Estimation of stature by using the dimensions of the right hand and right foot in Han Chinese adults

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Received June 3, 2016; accepted June 20, 2016; published online December 21, 2016

The Han Chinese people are the main ethnic group in China and the largest ethnic group in the world. The dimensions of the hands and feet have been successfully used for the estimation of stature. A total of 26,927 healthy adult subjects, comprising 13,221 men and 13,706 women, were recruited. The survey samples were chosen through random cluster sampling. The mean values were significantly higher in men than those in women for all measurements ($P<0.001$). All the measurements showed a statistically significant correlation with stature ($P<0.01$). The combination of the right hand length and the right foot length was the best predictor of stature because it had the lowest standard error of estimate. The use of multiple regression equations yielded better results than did the use of linear regression equations. The accuracy of stature prediction ranged from $\pm 4.81$ to $\pm 6.39$ cm. The present study was of great importance with regards to improving the physical anthropology database of ethnic groups in China.

\textbf{stature, forensic anthropology, anthropometry, foot length, foot width, Han Chinese}

\textbf{Citation:} Zhang, X., Wei, Y., Zheng, L., Yu, K., Zhao, D., Bao, J., Li, Y., Lu, S., Xi, H., Xu, G., and Wen, Y. (2017). Estimation of stature by using the dimensions of the right hand and right foot in Han Chinese adults. Sci China Life Sci 60, 81–90. doi: 10.1007/s11427-016-0051-8

\textbf{INTRODUCTION}

Forensic scientists are interested in the estimation of stature because of its importance in personal identification. There is a relationship between each part of the body and the whole body. The hand and foot dimensions may represent a person’s identity. Human stature is an anatomical complex of linear dimensions (Moorthy et al., 2014; Uhrová et al., 2015; Zaher et al., 2011).

Many researchers have found a relationship between stature and several different body parts such as the hands and feet (Abdel-Malek et al., 1990; Agnihotri et al., 2007; Agnihotri et al., 2008; Atamurk and Duyar, 2008; Cervantes et al., 1988; Fessler et al., 2005; Gordon and Buikstra, 1992; Habib and Kamal, 2010; Ishak et al., 2012; Kanchan et al., 2008; Kanchan et al., 2010; Krishan, 2008a; Krishan, 2008b; Ozden et al., 2005; Rastogi et al., 2008; Reel et al., 2012; Sanli et al., 2005; Saxena, 1984; Sen and Ghosh, 2008; Zeybek et al., 2008), face and head (Baume and Buschang, 1983; Hautvast, 1971; Sahni et al., 2010), vertebral column (Jason and Taylor, 1995; Karakas et al., 2011; Nagesh and Pradeep Kumar, 2006; Pelin et al., 2005; Pininski and Brits, 2014; Qing et al., 2013; Terazawa et al., 1990; Tibbetts, 1981; Torimitsu...
et al., 2014; Zhang et al., 2008; Zhang et al., 2015), and upper-limb and lower-limb bones (Ahmed, 2013; Aldegheri and Dall’Oca, 2001; Choi et al., 1997; Ikeda et al., 1977; Lavelle, 1977; Mahakkanukrauh et al., 2011; Stanitski, 2004; Trotter and Gleser, 1958). The results have supported their claim that stature can be estimated successfully from all kinds of body parts. The hand and foot dimensions have been successfully used for the estimation of stature. The standards for the estimation of stature are based on anatomical and mathematical methods.

A previous study has confirmed that the correlation coefficients for stature and right hand/foot length are equal to those for stature and left hand/foot length (Uhrová et al., 2015). The aim of this study was to assess the relationship of the dimensions of the right hand and right foot with the stature, and to provide equations for stature estimation in Han Chinese adults. The Han Chinese people are the main ethnic group in China and the largest ethnic group in the world. The results of our research have practical use in the forensic field as well as in the field of sport and physical anthropology. The present study is of great significance in improving the physical anthropology database of ethnic groups in China.

The fact that the equations derived from one population cannot be used for other populations needs to be taken into the consideration, as body dimensions show ethnic variations due to genetic factors and environmental conditions. A single formula cannot represent the nationwide or worldwide population (Fawzy and Kamal, 2010; Jasuja et al., 1991; Krishan et al., 2012). It would be useful, however, to assess whether this method of stature estimation has forensic potential in other populations.

RESULTS

The descriptive statistical results of means and standard deviations for stature, right hand measurements, and right foot measurements are shown in Table 1. The mean stature in men was higher than that in women. The mean values were significantly higher in men than those in women for all measurements (Table 1).

The correlation coefficients for stature and right hand/foot measurements are shown in Table 2. All the measurements showed a statistically significant correlation with stature (P<0.01). In men, the highest correlation coefficient was between the stature and right foot length (r=0.602), and the lowest was between the stature and right hand breadth (r=0.240). Similarly, in women, the right foot length resulted in the highest correlation coefficient (r=0.565), whereas the right hand breadth showed the lowest correlation (r=0.175) with stature.

