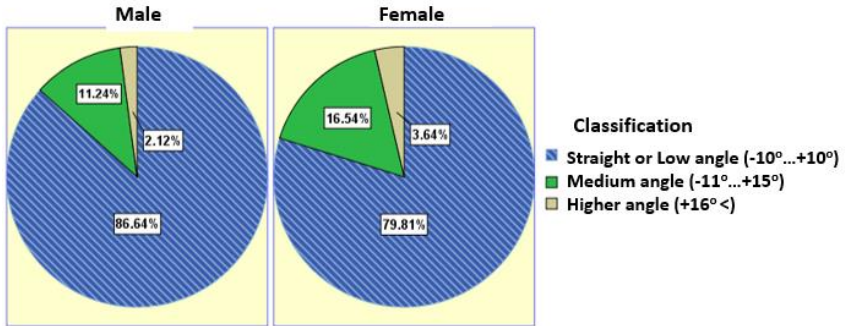


Figure 8 - Angle of Bunion in the foot classification by gender

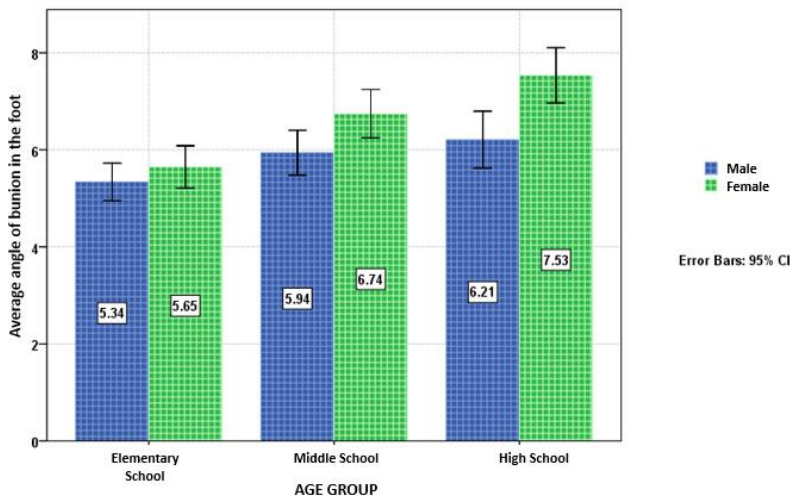


Figure 9 - Average angle of bunion in the foot by age group

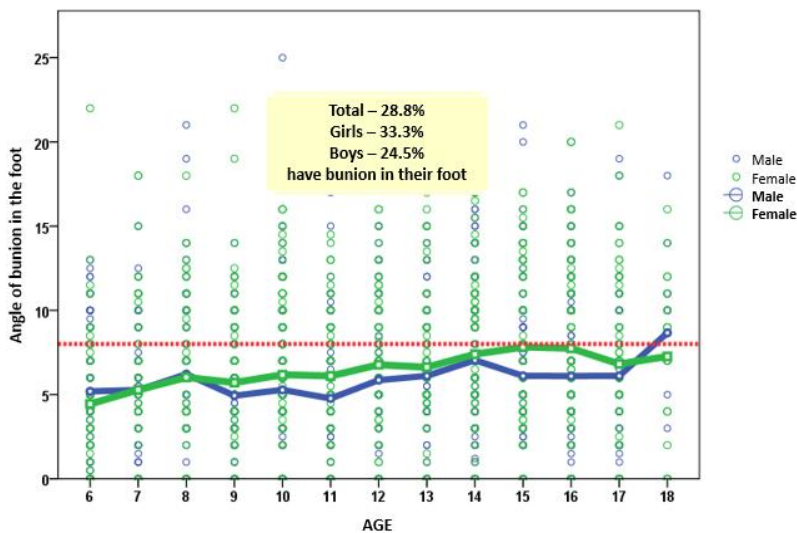


Figure 10 - Children age and angle of bunion in the foot by gender

Figure 10 illustrates the distribution of the angle of the bunion in the foot of both girls and boys, age 6-18. The girls' results are much higher than boys, age between 8 and 17.

Conclusion

As a conclusion, we can say the gender difference is affecting foot pattern change. The foot length change is more on boys, on the other hand, foot width change is high on girls. The research reveals that the children's crosswise angle of foot arch development and change dependent from the age and gender of the child. Age can be a prediction variable to know the arch angle since children getting older, foot arch distribution is lowering.

From the result of our study, 28,8% of 6-18 years old 2018 children, 33,3% and 24,5%, girls and boys respectively, have hallux valgus, in other words, angle of the higher bunion in their feet (Higher than 8° degrees). There is no common description of a healthy, straight, or lower angle of the bunion. Studies use different levels of angles to describe this. For instance, some study says 8° degrees and other says 10° degrees, even 15° degrees.