Research on the Characteristics of Hand Shape in Different Countries

Jing Zhao, Fan Zhang, Gang Wu, Chao Zhao, Haitao Wang, and Xinyu Cao(✉)

China National Institute of Standardization, Beijing, China
caoxy@cnis.gov.cn

Abstract. For a long time, science has been dedicated to revealing various indicators of the human body, including height and weight. The same purpose is also for this paper. Based on data on the hand of people from ten different countries, this paper do some research with the help of multi-variate analysis tools. According to the different characteristics of the data, this paper first carried out the analysis of variance on hand length. Then, according to the different dimension of hand shape, including the vertical length of the palm, the metacarpal and the length of the index finger, factor analysis was carried out, and two influence factors were extracted. Then, multiple regressions were performed on these variables, at the same time, stepwise regression method was adopted, and the main independent variables were chose from the constructed model. Finally, gender is set to a dummy variable to study the impact of gender differences on the hand length.

Keywords: Hand · Analysis of variance · Factor analysis · Multiple regression · Dummy variable

1 Introduction

Most scientific research is about people's intuitive physical data, indicating height and weight. However, research on details, such as the study of the hands and feet, is more conducive in other disciplines. For example, reference [1] mentions the improvement of suggestions and opinions on the production of Chinese shoes by analyzing the data of the collected feet. The measurement of the hand has different measurement methods. Reference [2] gives two methods in detail. Overall, there are little literatures discussing the hand characteristics. [2] also gave some comparison of hand anthropometry of females in three ethnic groups: Western Europeans, Indian and West Indian. Additionally, appreciation of the gender differences in hand shape is essential to the proper design of both men's and women's hand tools, gloves. Traditionally, women's gloves are often made using a small version of a men's glove with all dimensions proportionally scaled according to hand length. However, if women's hands differ in shape from men's hands, this is an inappropriate model and could lead to improper gloves fit in women. Courtney [3] carried out an anthropometric study of hand dimensions of Hong Kong Chinese female workers compared to other ethnic groups. Twenty-three hand dimensions were measured and compared with data from the United Kingdom,

G. Di Bucchianico (Ed.): AHFE 2019, AISC 954, pp. 469–479, 2020.
https://doi.org/10.1007/978-3-030-20444-0_49

Japan and the United States of America. Other research referred to hand anthropometric study, please see literatures [4–6].

The data information we analyzed is from ISO/TR 7250-2:2010 "Basic human body measurements for technological design—Part 2: Statistical summaries of body measurements from national populations". This technical report is intended to serve as a continually updated repository of the most current national anthropometric data. It also provides statistical summaries of body measurements together with database background information for working age people in the national population.

2 Method

At first, we conduct the direct comparison among these countries based on analysis of variance (ANOVA). It is because we want to know whether hand length are significantly different among these countries as well as between male and female in these countries. We take hand length as response variable, gender and country as two factors. Analysis of variance is used to analyze the effects of factors, which may have impact on the result of an experiment.

Secondly, we performed factor analysis on the five variables that affect the hand length to extract more intuitive data features. The five variables are the vertical length of the palm, the metacarpal, the length of the index finger, the width of the proximal end of the index finger, and the width of the distal end. We want to know if there are any internal dependencies between these five variables.

Thirdly, we construct a multiple regression analysis of the above five variable opponents, and study how these five variables affect the human hand length, because the stepwise regression method is adopted, resulting the fifth independent variable removed from the model.

At last, we also want to know how much influence the gender has, so we set gender as a dummy variable. The study found that men's hands are about 2% taller than female hands.

3 Results

3.1 Results of ANOVA for Hand Length

The general linear model procedure is used to do analysis with the help of SPSS software. The general linear model procedure has the following advantages: (1) it could be used in unbalanced designs; (2) it can evaluate differences between individual level means; (3) it allows covariates, random factors and nested factors.

As we know, ANOVA based on three assumptions: (1) the dependent variables of each population are normally distributed, (2) the variance of each population is equal, and (3) the samples of each population are randomly sampled independently. Then, first we perform homogeneity tests through Levene's method. The results are in Table 1. From the p-value we can conclude that the data has equal variance.

Table 1. Levene's test of equality of error variances

Dependent variable: hand length			
F	DF1	DF2	P-value
.073	19	40	1.000
Test the full hypothesis that the error variance of the dependent variable is equal across groups			

In Table 2, DF stands for degree of freedom. Without loss of generality we take nominal significance level as 0.05. That means if P-value of one factor is less than 0.05, we think it is significant; otherwise it is not significant.