The linear regression equations for the estimation of stature from the right hand and right foot dimensions are shown in Table 3. The regression coefficients are significant for all parameters. For the analysis of right hand and right foot measurements, the standard error of estimate (SEE) ranged between ±5.251 and ±6.385 cm for men and between ±4.850 and ±5.788 cm for women. In Table 3, the right foot lengths showed the lowest SEE. Therefore, the right foot length would provide the most reliable stature estimation.

Tables 4 and 5 show that the combination of right hand/foot length is the best predictor of stature because it had the lowest SEE; for men, it was the combination of right hand length and right foot length (SEE=±5.188 cm), and for women it was the combination of right foot length and right hand length (SEE=±4.822 cm). Tables 4 and 5 show that multiple regression equations resulted in lower SEE values than did linear regression equations, ranging between ±5.179 and ±6.128 cm for men, and between ±4.812 and ±5.636 cm for women.

DISCUSSION

In this study of Han Chinese adults, the stature and right hand/foot dimensions were found to be higher in men than in women. The results were consistent with those of previous findings (Agnihotri et al., 2008; Ahmed, 2013; Ishak et al., 2012; Kanchan et al., 2008; Kanchan et al., 2010; Krishan and Sharma, 2007; Rastogi et al., 2008; Sen and Ghosh, 2008; Uhrová et al., 2013; Uhrová et al., 2015; Zeybek et al., 2008; Zheng et al., 2013; Zheng et al., 2015). The values for Han Chinese men were higher than those for Han Chinese women, with a significant difference between sexes (Table 1). The mean values of men were higher than those of women owing to their later maturity and growth cessation. Many previous studies have confirmed the presence of a positive correlation between several different body parts and stature (Agnihotri et al., 2007; Ahmed, 2013; Ishak et al., 2012; Krishan and Sharma, 2007; Uhrová et al., 2015). We found that the highest correlation coefficient was between stature and right foot length in men and women, whereas the correlation coefficient between stature and right hand breadth was the lowest.

The study showed that the ratios of foot dimensions to stature changed considerably with age and sex. Consequently, the regression equations that include these variables yielded more reliable results (Atamurk and Duyar, 2008). Our results indicated that age and sex should be taken into consideration when predicting human stature.

The results of this study showed that the right foot lengths with the lowest SEE would provide the most reliable stature estimation. The regression equations of stature from the right foot length for Han Chinese men and women were both statistically significant in the test of the regression effect. There was a significant linear regression relationship between stature and right foot length, and stature could be estimated by using the following regression equations: 

\[ S = 88.522 + 3.225RFL \] for men and 

\[ S = 89.811 + 2.941RFL \] for women. The SEE values of multiple regression equations
### Table 1
Descriptive statistics: stature, right hand dimensions (cm), and right foot dimensions (cm) in men and women[^a^]

