

УДК 612.75

DOI 10.47367/0021-3497\_2022\_1\_340

## STUDY OF FOOT MORPHOLOGICAL CHANGE OF MONGOLIAN CHILDREN

### ИЗУЧЕНИЕ МОРФОЛОГИЧЕСКИХ ИЗМЕНЕНИЙ СТОПЫ У МОНГОЛЬСКИХ ДЕТЕЙ

*B. BATDULAM, L. UDVAL, B. TSATSRAL*

*Б. БАТДУЛАМ, Л. УДВАЛ, Б. ТСАТСПАЛ*

**(School of Industrial Technology of University of Science and Technology, Mongolia)**

**(Школа промышленной технологии университета науки и технологии, Монголия)**

Email: batdulat\_b@must.edu.mn; udval\_lodoi@must.edu.mn; tsatsralbyambadorj@gmail.com

*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, in Mongolia, no certain standard of children footwear, lack of studies of measurement, and morphological researches about children's foot development in the recent decade. Besides, Mongolian adult's foot measurement study results show that Mongolian children are wearing unfitting shoes from their young age, which distorts the foot shape.*

*Therefore, the research aims to fill this gap and study the growth and morphological change of Mongolian children, who are the future of the country, by taking a plantogram (foot pattern picture) of 6-18 years old children and determining foot arch index and angle of the bunion in the foot.*

*В наши дни страны по всему миру различаются в экономическом и социальном отношении, однако дизайн обуви стал более похожим. Пока нет единых стандартов, принципов и правил. Ведущие страны-производители обуви, включая Чехию, Германию и Италию, широко рассматривают дизайн обуви, которая является повседневной, отвечающей человеческим потребностям, и наиболее стратегически важной для детей, учитывая их растущий организм. Однако в Монголии нет определенного стандарта детской обуви, отсутствуют исследования по измерениям и морфологическим исследованиям развития детской стопы в последнее десятилетие. Кроме того, результаты исследования стопы взрослых в Монголии показывают, что монгольские дети с раннего возраста носят неподходящую обувь, что искажает форму стопы.*

*Таким образом, исследование направлено на восполнение этого пробела и изучение роста и морфологических изменений монгольских детей, которые являются будущим страны, путем создания плантограммы (изображения рисунка стопы) детей 6...18 лет и определения индекса свода стопы и угла плоскостопия.*

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

**Ключевые слова: морфология стопы, дети, обувная колодка, обувь, длина стопы, свод стопы, извилистость, размеры стопы.**

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.

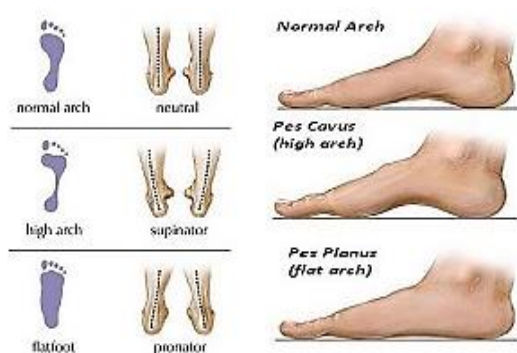


Fig 1

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. When age is higher, this number is get-

ting 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 (Fig. 1).

Bunion in the foot, in medical terms - hallux valgus, is increasing among young children in recent years (Fig. 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.

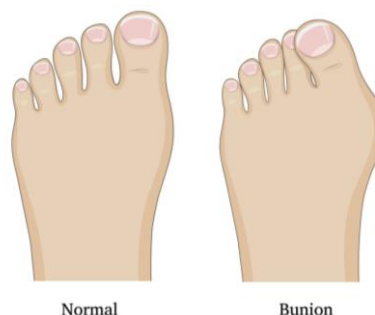


Fig 2

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.

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 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 Size

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

Age group	Age	Number of samples		Total sample	Percentage
		Male	Female		
Elementary school	6-	432	403	835	41.4%
	10				
Secondary school	11-	349	323	672	33.3%
	14				
High school	15-	236	275	511	25.3%
	18				
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.



Fig. 3

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 hal-

lux valgus is classified by Chentsov's method.