Table 2. Tests of between-subjects effects

Dependent variable: hand length					
Source	Sum of square	DF	Mean square	F	Sig.
Corrected model	5463.400[a]	19	287.547	1.221	.290
Intercept	2040939.267	1	2040939.267	8663.343	.000
Country	2289.067	9	254.341	1.080	.399
Gender	3024.600	1	3024.600	12.839	.001
Country * gender	149.733	9	16.637	.071	1.000
Error	9423.333	40	235.583		
Total	2055826.000	60			
Corrected total	14886.733	59			

[a]R squared = .367 (Adjusted R squared = .066)

Table 2 provides the results of the analysis of variance for the model. The first line (Corrected Model) is the overall test of all the effects of the model. The significance of two factors, country and gender, is 0.399 and 0.001, respectively. Gender is significant, but country is not significant. However, the test result of the interaction effect between the two factors (country * gender) is extremely insignificant. The table also provides that determination coefficient (R Squared) of the model is equal to 0.367, indicating that the main effect and interaction effect of the two factors in the model together account for 36.7% of the total variation of the dependent variable. However, although the sample analysis shows that the effects of the model have some explanatory ability for the dependent variable, the statistical test of the effects shows that only one effect is beyond the random fluctuation range but that cannot be inferred to the whole.

Figure 1 is the interaction plot for hand length. From Fig. 1, we can obtain the following information: (1) Overall, the hand length of men is larger than hand length of women in all ten countries. (2) The ten countries fall into about three groups: The Netherlands and United States had significantly larger hand length than the other eight countries; The India had the smallest hand length. (3) On average, the hand length of male in the Netherlands and the United States are largest and the hand length of female in United States and Kenya are the largest. The hand length of people in Germany and Italy is similar.

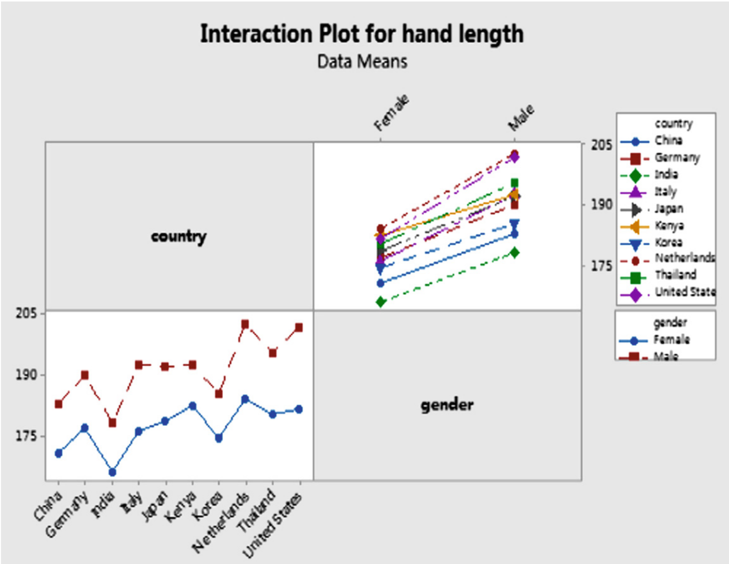

Fig. 1. Interaction plot for hand length

3.2 Results of Factor Analysis

As the original data has some missing values, especially the United States, we do some basic data pretreatment under the help of R software. At first, in order to make sure the accuracy of the data, we delete the information about USA's hand data, then, we make use of R software to multiple interpolate missing values. Furthermore, we try to find some common factors which effect the length of hand in nine countries (except the United States) no matter women or men. Aiming at above purposes, we take the method of Factor Analysis followed.

The purpose of factor analysis is to simplify the data or find out the basic data structure. Therefore, the premise of factor analysis is that there should be a strong correlation between observed variables. If the correlation between variables is small, they cannot share a common factor. Therefore, we produced the correlation coefficient matrix of the five variables in the table and conducted Bartlett's test of sphericity and KMO measures.

Table 3. Correlation matrix

		x1	x2	x3	x4	x5
Correlation	x1	1.000	.843	.838	.754	.750
	x2	.843	1.000	.867	.785	.816
	x3	.838	.867	1.000	.710	.957
	x4	.754	.785	.710	1.000	.650
	x5	.750	.816	.957	.650	1.000

x1 indicates Palm length perpendicular
x2 indicates metacarpals
x3 indicates Index finger length
x4 indicates Index finger breadth, proximal
x5 indicates Index finger breadth, distal

Table 4. KMO and bartlett's test

KMO measure of sampling adequacy		.823
Bartlett's test of sphericity	Approx. chi-square	325.618
	df	10
	Sig.	.000

The correlation analysis of five variables (Table 3) shows that there is a strong correlation between Index finger length and Index finger breadth, distal, which reaches about 0.957. The other three variables have a mutually strong correlation as well. All of these correlation values reach above 0.65. Looking at Table 4, the KMO measured value reaches above 0.8, and the significance level of Bartlett spherical test is extremely high, which indicates that factor analysis can be conducted on this data.