| Ethnic groups          | Age groups (Years) | Value of r | Mean     | SD      | Mean     | SD      | t-value | P     |
|------------------------|--------------------|------------|----------|---------|----------|---------|---------|-------|
|                         |                    |            | Men      |         | Women    |         |         |       |
| **19–29**               |                    |            |          |         |          |         |         |       |
| Men (n=1,131)           | S                  | 171.28     | 6.034    | 158.667 | 5.459    | 52.006  | 0.000   |
| RHL                    | 18.199             | 1.972      | 16.923   | 1.627   | 16.749   | 0.000   |
| Women (n=1,121)         | RHB                | 8.101      | 0.569    | 7.193   | 0.540    | 38.854  | 0.000   |
| S                      | 168.343            | 5.665      | 157.278  | 5.517   | 47.886   | 0.000   |
| Men (n=1,149)           | RHL                | 18.232     | 1.813    | 17.046  | 1.736    | 16.174  | 0.000   |
| Women (n=1,193)         | RHB                | 8.255      | 0.525    | 7.431   | 0.521    | 38.114  | 0.000   |
| RFL                    | 24.266             | 1.205      | 22.413   | 1.151   | 38.049   | 0.000   |
| RFB                    | 9.404              | 0.705      | 8.491    | 0.646   | 32.034   | 0.000   |
| **30–39**               |                    |            |          |         |          |         |         |       |
| Men (n=1,170)           | RHL                | 18.397     | 1.730    | 17.225  | 1.617    | 17.032  | 0.000   |
| Women (n=1,196)         | RHB                | 8.287      | 0.578    | 7.517   | 0.529    | 33.811  | 0.000   |
| RFL                    | 24.376             | 1.262      | 22.443   | 1.266   | 37.803   | 0.000   |
| RFB                    | 9.622              | 0.681      | 8.764    | 0.628   | 32.348   | 0.000   |
| **50–59**               |                    |            |          |         |          |         |         |       |
| Men (n=1,180)           | RHL                | 18.393     | 1.810    | 17.304  | 1.488    | 15.873  | 0.000   |
| Women (n=1,158)         | RHB                | 8.395      | 0.578    | 7.536   | 0.485    | 32.518  | 0.000   |
| RFL                    | 24.310             | 1.207      | 22.271   | 1.111   | 42.481   | 0.000   |
| RFB                    | 9.595              | 0.660      | 8.726    | 0.681   | 31.317   | 0.000   |
| **60+**                 |                    |            |          |         |          |         |         |       |
| Men (n=1,386)           | RHL                | 17.958     | 1.545    | 16.886  | 1.336    | 20.106  | 0.000   |
| Women (n=1,535)         | RHB                | 8.162      | 0.427    | 7.353   | 0.383    | 53.993  | 0.000   |
| RFL                    | 24.003             | 1.151      | 22.245   | 1.081   | 45.968   | 0.000   |
| RFB                    | 9.379              | 0.628      | 8.668    | 0.569   | 32.107   | 0.000   |
| **40–49**               |                    |            |          |         |          |         |         |       |
| Men (n=1,499)           | RHL                | 17.945     | 1.679    | 17.019  | 1.363    | 16.944  | 0.000   |
| Women (n=1,613)         | RHB                | 8.231      | 0.454    | 7.453   | 0.396    | 51.039  | 0.000   |
| RFL                    | 24.003             | 1.222      | 22.232   | 1.101   | 42.599   | 0.000   |
| RFB                    | 9.492              | 0.642      | 8.748    | 0.577   | 34.011   | 0.000   |
| **50–59**               |                    |            |          |         |          |         |         |       |
| Men (n=1,442)           | RHL                | 18.190     | 1.466    | 17.012  | 1.314    | 23.363  | 0.000   |
| Women (n=1,595)         | RHB                | 8.224      | 0.430    | 7.478   | 0.396    | 49.716  | 0.000   |
| RFL                    | 24.023             | 1.224      | 22.197   | 1.114   | 43.033   | 0.000   |
| RFB                    | 9.532              | 0.646      | 8.746    | 0.590   | 35.026   | 0.000   |
| **60+**                 |                    |            |          |         |          |         |         |       |
| Men (n=1,457)           | RHL                | 18.036     | 1.438    | 17.079  | 1.375    | 18.553  | 0.000   |
| Women (n=1,520)         | RHB                | 8.108      | 0.429    | 7.442   | 0.381    | 44.831  | 0.000   |
| RFL                    | 23.800             | 1.192      | 22.046   | 1.092   | 41.893   | 0.000   |
| RFB                    | 9.511              | 0.670      | 8.704    | 0.610   | 34.370   | 0.000   |
| **Southern Han total**  |                    |            |          |         |          |         |         |       |
| Men (n=7,379)           | RHL                | 18.034     | 1.523    | 16.948  | 1.345    | 46.638  | 0.000   |
| Women (n=7,814)         | RHB                | 8.144      | 0.437    | 7.363   | 0.413    | 113.173 | 0.000   |
| RFL                    | 24.019             | 1.196      | 22.136   | 1.086   | 101.708  | 0.000   |
| RFB                    | 9.440              | 0.641      | 8.658    | 0.590   | 78.326   | 0.000   |
| **Han Chinese total**   |                    |            |          |         |          |         |         |       |
| Men (n=13,221)          | RHL                | 18.158     | 1.672    | 17.028  | 1.469    | 58.917  | 0.000   |
| Women (n=13,706)        | RHB                | 8.189      | 0.501    | 7.394   | 0.470    | 134.391 | 0.000   |
| RFL                    | 24.179             | 1.228      | 22.249   | 1.130   | 134.299  | 0.000   |
| RFB                    | 9.490              | 0.669      | 8.675    | 0.617   | 103.951  | 0.000   |

[^a^]: S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; SD, standard deviation.
Table 2  Correlation between stature and dimensions of the right hand and right foot

