

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

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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.

**stature, forensic anthropology, anthropometry, foot length, foot width, Han Chinese**

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### 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; Atamturk 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

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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  $\pm 5.251$  and  $\pm 6.385$  cm for men and between  $\pm 4.850$  and  $\pm 5.788$  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 ( $SEE \pm 5.188$  cm), and for women it was the combination of right foot length and right hand length ( $SEE \pm 4.822$  cm). Tables 4 and 5 show that multiple regression equations resulted in lower SEE values than did linear regression equations, ranging between  $\pm 5.179$  and  $\pm 6.128$  cm for men, and between  $\pm 4.812$  and  $\pm 5.636$  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 (Atamturk 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<sup>a)</sup>

Ethnic groups	Age groups (Years)	Value of <i>r</i>	Men		Women		<i>t</i> -test	
			Mean	SD	Mean	SD	<i>t</i> -value	<i>P</i>
Northern Han	19–29	S	171.280	6.034	158.667	5.459	52.006	0.000
	Men ( <i>n</i> =1,131)	RHL	18.199	1.972	16.923	1.627	16.749	0.000
	Women ( <i>n</i> =1,121)	RHB	8.101	0.569	7.193	0.540	38.854	0.000
		RFL	24.511	1.265	22.372	1.174	41.573	0.000
		RFB	9.404	0.705	8.491	0.646	32.034	0.000
		S	168.343	5.665	157.278	5.517	47.886	0.000
	30–39	RHL	18.232	1.813	17.046	1.736	16.174	0.000
	Men ( <i>n</i> =1,149)	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	9.515	0.727	8.719	0.617	28.612	0.000
		S	167.376	5.955	156.712	5.780	44.850	0.000
	40–49	RHL	18.339	1.827	17.166	1.560	17.040	0.000
	Men ( <i>n</i> =1,212)	RHB	8.330	0.551	7.491	0.518	38.753	0.000
		RFL	24.439	1.238	22.488	1.174	39.912	0.000
		RFB	9.622	0.681	8.764	0.628	32.348	0.000
		S	166.584	6.002	155.266	5.509	47.806	0.000
	50–59	RHL	18.397	1.730	17.225	1.617	17.032	0.000
	Men ( <i>n</i> =1,170)	RHB	8.287	0.578	7.517	0.529	33.811	0.000
		RFL	24.376	1.262	22.443	1.226	37.803	0.000
		RFB	9.624	0.695	8.776	0.643	30.789	0.000
		S	165.139	5.907	152.943	5.431	51.945	0.000
	60+	RHL	18.393	1.810	17.304	1.488	15.873	0.000
	Men ( <i>n</i> =1,180)	RHB	8.254	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	
S		167.712	6.254	156.164	5.867	103.161	0.000	
Northern Han total	RHL	18.313	1.832	17.134	1.613	37.002	0.000	
Men ( <i>n</i> =5,842)	RHB	8.247	0.566	7.436	0.533	79.922	0.000	
	RFL	24.380	1.238	22.399	1.170	89.090	0.000	
	RFB	9.554	0.698	8.698	0.651	68.662	0.000	
	S	169.554	5.956	157.300	5.198	61.413	0.000	
19–29	RHL	18.042	1.464	16.744	1.314	26.158	0.000	
Men ( <i>n</i> =1,595)	RHB	8.005	0.404	7.085	0.376	66.136	0.000	
	RFL	24.246	1.148	22.055	1.023	56.473	0.000	
	RFB	9.299	0.587	8.421	0.538	43.723	0.000	
	S	166.521	6.121	155.723	5.167	51.671	0.000	
30–39	RHL	17.958	1.545	16.886	1.336	20.106	0.000	
Men ( <i>n</i> =1,386)	RHB	8.162	0.427	7.353	0.383	53.993	0.000	
	RFL	24.003	1.151	22.145	1.081	44.968	0.000	
	RFB	9.379	0.628	8.668	0.569	32.107	0.000	
	S	165.079	6.262	155.158	5.373	47.530	0.000	
40–49	RHL	17.945	1.679	17.019	1.363	16.944	0.000	
Men ( <i>n</i> =1,499)	RHB	8.231	0.454	7.453	0.396	51.039	0.000	
	RFL	24.003	1.222	22.232	1.101	42.509	0.000	
	RFB	9.492	0.642	8.748	0.577	34.011	0.000	
	S	164.124	6.276	153.494	5.438	50.000	0.000	
50–59	RHL	18.190	1.466	17.012	1.314	23.363	0.000	
Men ( <i>n</i> =1,442)	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	
	S	162.023	6.176	151.106	5.832	49.603	0.000	
60+	RHL	18.036	1.438	17.079	1.375	18.553	0.000	
Men ( <i>n</i> =1,457)	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	
	S	165.527	6.665	154.566	5.795	108.335	0.000	
Southern Han total	RHL	18.034	1.523	16.948	1.345	46.638	0.000	
Men ( <i>n</i> =7,379)	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	
	S	166.492	6.576	155.253	5.879	147.960	0.000	
Han Chinese total	RHL	18.158	1.672	17.028	1.469	58.917	0.000	
Men ( <i>n</i> =13,221)	RHB	8.189	0.501	7.394	0.470	134.391	0.000	
	RFL	24.179	1.228	22.249	1.130	134.239	0.000	
	RFB	9.490	0.669	8.675	0.617	103.951	0.000	
	S	166.492	6.576	155.253	5.879	147.960	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<sup>a)</sup>

