

# Anthropometric Measurement of the Feet of Chinese Children

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**Abstract.** This paper presents the results of a nationwide anthropometric survey conducted on children in China. Foot length and foot breadth were measured from 20,000 children with age ranged from 4 to 17 years old by 3D foot scanner. Mean values, standard deviations, and the 5th, 95th percentile for the two items were estimated. The dimension difference between age and gender were discussed, and the classification of foot shape was analyzed. It was found that the mean values of the dimensions showed a gradual increase by age. The dimensions had no significant difference between genders for the children from 4 to 12, but the difference became significant for the children from 13 to 17. For both boys and girls, the intermediate type foot has the greatest proportion. These data, previously lacking in China, can benefit the children's products design.

**Keywords:** Foot; anthropometric measurement; Chinese children.

## 1 Introduction

Anthropometric data are essential for the correct design of various facilities. Without such data, the designs can not fit people properly. This is especially true for children. The comfort and functional utility of the workspace, equipments and products which designed based on the anthropometric data are related with children's health and safety. Many anthropometric studies had been undertaken to determine the size of children [1][2][3][4]. In china, a nationwide anthropometric survey project for children from 4 to 17 was completed from 2005 to 2008. This survey measured more than 100 anthropometric dimensions, including body size as well as head, foot and hand size. The foot length and foot breadth data for the children are presented in this paper. The purpose is to determine foot length and foot breadth dimensions in different age groups to facilitate the design of such products as shoes, socks and other components in their daily life.

## 2 Methods

### 2.1 Subjects

China is a vast country with an area of over 96 million square kilometers. Children in different regions have large difference in body development status and body shape.

To make the anthropometric survey more representative, a stratified cluster sampling method was used to determine the distribution of the samples.

The whole country was divided into six geographical areas, which was in accordance with the adult anthropometric survey in 1988[5]: north and northeast area, central and western area, the lower reaches of the Changjiang River area, the middle reaches of the Changjiang River area, Guangdong-Guangxi-Fujian area, Yunnan-Guizhou-Sichuan area. From the statistical point of view, the people within each area have similar body shape and body size, but body shape and size for the people in different areas are different with each other.

The sample size in each area was determined based on the distribution of children's population reported by China National Bureau of Statistics [6]. One or two cities in each area were selected and some kindergartens, primary schools and high schools were taken from these cities. Within each kindergarten, primary school or high school selected, a number of classes were taken and all the children in which were measured until the number of children desired in per age group was met.

According to Report on the Physical Fitness and Health Surveillance of Chinese School Students(2000)[7] and Report on the Second National Physical Fitness Surveillance(2000)[8], the children were subdivided into five age groups: preschool(4-6 years old),lower primary(7-10 years old),upper primary(11-12 years old) middle school(13-15 years old) high school(16-17 years old). In this survey, for example, 10 years old means ones whose age is from 9.5 to 10.5 years old. The sample size in each age group was distributed according to the children's body development status. The sample size of preschool age group may be smaller. Within lower primary and middle school age group, sample size should be increased, and for upper primary and high school age group the sample size can be reduced appropriately.

Based on this sampling plan, body dimension data were obtained from about 20,000 children in ten provinces distributed in the six geographical areas.

## 2.2 Dimension Measurements

Instead of traditional Martin type anthropometer, the PEDUS 3D Foot Scanner was adopted for foot anthropometric survey. The accuracy of the scanner is 1mm, and the scan time is less than 10 second one person. The 3D scanning system is much faster than Martin method for collecting foot data and it is more applicable for large-scale anthropometric surveys. And it would provide a permanent record from which any measurement dimensions can be taken as needed.

To achieve a greater scientific uniformity, measurements were always carried out on the right foot. After each scanning, a view to the scanning results was required to prevent the scanning failure caused by foot shifting.

Before the start of the survey, the measurement team was trained in anthropometric techniques and was checked for consistency in their survey procedures to ensure the reliability of the anthropometric data. In each survey spot, the parents or teachers were asked to fill a form including their children's name, sex, birth date and place, nationality, the school and grade, etc. The whole survey was completed in a period of about two years.

### 2.3 Data Processing and Statistical Analysis

Scanworx Foot Measure software was used to calculate the foot data.. This software can calculate some foot data automatically, and it also allows the user to calculate foot data interactively. In this paper, foot length and foot breadth were taken from this software. Both definitions of the two foot dimensions were taken from ISO 7250:2004[9].