| Ethnic groups | Age groups (Years) | Value of r | Men       | Women     |
|---------------|-------------------|------------|-----------|-----------|
|               |                   |            | 19–29     | 0.317**  | 0.205**  |
| Southern Han  |                   |            | Men (n=1,131) | 0.246**  | 0.182**  |
|               |                   |            | Women (n=1,121) | 0.578**  | 0.582**  |
|               |                   |            | 30–39     | 0.285**  | 0.224**  |
|               |                   |            | Men (n=1,149) | 0.224**  | 0.169**  |
|               |                   |            | Women (n=1,193) | 0.587**  | 0.520**  |
|               |                   |            | 40–49     | 0.300**  | 0.298**  |
|               |                   |            | Men (n=1,212) | 0.288**  | 0.250**  |
|               |                   |            | Women (n=1,224) | 0.605**  | 0.594**  |
|               |                   |            | 50–59     | 0.308**  | 0.268**  |
|               |                   |            | Men (n=1,170) | 0.294**  | 0.229**  |
|               |                   |            | Women (n=1,196) | 0.591**  | 0.548**  |
|               |                   |            | 60+       | 0.274**  | 0.246**  |
|               |                   |            | Men (n=1,180) | 0.317**  | 0.286**  |
|               |                   |            | Women (n=1,158) | 0.551**  | 0.563**  |
|               |                   |            | Northern Han total | 0.263**  | 0.208**  |
|               |                   |            | Men (n=5,842) | 0.210**  | 0.144**  |
|               |                   |            | Women (n=5,892) | 0.556**  | 0.540**  |
|               |                   |            | 19–29     | 0.303**  | 0.370**  |
| Southern Han  |                   |            | Men (n=1,595) | 0.283**  | 0.229**  |
|               |                   |            | Women (n=1,551) | 0.663**  | 0.610**  |
|               |                   |            | 30–39     | 0.362**  | 0.311**  |
|               |                   |            | Men (n=1,386) | 0.293**  | 0.304**  |
|               |                   |            | Women (n=1,535) | 0.627**  | 0.616**  |
|               |                   |            | 40–49     | 0.466**  | 0.368**  |
|               |                   |            | Men (n=1,499) | 0.247**  | 0.344**  |
|               |                   |            | Women (n=1,613) | 0.638**  | 0.601**  |
|               |                   |            | 50–59     | 0.381**  | 0.360**  |
|               |                   |            | Men (n=1,442) | 0.400**  | 0.357**  |
|               |                   |            | Women (n=1,595) | 0.621**  | 0.629**  |
|               |                   |            | 60+       | 0.349**  | 0.310**  |
|               |                   |            | Men (n=1,457) | 0.388**  | 0.384**  |
|               |                   |            | Women (n=1,520) | 0.602**  | 0.620**  |
|               |                   |            | Southern Han total | 0.341**  | 0.291**  |
|               |                   |            | Men (n=7,379) | 0.249**  | 0.192**  |
|               |                   |            | Women (n=7,814) | 0.621**  | 0.575**  |
|               |                   |            | 19–29     | 0.310**  | 0.256**  |
| Han Chinese   |                   |            | Men (n=13,221) | 0.240**  | 0.175**  |
|               |                   |            | Women (n=13,706) | 0.602**  | 0.565**  |
|               |                   |            | 40–49     | 0.271**  | 0.245**  |
|               |                   |            | 50–59     | 0.384**  | 0.290**  |
|               |                   |            | 60+       | 0.349**  | 0.310**  |
|               |                   |            | 19–29     | 0.310**  | 0.256**  |
|               |                   |            | Men (n=13,221) | 0.240**  | 0.175**  |
|               |                   |            | Women (n=13,706) | 0.602**  | 0.565**  |

a) $r$, correlation coefficient. **, Significant at <0.01.
### Table 3  Linear regression equations for stature estimation (cm) from right hand/foot dimensions\(^{a}\)