Ethnic groups	Age groups (Years)	Value of <i>r</i>	Men	Women
Northern Han	19–29	RHL	0.317**	0.205**
	Men ( <i>n</i> =1,131)	RHB	0.246**	0.182**
	Women ( <i>n</i> =1,121)	RFL	0.578**	0.582**
		RFB	0.343**	0.234**
	30–39	RHL	0.285**	0.224**
	Men ( <i>n</i> =1,149)	RHB	0.224**	0.169**
	Women ( <i>n</i> =1,193)	RFL	0.587**	0.520**
		RFB	0.244**	0.267**
	40–49	RHL	0.300**	0.298**
	Men ( <i>n</i> =1,212)	RHB	0.288**	0.250**
	Women ( <i>n</i> =1,224)	RFL	0.605**	0.594**
		RFB	0.326**	0.333**
	50–59	RHL	0.308**	0.268**
	Men ( <i>n</i> =1,170)	RHB	0.294**	0.229**
	Women ( <i>n</i> =1,196)	RFL	0.591**	0.548**
		RFB	0.319**	0.279**
	60+	RHL	0.274**	0.246**
	Men ( <i>n</i> =1,180)	RHB	0.317**	0.286**
	Women ( <i>n</i> =1,158)	RFL	0.551**	0.563**
		RFB	0.309**	0.305**
Northern Han total	RHL	0.263**	0.208**	
Men ( <i>n</i> =5,842)	RHB	0.210**	0.144**	
Women ( <i>n</i> =5,892)	RFL	0.556**	0.540**	
	RFB	0.244**	0.234**	
Southern Han	19–29	RHL	0.303**	0.370**
	Men ( <i>n</i> =1,595)	RHB	0.283**	0.229**
	Women ( <i>n</i> =1,551)	RFL	0.663**	0.610**
		RFB	0.334**	0.278**
	30–39	RHL	0.362**	0.311**
	Men ( <i>n</i> =1,386)	RHB	0.293**	0.304**
	Women ( <i>n</i> =1,535)	RFL	0.627**	0.616**
		RFB	0.336**	0.330**
	40–49	RHL	0.466**	0.368**
	Men ( <i>n</i> =1,499)	RHB	0.247**	0.344**
	Women ( <i>n</i> =1,613)	RFL	0.638**	0.601**
		RFB	0.384**	0.290**
	50–59	RHL	0.381**	0.360**
	Men ( <i>n</i> =1,442)	RHB	0.400**	0.357**
	Women ( <i>n</i> =1,595)	RFL	0.621**	0.629**
		RFB	0.354**	0.330**
	60+	RHL	0.349**	0.310**
	Men ( <i>n</i> =1,457)	RHB	0.388**	0.384**
	Women ( <i>n</i> =1,520)	RFL	0.602**	0.620**
		RFB	0.345**	0.372**
Southern Han total	RHL	0.341**	0.291**	
Men ( <i>n</i> =7,379)	RHB	0.249**	0.192**	
Women ( <i>n</i> =7,814)	RFL	0.621**	0.575**	
	RFB	0.271**	0.245**	
Han Chinese	Han Chinese total	RHL	0.310**	0.256**
	Men ( <i>n</i> =13,221)	RHB	0.240**	0.175**
	Women ( <i>n</i> =13,706)	RFL	0.602**	0.565**
		RFB	0.268**	0.242**

a) *r*, correlation coefficient. \*\*, Significant at  $\leq 0.01$ .