According to the eigenvalues criterion, only one factor can be selected for the hand data including nine countries (except USA). In order to illustrate explicitly, we have selected two factors. From Table 5, it shows the concrete information. The first column "Component" indicates the different kinds of factors, the following three columns are the initial eigenvalues, "Total" column refers to the eigenvalues, "% of Variance" is the percentage of Variance, and "Cumulative %" is the cumulative percentage of variance. For instance, the first two factors explain the data's variance 83.902% and 8.425% respectively. While these two factors explain the vast majority of the total data variance accumulatively, reaching more than 90%. The middle three columns show the two factors selected, as well as their explanatory variance ratio and cumulative ratio. The last three columns are the variance explanations of each selected factor after factor rotation.

Table 5. Total variance explain

Component	Initial eigenvalues			Extraction sum of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.195	83.902	83.902	4.195	83.902	83.902	2.546	50.914	50.914
2	.421	8.425	92.327	.421	8.425	92.327	2.071	41.413	92.327
3	.215	4.307	96.634						
4	.138	2.764	99.398						
5	.030	.602	100.000						

Extraction Method: Principal Component Analysis

Communalities is also one of the important judgment principles for determining the number of factors. Table 6 provides information in this respect. In the table, “Initial” is the Initial value, while “Extraction” is the communalities of each variable. The results show that the communalities of the five variables is very high, and the information of each variable contain more than 84%.

Table 6. Communalities

	Initial	Extraction
x1	1.000	.849
x2	1.000	.891
x3	1.000	.976
x4	1.000	.940
x5	1.000	.960

According to the order in which factors are extracted, we portray the screen plot about the change of factor eigenvalues (vertical axis) with the number of factors (horizontal axis). Actually, the number of factors is also judged according to the shape of the figure. It can be seen from the scree plot: from the first factor, the curve goes down rapidly, then becomes gentle, and finally becomes an approximately straight line. The factor load after rotation with the “varimax” method shows in Fig. 2 as well. We can conclude that “Index finger breadth, proximal” (x4) is close to the second factor, and “Index finger length” (x3) and “Index finger breadth, distal” (x5) are closer to the first factor.

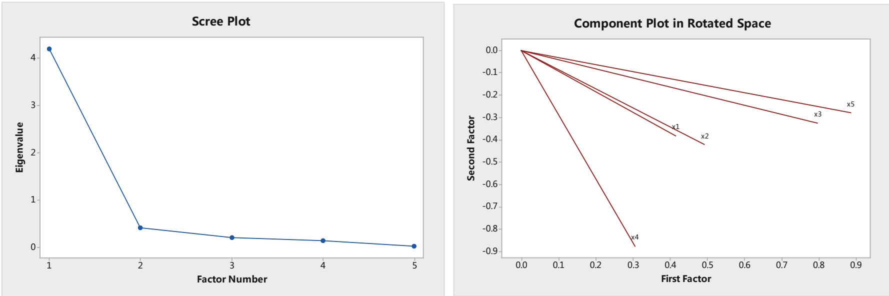

Fig. 2. Screen plot and component plot

3.3 Results of Multiple Regressiom

In order to study how the five variables in the data affect the hand length including nine countries, we build a linear regression model with the stepwise method. Since more than one variable is included in the independent variable, we take multiple linear regression model. The model structure is as follows:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + \varepsilon \quad (1)$$

Among them, y indicates hand length, x_1 = Palm length perpendicular, x_2 = metacarpals, x_3 = Index finger length, x_4 = Index finger breadth, proximal, x_5 = Index finger breadth, distal. b_1, b_2......b_5 are model parameters, b_0 is intercept value.

Table 7. Model summary

Model	R	R square	Adjusted R square	Std. error of the estimate	Durbin watson
1	.941[a]	.886	.884	5.304	
2	.972[b]	.946	.944	3.694	
3	.979[c]	.958	.956	3.271	
4	.981[d]	.962	.959	3.152	1.192

[a]Predictors: (Constant), x3
[b]Predictors: (Constant), x3, x1
[c]Predictor: (Constant), x3, x1, x2
[d]Predictor: (Constant), x3, x1, x2, x4
[e]Dependent Variable: y

Table 7 shows the interpreting proportion of each model by means of stepwise regression. The order of taking independent variables into the model is Index finger length (x3), Palm length perpendicular (x1), metacarpals (x2), Index finger breadth, proximal (x4). The last model has accounted for hand length more than 95%, but the Durbin-Watson test value of the model is 1.192, which cannot support the premise of error independence, so the regression model is only for reference.