| Ethnic groups | Age groups (Years) | Equation | \(R^2\) | SEE | Equation | \(R^2\) | SEE |
|---------------|-------------------|----------|-------|-----|----------|-------|-----|
|               | Men (n=1,131)     | \(S=150.147+2.609\text{RHB}\) | 0.060 | ±5.851 | \(S=145.445+1.838\text{RHB}\) | 0.033 | ±5.370 |
|               | Women (n=1,121)   | \(S=103.698+2.738\text{RFL}\) | 0.334 | ±4.925 | \(S=98.195+2.703\text{RFL}\) | 0.338 | ±4.443 |
|               | Men (n=1,149)     | \(S=148.411+2.415\text{RHB}\) | 0.050 | ±5.524 | \(S=143.983+1.789\text{RHB}\) | 0.029 | ±5.440 |
|               | Women (n=1,193)   | \(S=101.351+2.761\text{RFL}\) | 0.345 | ±5.878 | \(S=101.452+2.491\text{RFL}\) | 0.270 | ±4.715 |
| 40–49         | Men (n=1,212)     | \(S=150.233+1.901\text{RFB}\) | 0.060 | ±5.496 | \(S=136.454+2.388\text{RFB}\) | 0.071 | ±5.319 |
|               | Women (n=1,224)   | \(S=149.426+0.979\text{RHL}\) | 0.090 | ±5.682 | \(S=137.776+1.103\text{RHL}\) | 0.089 | ±5.520 |
| Northern Han  | Men (n=1,170)     | \(S=139.970+2.848\text{RFB}\) | 0.106 | ±6.633 | \(S=129.851+3.065\text{RFB}\) | 0.111 | ±5.452 |
|               | Women (n=1,196)   | \(S=94.392+2.948\text{RFL}\) | 0.349 | ±5.201 | \(S=99.961+2.464\text{RFL}\) | 0.301 | ±4.609 |
| 60+           | Men (n=1,180)     | \(S=148.696+0.894\text{RHL}\) | 0.095 | ±6.135 | \(S=139.568+0.911\text{RHL}\) | 0.072 | ±5.310 |
|               | Women (n=1,158)   | \(S=99.632+2.695\text{RFL}\) | 0.303 | ±4.933 | \(S=91.659+2.752\text{RFL}\) | 0.317 | ±4.491 |
| Northern Han  | Men (n=5,842)     | \(S=148.517+2.325\text{RHB}\) | 0.044 | ±6.110 | \(S=144.388+1.584\text{RHB}\) | 0.021 | ±5.806 |
|               | Women (n=5,892)   | \(S=99.220+2.809\text{RFL}\) | 0.309 | ±5.198 | \(S=95.546+2.706\text{RFL}\) | 0.291 | ±4.939 |
| 19–29         | Men (n=1,595)     | \(S=136.182+4.169\text{RHB}\) | 0.092 | ±5.677 | \(S=132.785+1.464\text{RHL}\) | 0.137 | ±4.830 |
|               | Women (n=1,551)   | \(S=86.182+3.439\text{RFL}\) | 0.439 | ±4.462 | \(S=88.986+3.098\text{RFL}\) | 0.372 | ±4.120 |
| 30–39         | Men (n=1,386)     | \(S=132.311+4.191\text{RHB}\) | 0.086 | ±5.855 | \(S=125.628+4.093\text{RHB}\) | 0.092 | ±4.925 |
|               | Women (n=1,535)   | \(S=88.462+3.335\text{RFL}\) | 0.394 | ±4.769 | \(S=90.586+2.941\text{RFL}\) | 0.379 | ±4.073 |
| 40–49         | Men (n=1,499)     | \(S=133.855+1.740\text{RHL}\) | 0.218 | ±5.541 | \(S=130.447+1.452\text{RHL}\) | 0.136 | ±4.997 |
|               | Women (n=1,613)   | \(S=86.570+2.571\text{RFL}\) | 0.407 | ±4.822 | \(S=89.937+2.934\text{RFL}\) | 0.362 | ±4.294 |
| Southern Han  | Men (n=1,442)     | \(S=116.142+5.853\text{RHB}\) | 0.160 | ±5.754 | \(S=116.809+4.906\text{RHB}\) | 0.128 | ±5.080 |
|               | Women (n=1,595)   | \(S=87.588+3.186\text{RFL}\) | 0.386 | ±4.920 | \(S=85.324+3.071\text{RFL}\) | 0.396 | ±4.227 |
| 60+           | Men (n=1,457)     | \(S=116.721+5.587\text{RHB}\) | 0.151 | ±5.693 | \(S=107.418+5.871\text{RHB}\) | 0.147 | ±5.386 |
|               | Women (n=1,520)   | \(S=87.784+3.119\text{RFL}\) | 0.362 | ±4.934 | \(S=78.148+3.309\text{RFL}\) | 0.384 | ±4.578 |
| Southern Han  | Men (n=7,379)     | \(S=134.643+3.792\text{RHB}\) | 0.062 | ±6.456 | \(S=134.674+2.702\text{RHB}\) | 0.037 | ±6.878 |
|               | Women (n=7,814)   | \(S=82.335+3.464\text{RFL}\) | 0.386 | ±5.222 | \(S=86.651+3.068\text{RFL}\) | 0.330 | ±4.743 |
| 19–29         | Han Chinese total | \(S=144.333+1.220\text{RHL}\) | 0.096 | ±6.252 | \(S=133.712+2.409\text{RHL}\) | 0.066 | ±5.683 |
|               | Men (n=13,221)    | \(S=140.718+3.147\text{RHB}\) | 0.057 | ±6.385 | \(S=139.013+2.196\text{RHB}\) | 0.031 | ±5.788 |
|               | Women (n=13,706)  | \(S=88.522+3.225\text{RFL}\) | 0.363 | ±5.251 | \(S=89.811+2.941\text{RFL}\) | 0.320 | ±4.850 |
|               | Han Chinese total | \(S=141.529+2.630\text{RFB}\) | 0.072 | ±6.337 | \(S=135.253+2.305\text{RFB}\) | 0.059 | ±5.705 |