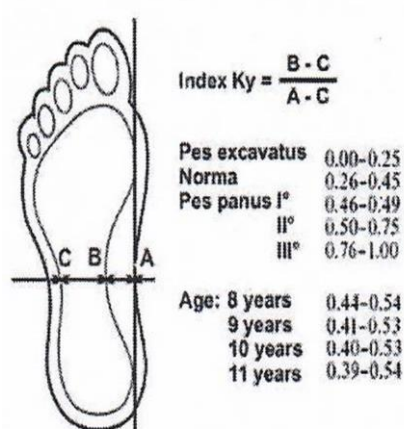


Fig. 4



Fig. 5

#### 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

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%

3.37% 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).

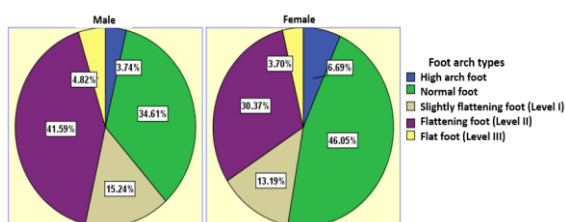


Fig. 6

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).

Table 3

Foot arch types		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

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).

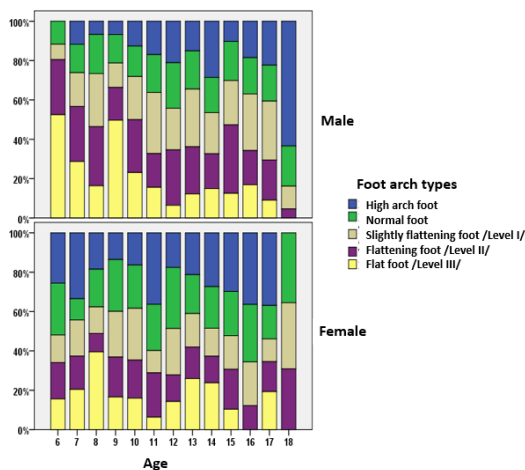


Fig. 7

**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	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).

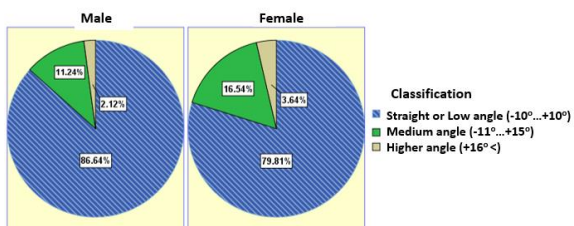


Fig. 8

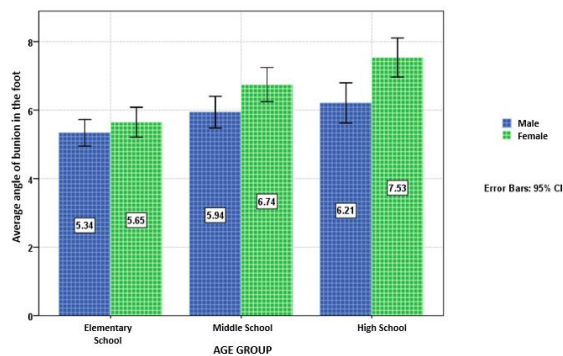


Fig. 9

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.

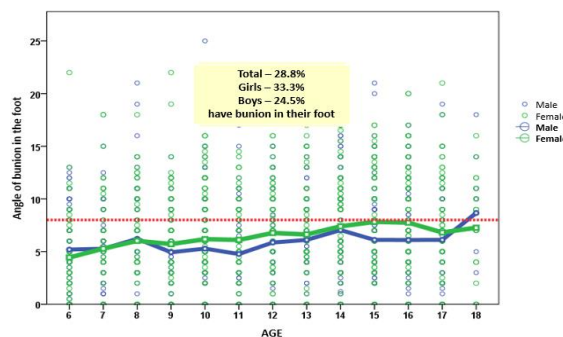


Fig. 10

## 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 cross-wise 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.