Table 8. Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		Beta	Std. error	Beta		
1	(Constant)	40.186	7.178		5.598	.000
	x3	2.039	.102	.941	20.083	.000
2	(Constant)	19.086	5.738		3.326	.002
	x3	1.226	.130	.566	9.458	.000
	x1	.741	.099	.448	7.494	.000
3	(Constant)	23.016	5.180		4.443	.000
	x3	.936	.137	.432	6.834	.000
	x1	.580	.097	.351	5.983	.000
	x2	.413	.106	.249	3.882	.000
4	(Constant)	21.093	5.068		4.162	.000
	x3	.931	.132	.430	7.055	.000
	x1	.635	.097	.384	6.568	.000
	x2	.503	.110	.303	4.557	.000
	x4	−.604	.275	−.103	−2.200	.033

Dependent Variable: y

Table 8 shows the coefficients of each model after stepwise regression. In the first step, there is only an independent variable, and the regression coefficient is a large positive value (2.039), reflecting that the larger "Index finger length" (x_3) is, the larger hand length is. The second step regression model increase the independent variable "Palm length perpendicular" (x_1), whose standardized coefficient is 0.448, that is similar to "Index finger length" (x_3). The third step takes "metacarpals" (x_2) into regression model, the fourth step increases the "Index finger breadth, proximal" (x_4).

$$y = 0.384x_1 + 0.303x_2 + 0.43x_3 - 0.103x_4 \quad (2)$$

The above formula is the standardized performance of stepwise regression in the last model. From the standardized coefficients respectively, "Index finger length" (x_3) has the greatest influence on the hand length, each unit it increases, the hand length increases by 0.43 unit. In addition, both "Palm length perpendicular" (x_1) and "metacarpals" (x_2) have positive effects on hand length. From their standardized coefficients (0.384 and 0.303, respectively), the effects of the two variables are similar. Finally, "Index finger breadth, proximal" (x_4) has a negative effect on hand length, whose coefficient is -0.103.

Then, we draw four-in-one residual plot (Fig. 3), we explain the figures in the following:

Normal Probability Plot – Because the points on the normal probability plot roughly follow a straight line, we can assume that the residuals do not deviate substantially from a normal distribution.

Histogram – Use the normal probability plot to make decisions about the normality of the residuals. With a reasonably large sample size, the histogram displays compatible information.

Versus Fits – The constant variance assumption does not appear to be violated, because the residuals are randomly scattered about zero.

Versus Order – The plot of the residuals versus order does not show any pattern. Therefore, there is no time dependence in the residuals.

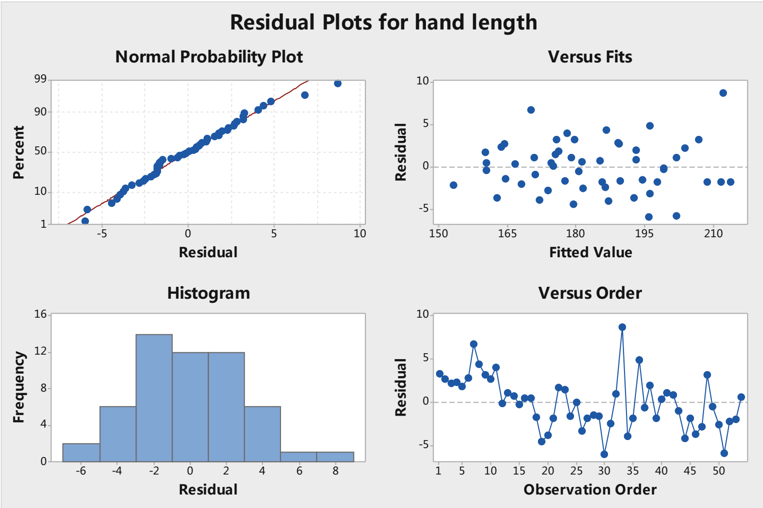

Fig. 3. Residual plots for hand length

3.4 Results of Adding Dummy Variable

Next, considering the impact of gender on hand length in the data of these nine countries, we take gender as a dummy variable in the regression equation, and the other independent variables do not change. Building a multivariate regression equation with dummy variables, Table 9 provides a global test of the regression equation, showing that the F value of the regression equation is 199.989, which is statistically significant at the 0.000 level, indicating that there is at least one independent variable which owns a very significant linear relationship with dependent variable in the equation.