\(a\) S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; \(R^2\), coefficient of determination; SEE, standard error of estimate.
| Ethnic groups   | Age groups (Years) | Equation                                                                                                  | Men R² | SEE             |
|----------------|--------------------|----------------------------------------------------------------------------------------------------------|-------|-----------------|
|               | 19–29              | $S = 103.689 + 2.759RFL$                                                                               | 0.334 | ±4.925          |
| Men (n=1,131) |                    | $S = 98.987 + 2.538RFL + 0.554RHL$                                                                     | 0.365 | ±4.812          |
| Women (n=1,121)|                    | $S = 135.732 + 0.941RHL + 2.341RHB$                                                                     | 0.149 | ±5.572          |
|                | 30–39              | $S = 102.477 + 2.690RFL − 0.516RFB$                                                                    | 0.337  | ±4.917          |
| Men (n=1,149) |                    | $S = 94.764 + 2.363RFL + 0.262RFB + 0.550RHL + 0.756RFL                                              | 0.371  | ±4.792          |
| Women (n=1,193)|                    | $S = 101.351 + 2.761RFL                                                                               | 0.345  | ±5.587          |
|                |                    | $S = 137.402 + 0.800RHL + 1.982RHB                                                                    | 0.114  | ±5.337          |
| Men (n=1,212) |                    | $S = 102.346 + 2.880RFL − 0.410RFB                                                                    | 0.347  | ±4.582          |
| Women (n=1,224)|                    | $S = 94.174 + 2.655RFL + 0.449RFB + 0.487RHL + 0.622RHB                                             | 0.375  | ±4.487          |
|                | 50–59              | $S = 96.222 + 2.91RFL                                                                                 | 0.367  | ±4.741          |
| Men (n=1,170) |                    | $S = 90.916 + 2.734RFL + 0.516RHL                                                                     | 0.368  | ±5.128          |
| Women (n=1,196)|                    | $S = 127.039 + 0.941RHL + 2.639RHB                                                                   | 0.150  | ±5.944          |
|                |                    | $S = 93.712 + 2.884RFL − 0.232RFB                                                                    | 0.350  | ±5.199          |
| Men (n=1,180) |                    | $S = 87.181 + 2.620RFL − 0.033RFB + 0.489RHL + 0.787RHB                                             | 0.372  | ±5.112          |
| Women (n=1,158)|                    | $S = 99.632 + 2.695RFL                                                                               | 0.303  | ±4.933          |
|                | 60+                | $S = 91.317 + 2.244RFL − 0.322RFB + 0.422RHL + 1.020RHB                                             | 0.331  | ±4.841          |
| Northern Han  |                    | $S = 136.892 + 0.809RHL − 1.942RHB                                                                   | 0.099  | ±5.937          |
|                |                    | $S = 5,842 + 2.899RFL − 0.327RFB                                                                     | 0.310  | ±5.194          |
| Men (n=5,842) |                    | $S = 94.650 + 2.709RFL − 0.422RFB + 0.447RHL + 0.349RHB                                             | 0.328  | ±5.129          |
| Women (n=5,892)|                    | $S = 86.182 + 3.439RFL                                                                               | 0.435  | ±4.462          |
| Men (n=1,595) |                    | $S = 83.585 + 3.286RFL + 0.350RHL                                                                     | 0.446  | ±4.437          |
| Women (n=1,551)|                    | $S = 132.702 + 1.051RHL + 3.437RHB                                                                    | 0.144  | ±5.513          |
|                |                    | $S = 85.321 + 3.377RFL + 0.252RFB                                                                    | 0.440  | ±4.462          |
| Men (n=1,386) |                    | $S = 86.462 + 3.335RFL                                                                               | 0.794  | ±4.769          |
| Women (n=1,535)|                    | $S = 91.849 + 2.516RFL + 0.438RHL                                                                     | 0.420  | ±4.767          |
|                |                    | $S = 118.045 + 1.241RHL + 3.208RHB                                                                   | 0.179  | ±5.550          |
|                |                    | $S = 85.744 + 3.265RFL − 0.258RFB                                                                    | 0.394  | ±4.768          |
| Men (n=1,499) |                    | $S = 94.988 + 2.643RFL + 0.453RHL                                                                     | 0.330  | ±5.194          |
| Women (n=1,613)|                    | $S = 86.570 + 3.271RFL                                                                               | 0.361  | ±4.822          |
| Southern Han  | 50–59              | $S = 86.570 + 3.271RFL                                                                               | 0.409  | ±4.819          |
| Men (n=1,442) |                    | $S = 86.570 + 3.271RFL                                                                               | 0.386  | ±4.920          |
| Women (n=1,595)|                    | $S = 85.340 + 3.133RFL + 0.478RFB                                                                    | 0.409  | ±4.817          |
|                |                    | $S = 87.588 + 3.186RFL                                                                               | 0.463  | ±4.595          |
| Men (n=1,457) |                    | $S = 84.435 + 2.857RFL + 0.532RHL                                                                     | 0.375  | ±4.886          |
| Women (n=1,520)|                    | $S = 105.594 + 1.105RHL + 4.502RHB                                                                   | 0.211  | ±5.489          |
|                |                    | $S = 86.289 + 2.969RFL + 0.532RFB                                                                    | 0.365  | ±4.926          |
| Men (n=1,457) |                    | $S = 74.883 + 2.536RFL + 0.214RFB + 0.618RHL + 1.829RHB                                             | 0.420  | ±4.786          |
| Women (n=1,520)|                    | $S = 87.784 + 3.19RFL                                                                                | 0.362  | ±4.934          |
|                | 60+                | $S = 87.588 + 3.186RFL                                                                               | 0.386  | ±4.595          |
| Men (n=1,457) |                    | $S = 87.683 + 2.536RFL + 0.214RFB + 0.618RHL + 1.829RHB                                             | 0.420  | ±4.786          |
| Women (n=1,520)|                    | $S = 87.835 + 3.202RFL + 0.542RHL                                                                     | 0.399  | ±5.166          |
|                | 50–59              | $S = 87.784 + 3.19RFL                                                                                | 0.362  | ±4.934          |
| Men (n=1,379) |                    | $S = 117.913 + 1.333RHL + 2.895RHB                                                                   | 0.151  | ±6.141          |
| Women (n=1,714)|                    | $S = 83.688 + 3.570RFL + 0.409RFB                                                                    | 0.387  | ±5.217          |
|                | 50–59              | $S = 87.784 + 3.19RFL                                                                                | 0.362  | ±4.934          |
| Men (n=1,379) |                    | $S = 83.688 + 3.570RFL + 0.409RFB                                                                    | 0.387  | ±5.217          |
| Women (n=1,714)|                    | $S = 87.337 + 3.286RFL − 0.567RFB + 0.539RHL + 0.480RHB                                             | 0.401  | ±5.158          |

