Correlation Analysis on the Main and Basic Body Dimension for Chinese Adults

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Abstract. In this paper, the correlations between the basic and five main body dimensions are studied based on the latest anthropometric data for the Chinese adults. Then the linear regression equations are established, which can provide technical support for optimizing anthropometric measurements. Application of this research finding in anthropometry can effectively reduce the working difficulty, shorten the working hours and cut capital investment. It can help expediting the update of the anthropometric data.

Keywords: Body dimension · Anthropometric data · Correlation · Regression equation

1 Foreword

Anthropometric data, as a kind of important fundamental data resource, are the basis of product modeling and spatial arrangement. Its applications involve almost all sectors of industrial designs. When we research human behavior in the virtual, anthropometric data is very necessary. With the social advancement and technological development, people are paying more and more attention to industrial design and the application of ergonomics, while anthropometric data are just the premises and foundation of launching industrial designs and applying ergonomics. All human related standards are established on the basis of anthropometric data, and further on applied in industrial designs [1, 2].

Anthropometric data demands stringent timeliness. According to the requirement of Anthropometry, large-scale anthropometric measurement work should be conducted every 10 years [3]. However, due to all sorts of restrictions (heavy workload, huge investment, considerable difficulty), it is hard to update the anthropometric data every 10 years. For example, China issued the Anthropometric Data of the Chinese Adults (GB 10000-88) in 19884, which was the national standard for the anthropometric data of the Chinese adults. Now, more than two decades have passed, yet no update has been made to the data. Over the past 20 plus years, China's industrial designs have always been adopting the anthropometric data released in 1988. In fact, with the improvement of the people's living standard, the Chinese people's physical characteristics have seen

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significant changes. Therefore, those outdated and non-timely anthropometric data are far from being able to satisfy the demands of industrial designs.

Currently, China's anthropometric data are being updated slowly, while industrial designs are in urgent need of these time-efficient anthropometric data. In light of this situation, it is necessary to find a new approach so as to facilitate the progress of updating the anthropometric data. Hence, this essay has proposed to find out the correlation between anthropometric measurements through studying the correlation of anthropometric data, in a bid to optimize the anthropometric measurements, and further on shorten the working hours, reduce the working difficulty, and cut capital investment, help collect the anthropometric data, and satisfy industrial designs' actual demands for anthropometric data.

2 The Body Dimensions Applied in the Analysis of Correlation

This article has adopted the national standard—Basic Human Body Measurements for Technological Design (GB/T 5703—1999) 5 as the major target of studies. This standard has specified the basic body dimensions needed in designing humans' working and living sites (Please refer to Table 1). There are a total of 56 anthropometric items including 41 ones at the trunk, 6 ones at the hands, 2 ones at the feet, and 6 ones at the head and face, and 1 in another category (weight).

3 Analysis of the Correlation of Anthropometric Data

According to the human being's physical characteristics, the indexes of all parts of human body are not entirely mutually independent 6. There's a close correlation between all characteristic parameters. To study the correlations between the anthropometric measurements, this research has selected the five key anthropometric items (stature, weight, chest circumference, waist circumference, and hip circumference) that influence human body's basic physical features as the independent variables of the correlation analysis, and selected the 56 basic measurements stipulated in GB/T 5703—1999 as the dependent variables.

3.1 Studies of the Relevant Parameters

This article, based on the anthropometric data of more than 3,000 Chinese adults collected by China National Institute of Standardization in 2009, attempts to study the correlation coefficient r between the anthropometric measurements of the Chinese adults, and judge the intimacy ratio of the correlations between all measurements. Correlation coefficient, also called linear correlation coefficient, is the statistical analysis index that measures the linear correlation between variables. The equation of $0 < |r| < 1$ indicates that there's linear correlation to some extent between two variables. The more $|r|$ approaches 1, the closer the linear correlation between the two variables