## REFERENCES

1. BSI (1990) Body measurements of boys and girls from birth up to 16.9 years. Part 1. London, UK, British Standards Institute.
2. *Cheng F.T., Peng D.B.* (1999) A systematic approach for developing a foot size information system for shoe last design. *International Journal of Industrial Ergonomics*. – 25:171-85.
3. *Cheskin M.P., Sherkin K.J., Bates B.T.* (1987) Construction of athletic footwear. *The Complete Handbook of Athletic Footwear*, New York, Fairchild Publications: 121-72.
4. Clarks, Ltd. Training Department (1976) Manual of shoemaking, second ed. Training Department Clarks, UK.
5. DIN (1981) Body dimensions of people. Berlin, Germany, Deutes Institut fur Normung e. V. (German Standards Institute).
6. *Feng J.* (2002) Footwear fit modeling and evaluation. Mater thesis, Hong Kong University of Science and Technology, Hong Kong.
7. *Gould N.* (1982) Shoes and shoe modifications. In: M. Jahss (Ed). *Disorders of the Foot*. Philadelphia; WB Saunders Co. 2:1745-82
8. *Janisse D.J.* (1992) The art and science of fitting shoes. *Foot Ankle*. – 13(5):257- 62
9. *Pheasant S.T.* (1986) *Body space: Anthropometric ergonomics & design*, London, UK, Taylor & Francis.
10. *Steenbekkers L.P.A.* (1993) Child development, design implications and accident prevention,. Delft. The Netherlands; TU Delft (Delft University of Technology).
11. *Snyder R.G., Schneider L.W., Owings C.L., Reynolds H.M., Golomb D.H., Schork M.A.* (1977) Anthropometry of infants, children and youths to age 18 for product safety design, Bathesda, Maryland, Consumer Product Safety Commission.
12. *Venkatappaiah B.* (1997) Introduction to the Modern Footwear Technology, Footwear Science and Engineering (Rtd) Central Leather Research Institute, Chennai.
13. *Volpon J.B.* (1994) Footprint analysis during the growth period. *J Pediatr Orthop*, 14(1):83-85.
2. *Cheng F.T., Perng D.B.* Системный подход к разработке информационной системы о размере стопы для дизайна обуви // *Международный журнал промышленной эргономики*. – 1999, 25: 171-85.
3. *Ческин М.П., Шеркин К.Дж., Бейтс Б.Т.* Конструирование спортивной обуви. Полный справочник по спортивной обуви, Нью-Йорк, Fairchild Publications. – 1987, 121-72.
4. Clarks, Ltd. Учебный отдел (1976) Руководство по изготовлению обуви, второе изд. Учебный отдел Кларкс, Великобритания.
5. DIN (1981) Размеры тела человека. Берлин, Германия. Deutes Institut fur Normung e. V. (1 немецкий институт стандартов).
6. *Feng J.* (2002) Моделирование и оценка подгонки обуви. Дипломная работа. Гонконгский университет науки и технологий, Гонконг.
7. *Гулд И.И.* (1982) Обувь и модификации обуви. В: М. Jahss (Ed). *Заболевания стопы*. Филадельфия; WB Saunders Co. 2: 1745-82.
8. *Janisse D.J.* (1992) Искусство и наука подгонки обуви. Голеностопный сустав, 13 (5): 257-62.
9. *Фазан С.Т.* (1986) *Пространство тела: антропометрическая эргономика и дизайн*, Лондон, Великобритания, Тейлор и Фрэнсис.
10. *Steenbckkers L.P.A.* (1993) Развитие ребенка, значение дизайна и предотвращение несчастных случаев. Делфт. Нидерланды; TU Delft (Делфтский технологический университет).
11. *Снайдер Р.Г., Шнайдер Л.В., Оуингс К.Л., Рейнольдс Х.М., Голомб Д.Х., Шорк М.А.* (1977) Антропометрия младенцев, детей и подростков в возрасте до 18 лет для проектирования безопасности продукции. – Батесда, Мэриленд, Комиссия по безопасности потребительских товаров.
12. *Venkatappaiah B.* (1997) Введение в современные технологии обуви, Обувная наука и инженерия (Rtd), Центральный научно-исследовательский институт кожи. Ченнаи.
13. *Волной Дж.Б.* Анализ экологического следа в период роста // *Журнал Педиатр Оргон*. – 1994, 14(1): 83-85.

Поступила 21.01.22.

## ЛИТЕРАТУРА

1. BSI (1990) Размеры тела мальчиков и девочек от рождения до 16,9 лет. Часть 1. – Лондон, Великобритания, Британский институт стандартов.