a) $S$, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; $R^2$, coefficient of determination; SEE, standard error of estimate.
| Ethnic groups | Age groups (Years) | Equation | Women | R² | SEE |
|---------------|-------------------|----------|-------|----|-----|
|               | 19–29             |          |       |    |     |
| Men (n=1,131) | S=98.195+2.703RFL | 0.338±4.443 |       |    |     |
| Women (n=1,121) | S=93.009+2.620RFL+0.416RHL | 0.353±4.394 |       |    |     |
|               | 30–39             |          |       |    |     |
| Men (n=1,149) | S=137.010+0.612RHL+1.570RHB | 0.066±5.281 |       |    |     |
| Women (n=1,193) | S=99.590+2.818RFL−0.445RFB | 0.340±4.438 |   |      |     |
|               | 40–49             |          |       |    |     |
| Men (n=1,212) | S=101.452+2.491RFL | 0.270±4.715 |       |    |     |
| Women (n=1,224) | S=96.121+2.380RFL+0.459RHL | 0.291±4.651 |       |    |     |
|               | 50–59             |          |       |    |     |
| Men (n=1,170) | S=124.532+0.848RHL+2.146RHL | 0.114±5.190 |       |    |     |
| Women (n=1,196) | S=99.463+2.423RFL+0.161RFB | 0.301±4.610 |   |      |     |
|               | 60+                |          |       |    |     |
| Men (n=1,180) | S=85.647+2.730RFL | 0.375±4.574 |       |    |     |
| Women (n=1,224) | S=121.777+0.996RHL+2.381RHB | 0.133±5.385 |       |    |     |
|               | Northern Han      |          |       |    |     |
| Men (n=5,842) | S=89.044+2.926RFL | 0.335±4.650 |       |    |     |
| Women (n=5,892) | S=85.445+2.677RFL+0.266RHL+0.564RHL+0.150RHB | 0.376±4.575 |       |    |     |
|               | 50–59             |          |       |    |     |
| Men (n=1,158) | S=124.532+0.848RHL+2.146RHL | 0.114±5.190 |       |    |     |
| Women (n=1,196) | S=99.463+2.423RFL+0.161RFB | 0.301±4.610 |   |      |     |
|               | 60+                |          |       |    |     |
| Men (n=1,180) | S=85.647+2.730RFL | 0.375±4.574 |       |    |     |
| Women (n=1,224) | S=121.777+0.996RHL+2.381RHB | 0.133±5.385 |       |    |     |
|               | Northern Han total |          |       |    |     |
| Men (n=5,842) | S=89.044+2.926RFL | 0.335±4.650 |       |    |     |
| Women (n=5,892) | S=85.445+2.677RFL+0.266RHL+0.564RHL+0.150RHB | 0.376±4.575 |       |    |     |
|               | Southern Han      |          |       |    |     |
| Men (n=1,499) | S=85.899+2.632RFL+0.631RHL | 0.384±4.221 |       |    |     |
| Women (n=1,613) | S=108.607+1.169RHL+3.576RHB | 0.200±4.800 |       |    |     |
|               | 50–59             |          |       |    |     |
| Men (n=1,442) | S=82.039+2.823RFL+0.516RHL | 0.409±4.822 |       |    |     |
| Women (n=1,595) | S=106.765+1.128RHL+3.638RHB | 0.194±4.885 |       |    |     |
|               | 60+                |          |       |    |     |
| Men (n=1,457) | S=76.872+2.641RFL+0.131RFB+0.445RHL+1.241RHB | 0.416±4.159 |       |    |     |
| Women (n=1,520) | S=76.152+3.147RFL+0.327RHL | 0.389±4.561 |       |    |     |
|               | Southern Han total |          |       |    |     |
| Men (n=7,579) | S=84.412+2.900RFL+0.351RHL | 0.336±4.723 |       |    |     |
| Women (n=7,814) | S=123.789+1.105RHL+1.636RHB | 0.097±5.507 |       |    |     |
|               | Han Chinese total |          |       |    |     |
| Men (n=13,221) | S=89.762+3.028RFL+0.335RFB | 0.321±4.846 |       |    |     |
| Women (n=13,706) | S=89.455+2.925RFL+0.183RFB+0.394RHL−0.603RHB | 0.338±4.716 |       |    |     |