Table 9. ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	12324.111	6	2054.019	199.989	.000
	Residual	482.722	47	10.271		
	Total	12806.833	53			

Dependent Variable: y

Predictors: (Constant), x5, gender, x4, x1, x2, x3

Table 10 provides the regression coefficients for the respective variables after adding dummy variables, including unstandardized coefficients and standardized coefficients. Among them, the last two columns of the table also provide collinearity test items for multiple regression. When the independent variables are completely linearly related, the estimation of the regression model no longer has a unique solution, so the least squares method is no longer applicable, neither. It can be seen from the test that the tolerance of x_3 and x_5 is less than 0.1, which means their variance inflation factors are all greater than 10 but less than 25, indicating that there is a certain degree of correlation between independent variables, and it is necessary to carefully apply multiple regression equations.

Table 10. Coefficients

Model	Unstandardized coefficients		Standardized coefficients	t	Sig.	Collinearity statistics	
	B	Std. error	Beta			Tolerance	VIF
(Constant)	22.679	5.839		3.884	.000		
Gender	−.665	1.066	−.022	−.624	.536	.669	1.495
x1	.623	.106	.377	5.888	.000	.196	5.111
x2	.480	.118	.289	4.061	.000	.158	6.325
x3	.978	.299	.451	3.275	.002	.042	23.695
x4	−.588	.281	−.100	−2.095	.042	.351	2.853
x5	−.104	.825	−.014	−.126	.900	.066	15.053

Dependent Variable: y

We give the following regression equation for the dummy variable according to the column labeled the standardized coefficients in Table 9:

$$y = -0.022gender + 0.377x_1 + 0.289x_2 + 0.451x_3 - 0.1x_4 - 0.014x_5 \tag{3}$$

From the degree of significance of the coefficient, the t-statistic value of gender is -0.624, whose p-value is equal to 0.536 greater than 0.05, rejecting the null hypothesis. The index finger breadth, distal (x_5) is also not significant, rejecting the null hypothesis at the level of 0.9, so we should be careful when interpreting variables with the multiple regression model results. When constructing dummy variables, we use 0 for men and 1 for women. Therefore, the regression coefficient of gender shows that on average, men's hand length are 0.022 units higher than women, which is also a common sense that men's hands are larger than women's.

4 Conclusion

This paper mainly discussed the characteristics of body hand in ten countries based on the statistical data in ISO/TR 7250-2:2010 "Basic human body measurements for technological design—Part 2: Statistical summaries of body measurements from national populations". Based on the average data and percentile values of hand length we can conclude that the ten countries fall into about three groups: The Netherlands and United States had significantly larger hand length than the other eight countries, the India had the smallest hand length, other countries are in a same condition. We do a factor analysis for five variables, which indicates that we can extract two main factors. "Index finger breadth, proximal" is close to the second factor, "Index finger length" and "Index finger breadth, distal" are closer to the first factor. Finally, we do a multiple regression to find out what extended gender and other variables' impact on hand length. The results are "Index finger length" has a great significance and on average, men's hands are about 2% taller than female hands. The obtained results could be a reference for designing the export gloves to these countries. What's more, the obtained regression equations have a great reference value for forensic science and anthropology.

Acknowledgments. This research was supported by National Key Technology R&D Program (2017YFF0206503, 2017YFF0209004, 2016YFF0204205) and China National Institute of Standardization through the "special funds for the basic R&D undertakings by welfare research institutions" (522018Y-5941, 522018Y-5948).

References

1. Bandini: Statistical analysis of foot anthropometric data of young chinese male population. Tsinghua University (2012)
2. Davies, B.T., Abada, A., Benson, K., Courtney, A., Minto, I.: A comparison of hand anthropometry of females in three ethnic groups. Ergonomics **23**, 2 (1980)
3. Courtney, A.J.: Hand anthropometry of Hong Kong Chinese females compared to other ethnic groups. Ergonomics **27**(11), 1169–1180 (1984)
4. Imrhan, S.N., Sarder, M.D., Mandahawi, N.: Hand anthropometry in Bangladeshis living in America and comparisons with other populations. Ergonomics **52**(8), 987–998 (2009)
5. Imrhan, S.N., Nguyen, M.T., Nguyen, N.N.: Hand anthropometry of Americans of Vietnamese origin. Int. J. Ind. Ergon. **12**(4), 281–287 (1993)
6. Wunderlich, R.E., Cavanagh, P.R.: Gender differences in adult foot shape implications for shoe design. Med. Sci. Sports Exerc. **33**, 605–611 (2001)