Table 1. List of correlation coefficient (r) between the body dimensions

No.	List of measurements	Weight	Stature	Chest circumference	Waist circumference	Hip circumference
1	Weight	1	.517**	.816**	.809**	.817**
2	Stature	.517**	1	.118**	.093**	.158**
3	Eye height	.496**	.976**	.107**	.077**	.149**
4	Shoulder height	.529**	.958**	.155**	.126**	.199**
5	Elbow height	.531**	.925**	.172**	.144**	.220**
6	Lilac spine height	.408**	.862**	.091**	.060**	.128**
7	Crotch height	.275**	.857**	−.036	−.088**	.01
8	Fist(grip axis) height	.495**	.866**	.146**	.113**	.206**
9	Tibial height	.435**	.815**	.130**	.112**	.141**
10	Sitting height	.458**	.864**	.083**	.057**	.154**
11	Eye height, sitting	.474**	.850**	.108**	.085**	.166**
12	Cervical height, sitting	.532**	.804**	.196**	.186**	.250**
13	Shoulder height, sitting	.527**	.755**	.217**	.190**	.276**
14	Elbow height, sitting	.301**	.344**	.140**	.115**	.201**
15	Lower leg length	.279**	.659**	.025	.011	-.005
16	Knee height	.539**	.849**	.207**	.184**	.248**
17	Thorax depth at the nipple	.637**	−.063**	.872**	.791**	.749**
18	Chest depth, standing	.773**	.303**	.786**	.756**	.657**
19	Body depth, standing	.727**	.094**	.815**	.864**	.723**
20	Thigh clearance	.677**	.395**	.496**	.477**	.563**
21	Abdominal depth, sitting	.720**	−0.03	.856**	.911**	.785**
22	Buttock-abdomen depth sitting	.676**	−.043*	.818**	.856**	.782**
23	Chest breadth, standing	.764**	.416**	.696**	.667**	.579**
24	Hip breadth, standing	.649**	.154**	.634**	.634**	.843**

**Correlation is significant at the 0.01 level (2-tailed)

becomes. The more $|r|$ approaches 0, the weaker the linear correlation between the two variables becomes. We can classify it into three categories: $|r| < 0.4$ represents weaker linear correlation; $0.4 \leq |r| < 0.7$ represents significant linear correlation; $0.7 \leq |r| < 1$ represents closer linear correlation.

We utilized the statistical analysis software SPSS to analyze the correlations between the anthropometric data, and obtained the correlation coefficient *r* between the 56 basic anthropometric measurements and the five main ones (Please refer to Table 2). As we can learn from the statistical result, there're different levels of linear correlations between the 56 basic anthropometric measurements stipulated in the national standard—*Basic Human Body Measurements for Technological Design (GB/T 5703—1999)* and the five main measurements (stature, weight, chest circumference, waist circumference, and hip circumference), and they are of great significance in statistics. The 56 basic anthropometric measurements have higher linear correlation coefficients with weight, stature and chest circumference than with hip circumference and waist circumference. The detailed analysis results are as follows:

- There're significant linear correlations between weight and circumference/width/thickness related measurements (Correlation coefficients are basically above 0.6).
- There're comparatively closer correlations between stature and height related items, with the majority of the correlation coefficients being above 0.8. There're also

Table 2. List of correlation coefficient (*r*) between the body dimensions (continued)

No.	List of measurements	Weight	Stature	Chest circumference	Waist circumference	Hip circumference
25	Shoulder (biacromial) breadth	.542**	.656**	.285**	.274**	.242**
26	Shoulder (bideltoid) breadth	.790**	.552**	.624**	.609**	.555**
27	Elbow-to-elbow breadth	.665**	.166**	.698**	.682**	.633**
28	Hip breadth, sitting	.650**	.179**	.623**	.607**	.771**
29	Wall-acromion distance	.474**	.114**	.482**	.514**	.430**
30	Elbow-grip length	.472**	.702**	.207**	.201**	.213**
31	Grip reach; forward reach	.570**	.663**	.363**	.374**	.325**
32	Forearm-fingertip length	.556**	.827**	.313**	.243**	.247**
33	Shoulder-elbow length	.454**	.769**	.168**	.151**	.181**
34	Elbow-wrist length	.541**	.616**	.326**	.321**	.334**
35	Buttock-popliteal length (seat depth)	.442**	.596**	.259**	.233**	.348**
36	Buttock-knee length	.620**	.764**	.361**	.340**	.454**
37	Neck circumference	.813**	.455**	.690**	.709**	.589**
38	Chest circumference	.816**	.118**	1	.890**	.829**
39	Waist circumference	.809**	.093**	.890**	1	.814**
40	Wrist circumference	.715**	.306**	.643**	.667**	.623**
41	Thigh circumference	.698**	.139**	.660**	.617**	.815**
42	Calf circumference	.704**	.146**	.661**	.615**	.821**

**Correlation is significant at the 0.01 level (2-tailed)

comparatively significant linear correlations between stature and length related items, with the correlation coefficients being basically between 0.5 and 0.7.