a) S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; R², coefficient of determination; SEE, standard error of estimate.
were lower than those of linear regression equations. The finding is in agreement with the results of previous studies. The multiple regression equations of the northern Han people were as follows: $S = 94.650 + 2.709RFL - 0.422RFB + 0.447RHL + 0.349RHB$ for men and $S = 94.474 + 2.744RFL - 0.122RFB + 0.372RHL - 0.685RHB$ for women. The multiple regression equations of the southern Han people were as follows: $S = 78.337 + 3.286RFL - 0.567RFB + 0.539RHL + 0.480RHB$ for men and $S = 87.130 + 3.014RFL - 0.181RFB + 0.383RHL - 0.573RHB$ for women.

Estimation of stature from right hand and right foot dimensions by using regression equations has great implications and usefulness for physical and forensic anthropology. Because there is no sampling study for left hand/foot dimensions, the right foot lengths would provide the most reliable stature estimation. This study provides new forensic standards for the estimation of stature from the right hand and right foot measurements of Han Chinese adults.

**MATERIALS AND METHODS**

**Materials**

In this study, measurements taken from 26,927 healthy adult subjects (13,221 men, 13,706 women) currently residing in China were examined. The subjects were required to sign a consent form and complete a questionnaire containing basic demographic data and general questions, e.g., sex, age, and ethnicity. The subjects were between 19 and 75 years of age (mean age of men: 45.1±16.3 years, mean age of women: 45.0±15.6 years). All subjects were healthy local Han Chinese people who were native to their areas of residence for more than three generations. The modern Chinese population can be divided into the northern and southern groups, separated by Qinling Mountains and Huaihe River. The study included 11,734 northern Han (5,842 men, 5,892 women) and 15,193 southern Han (7,379 men, 7,814 women) subjects. The survey samples were chosen by means of random cluster sampling. These Han Chinese subjects were categorized in five subgroups according to their age ranges: 19–29, 30–39, 40–49, 50–59, and 60 years and older. The sampling locations included Sichuan, Inner Mongolia, Guangdong, Liaoning, Henan, Hebei, Shaanxi, Gansu, Jiangxi, Jiangsu, Hunan, Hainan, Anhui, Shanxi, Shandong, Zhejiang, Fujian, Hubei, Yunnan, Guizhou, Jilin, and Heilongjiang.

**Methods**

**Measurements**

Stature was measured by using an anthropometer. For stature, the distance from the vertex to the floor in the anatomical position with the head oriented in the Frankfurt plane was measured (Figure 1) (Martin and Saller, 1957).

Figure 1  Stature (S): the distance from the vertex to the floor in the anatomical position with the head oriented in the Frankfurt plane.

For hand length, the distance between the midpoint of the distal transverse crease of the wrist to the most anterior projection of the skin of the middle finger was measured (Ishak et al., 2012).

For hand breadth, the distance between the most lateral point on the head of the second metacarpal to the most medial point on the head of the fifth metacarpal was measured (Ishak et al., 2012).

For foot length, the maximum distance between the heel (pternion) and the longest toe (akropodian) (Hemy et al., 2013) was measured.

For foot breadth, the distance between the most prominent point on the medial side of the foot to the most prominent point on the lateral side (which corresponds to the heads of the first to fifth metatarsals) (Hemy et al., 2013) was measured.

With respect to establishing the reliability of obtaining stature and right hand and right foot measurements, we have verified that the degree of measurement error and reliability are well within acceptable standards ($R>0.9$; $rTEM<5\%$) (Perini et al., 2005; Knapp, 1992; Reynolds et al., 2008).

**Statistical analysis**

The data were statistically analyzed by using SPSS 17.0 for Windows and Microsoft Office Excel 2003. The significance of sex differences was tested by using an independent $t$-test. The association between stature and right hand or right foot measurements was determined by using Pearson correlation.
analysis. Linear regression analysis, stepwise regression, and multiple regression analyses were used to calculate the equations for the estimation of stature from right hand and right foot dimensions.

**Compliance and ethics** The author(s) declare that they have no conflict of interest.

**Acknowledgements** We would like to thank all the volunteers who participated in this project. This work was supported by the National Natural Science Foundation of China (30830602, 31401022).

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