The dimension values obtained were categorized according to sex and age groups and abnormality data examination was conducted. The extreme outliers and unreasonable results were identified and eliminated carefully by using  $3\sigma$  test, peak value test and logical value test. The Statistical Package for the Social Sciences (SPSS) for Windows version 16.0 was used in the following statistical analysis. The descriptive statistics, including arithmetic means (M), standard deviations (SD), and percentiles (5th and 95th) of the above measurements were calculated for both boys and girls.

## 3 Results

The statistical values of foot length and foot breadth are presented in table 1, including the number of subjects, gender (boys and girls) and age groups (4 to 17 years old). Estimates of mean, standard deviation (SD) and the 5th, 95th percentile are included in table 1. All dimensions are reported in mm.

**Table 1.** The statistical values of foot anthropometric dimensions

Gender	Age group	Number	Foot length				Foot breadth			
			M	SD	P5	P95	M	SD	P5	P95
boys	4-6	1026	172	14	149	194	67	8	52	79
	7-10	2113	205	15	180	231	77	8	63	90
	11-12	1987	229	15	206	254	83	9	69	97
	13-15	2794	248	14	225	270	88	9	73	104
	16-17	1726	252	12	232	272	90	9	75	104
girls	4-6	1065	169	14	145	191	64	7	53	75
	7-10	2146	201	16	173	228	73	9	58	87
	11-12	1941	225	13	204	245	80	8	68	93
	13-15	2733	231	11	213	250	83	8	71	95
	16-17	1800	231	11	213	248	83	8	70	95

## 4 Discussion

### 4.1 Differences between Age Groups

From table 1, it can be found that the mean values for the two dimensions increase gradually by age. Table 2 and table 3 show the interclass increase value and relative

odds ratio of the mean values. Both foot length and breadth show a trend for significant increase by age in boys and girls, and there are clear differences between the five age groups. For boys, the difference of foot length between age group(4-6) and (7-10) is 33mm. From (7-10) to (11-12), the foot length of boys increases by 24mm, and from (11-12) to (13-15) the increase value is 19mm. Also for girls, the increase of mean values of foot length are 32mm,24mm, 7mm respectively for the age group from (4-6) to (13-15) . The age group from (13-15) to (16-17) is the only exception and the interclass increase is -1mm.

Table 2 and table 3 also reveal that for both boys and girls, there is a stage in which the feet have a relatively fast growth rate. For boys, it is in the 4 to 15 years old, but for girls it is the 4 to 12 years old. When the boy grows up to 15, girls to 12, the foot growth rate slows down. According to the Report on the Physical Fitness and Health Surveillance of Chinese School Students (2000), children have a sudden increase in youth period. During this period, their physical size has an obvious change. In that report, the periods are 12-14 and 10-12 for the boys and girls respectively. It can be found that there is a certain degree of correlation between the foot dimension changes and age group.

**Table 2.** Mean value increase of foot length and breadth in different age groups (for boys)

Age group	Foot length		Foot breadth	
	Interclass increase (mm)	Relative odds ratio (%)	Interclass increase (mm)	Relative odds ratio (%)
(4-6) to (7-10)	33	119	10	115
(7-10) to (11-12)	24	111	7	109
(11-12) to (13-15)	19	108	5	106
(13-15) to (16-17)	4	102	2	102

**Table 3.** Mean value increase of foot length and breadth in different age groups (for girls)

Age group	Foot length		Foot breadth	
	Interclass increase (mm)	Relative odds ratio (%)	Interclass increase (mm)	Relative odds ratio (%)
(4-6) to (7-10)	32	119	8	113
(7-10) to (11-12)	24	112	8	110
(11-12) to (13-15)	7	103	3	103
(13-15) to (16-17)	-1	100	0	100

## 4.2 Gender Differences

The differences of foot length and foot breadth between boys and girls can be obtained in table 1. The differences of mean values of foot length range from 3mm to 22mm. In the age group (4-6) to (11-12), the foot length of the boys' is a little higher than girls',

but the differences are not obvious. In table 4 and table 5, the gender differences have become significant. In the age group of (13-15), the mean differences become significant which is 17mm. The differences keep increasing in the 16-17 age group by 22mm.

The significance of the differences between boys and girls was also examined by Mollison’s method [10] [11] across age groups. The formula is as followed:

$$S = \frac{A_1 - A_{11}}{S_{A11}} \times 100 \tag{1}$$

$A_1$  — Arithmetic mean of boys in each age group;

$A_{11}$  — Arithmetic mean of girls in each age group;

$S_{A11}$  — Standard deviation of girls in each age group;

Differences between the means of boys and girls are expressed in each measurement by percentage deviation. When the indicator of mean deviation is positive, then the value of the mean of boys is bigger than the mean of girls. The situation is reversed when the indicator is negative. If the result exceeds 100, then it shows that there is a significance difference between the two groups.