- There're comparatively closer correlations between chest circumference/waist circumference/hip circumference and weight/circumference/thickness/width related measurements. What's more, the correlations between chest circumference, waist circumference and hip circumference are also relatively closer. The correlation coefficients are all above 0.8.
- There're comparatively weaker correlations between head/face measurements and the five independent variables, with the correlation coefficients all being below 0.5.
- Among the hand and foot related measurements, only hand length, palm length and foot length have closer correlations with stature (Their correlation coefficients are above 0.7) (Table 3).

Table 3. List of correlation coefficient (r) between the body dimensions (continued)

NO.	List of measurements	Weight	stature	Chest circumference	Waist circumference	Hip circumference
43	Hand length	.554**	.799**	.383**	.009	.119**
44	Palm length perpendicular	.569**	.805**	.399**	.013*	.124**
45	Hand breadth at metacarpals	.594**	.657**	.475**	.063**	.146**
46	Index finger length	.445**	.629**	.307**	.042**	.163**
47	Index finger breadth, proximal	.557**	.611**	.460**	.064**	.108**
48	Index finger breadth, distal	.534**	.527**	.451**	.114**	.154**
49	Foot length	.558**	.792**	.244**	.228**	.250**
50	Foot breadth	.427**	.383**	.275**	.260**	.275**
51	Head length	.309**	.290**	.222**	.225**	.180**
52	Head breadth	.348**	.431**	.171**	.110**	.213**
53	Face length	.235**	.257**	.157**	.150**	.116**
54	Head circumference	.375**	.314**	.250**	.218**	.247**
55	Sagittal arc	.205**	.321**	.066**	.056**	.078**
56	Bitragion arc	.218**	.288**	.099**	.068**	.149**

**Correlation is significant at the 0.01 level (2-tailed)

3.2 Linear Regression Analysis

As we can see from the 3.1 correlation analysis result, there're linear correlations in the sense of statistics between the basic anthropometric measurements and weight, stature, chest circumference, waist circumference and hip circumference. Usually, when the

linear correlation coefficient $|r|$ is above 0.8, it is held that the two variables have a close linear correlation. Now, we shall launch the linear regression analysis on the trunk measurements and stature whose correlation coefficients are above 0.8. Please refer to Table 4 for the regression equations.

Table 4. Linear correlations (regression equation) between basic body dimensions and Stature (H_1)

		Chart is the mm units
1	Eye height	0.953 H_1 − 50.3
2	Shoulder height	0.819 H_1 − 24.5
3	Elbow height	0.620 H_1 − 2.3
4	Lilac spine height	0.536 H_1 − 2.6
5	Crotch height	0.447 H_1 − 47.1
6	Fist height	0.432 H_1 − 7.9
7	Tibial height	0.306 H_1 − 83.1
8	Sitting height	0.454 H_1 − 142.7
9	Eye height, sitting	0.428 H_1 − 65.8
10	Cervical height, sitting	0.352 H_1 − 60.7
11	Knee height	0.308 H_1 − 25.3
12	Forearm-fingertip length	0.259 H_1 + 6

3.3 Test of the Regression Equation

After checking the above regression equations by way of mathematical statistics, we've come to the conclusion that the regression equations and all variables' regression coefficients have passed the test of significance, and that the regression equations can accurately reflect the correlations between all measurements. Therefore, we can utilize the linear relations between all measurements to optimize the basic anthropometric measurements in the actual anthropometric work from now on. We can collect some major anthropometric measurements and utilize the regression equations to predict the anthropometric measurements that have closer correlations with the major measurements but are hard to collect.

4 Conclusion and Outlook

Based on the existing latest anthropometric data of the Chinese adults, we have conducted the correlation analysis between the basic measurements stipulated in GB/T 5703 and the five main anthropometric items, and set up the effective linear regression equations, which can serve as technical references for the optimization of the anthropometric measurements. This research result can be directly applied in the update work of the anthropometric data, which can lower the difficulty of anthropometric measurement work further.

In order to improve the practicability of the Chinese people's anthropometric data in industrial designs, we should continue to carry out researches on the correlations between all the human body dimensions, as well as between the industrial designs related body dimension and the basic body dimensions.

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