The indicator of mean deviation was calculated. The results showed that from 4 to 12 years old, no significant differences were found between boys and girls in both of the foot length and foot breadth. In age group (13-15) and (16-17), the differences of the foot length were significant. For the foot breadth, the differences become obvious in age group (13-15) and (16-17).

The results showed that the foot dimensions have very little differences between boys and girls for the children from 4-12 years old, which may imply that it was not necessary to consider gender difference in the design of some foot related products for children younger than 12 years old. But for children older than 12 years old, the difference should be taken into consideration.

**Table 4.** Classification of the foot shape

Gender	Age group	Narrow & long (%)	Intermediate type (%)	Short & wide (%)
boys	4-6	16	46	38
	7-10	24	54	22
	11-12	32	56	12
	13-15	41	48	10
	16-17	28	41	31
girls	4-6	17	53	30
	7-10	35	52	13
	11-12	38	54	8
	13-15	38	53	9
	16-17	34	56	10

### 4.3 Classification of the Foot Shape

According to the foot shape classification method of the former Soviet expert [12], the foot shape index was calculated (foot breadth/foot length\*100%). If the index is less than 34.9, the foot is narrow & long type; If the index is between 35.0-39.9, the foot is intermediate type; If the index is higher than 40.0, the foot is short & wide type. Table 4 shows the percentage of every classification of each age group.

From table 4, it can be found that the intermediate type has the greatest percentage and it is almost 50% of all the children. And next is the narrow & long type. The classification can be used for the design of the children's products.

## 5 Conclusion

This study was conducted to provide foot anthropometric information of Chinese children from 4 to 17 years old, which could be used for the ergonomic design of workspace and products. The foot length and foot breadth dimensions extracted from 20,000 children are listed in the forms of mean, standard deviation and percentile values. The differences among age groups, between boys and girls groups are discussed, and three kinds of foot shape type was analyzed. The results showed that the differences between the age groups were significant. In age group of (13-15) and (16-17), the gender difference was significant in the foot length. Foot shape of most of the Chinese children is the intermediate type. This survey provides the first foot anthropometric database of Chinese children.

## References

1. Wang, M.-J.J., Wang, E.M.-Y., Lin, Y.-C.: The Anthropometric Database for Children and Young Adults in Taiwan. *Applied Ergonomics* 33, 583-585 (2002)
2. Kayis, B., Ozok, A.F.: Anthropometry Survey Among Turkish Primary School Children. *Applied Ergonomics* 22, 55-56 (1991)
3. Steenbekkers, L.P., Molenbroek, J.F.: Anthropometric Data of Children for Non-specialist Users. *Ergonomics* 33(4), 421-429 (1990)
4. Prado-Leon, L.R., Avila-Chaurand, R., Gonzalez-Munoz, E.L.: Anthropometric Study of Mexican Primary School Children. *Applied Ergonomics* 32, 339-345 (2001)
5. Chinese National Standard, GB10000-1988: Human Dimension of Chinese Adults. Standards Press of China, Beijing (1988)
6. National Bureau of Statistics: Chinese Demographic Yearbook. China Statistics Press (2003)
7. Ministry of Education of the People's Republic of China, General Administration of Sports of China, Ministry of Health of the People's Republic of China, Ministry of Science and Technology, Sports and health study group of Chinese Students Allocation: Report on the Physical Fitness and Health Surveillance of Chinese School Students. Higher Education Press, Beijing (2000)
8. General Administration of Sports of China: Report on the Second National Physical Fitness Surveillance. Sports University Press, Beijing (2000)

9. International Standard, ISO 7250: Basic Human Body Measurements for Technological Design. International Standard Organization (2004)
10. Hu, H., Li, Z., Yan, J., Wang, X., Xiao, H., Duan, J., Zheng, L.: Anthropometric Measurement of the Chinese Elderly Living in the Beijing Area. *International Journal of Industrial Ergonomics* 37, 303–311 (2007)
11. Nowak, E.: Workspace for Disabled People. *Ergonomics* 32(9), 1077–1088 (1989)
12. Xiao, H., Ai, Q.: Foot shape study of Children of Kazak nationality. *Chinese Journal of Anatomy* 23(3) (2000)