**Table 3** Linear regression equations for stature estimation (cm) from right hand/foot dimensions<sup>a)</sup>

Ethnic groups	Age groups (Years)	Men			Women		
		Equation	R <sup>2</sup>	SEE	Equation	R <sup>2</sup>	SEE
Northern Han	19–29	$S=153.657+0.968RHL$	0.100	±5.726	$S=147.022+0.688RHL$	0.042	±5.345
		Men ( $n=1,131$ )	$S=150.147+2.609RHB$	0.060	±5.851	$S=145.445+1.838RHB$	0.033
	Women ( $n=1,121$ )	$S=103.689+2.758RFL$	0.334	±4.925	$S=98.195+2.703RFL$	0.338	±4.443
		$S=143.679+2.935RFB$	0.118	±5.670	$S=141.897+1.975RFB$	0.055	±5.310
	30–39	$S=152.120+0.890RHL$	0.081	±5.433	$S=145.136+0.712RHL$	0.050	±5.379
		Men ( $n=1,149$ )	$S=148.411+2.415RHB$	0.050	±5.524	$S=143.983+1.789RHB$	0.029
	Women ( $n=1,193$ )	$S=101.351+2.761RFL$	0.345	±4.587	$S=101.452+2.491RFL$	0.270	±4.715
		$S=150.253+1.901RFB$	0.060	±5.496	$S=136.454+2.388RFB$	0.071	±5.319
	40–49	$S=149.426+0.979RHL$	0.090	±5.682	$S=137.776+1.103RHL$	0.089	±5.520
		Men ( $n=1,212$ )	$S=141.453+3.112RHB$	0.083	±5.705	$S=135.836+2.787RHB$	0.062
	Women ( $n=1,224$ )	$S=96.222+2.911RFL$	0.367	±4.741	$S=90.904+2.926RFL$	0.353	±4.650
		$S=139.970+2.848RFB$	0.106	±5.633	$S=129.851+3.065RFB$	0.111	±5.452
	50–59	$S=145.536+1.123RHL$	0.095	±6.135	$S=139.568+0.911RHL$	0.072	±5.310
		Men ( $n=1,170$ )	$S=139.508+3.223RHB$	0.087	±6.162	$S=137.368+2.381RHB$	0.052
	Women ( $n=1,196$ )	$S=94.392+2.948RFL$	0.349	±5.201	$S=99.961+2.464RFL$	0.301	±4.609
		$S=137.896+2.942RFB$	0.102	±6.111	$S=134.264+2.393RFB$	0.078	±5.292
	60+	$S=148.696+0.894RHL$	0.075	±5.684	$S=137.388+0.899RHL$	0.061	±5.266
		Men ( $n=1,180$ )	$S=138.402+3.239RHB$	0.101	±5.605	$S=128.860+3.196RHB$	0.082
	Women ( $n=1,158$ )	$S=99.632+2.695RFL$	0.303	±4.933	$S=91.659+2.752RFL$	0.317	±4.491
		$S=138.595+2.766RFB$	0.096	±5.620	$S=131.739+2.430RFB$	0.093	±5.175
Northern Han total	$S=151.297+0.896RHL$	0.069	±6.035	$S=143.180+0.758RHL$	0.043	±5.738	
Men ( $n=5,842$ )	$S=148.537+2.325RHB$	0.044	±6.115	$S=144.388+1.584RHB$	0.021	±5.806	
Women ( $n=5,892$ )	$S=99.220+2.809RFL$	0.309	±5.198	$S=95.546+2.706RFL$	0.291	±4.939	
	$S=146.830+2.186RFB$	0.060	±6.065	$S=137.789+2.113RFB$	0.055	±5.704	
Southern Han	19–29	$S=147.299+1.233RHL$	0.092	±5.677	$S=132.785+1.464RHL$	0.137	±4.830
		Men ( $n=1,595$ )	$S=136.182+4.169RHB$	0.080	±5.715	$S=134.831+3.171RHB$	0.053
	Women ( $n=1,551$ )	$S=86.182+3.439RFL$	0.439	±4.462	$S=88.965+3.098RFL$	0.372	±4.120
		$S=138.041+3.389RFB$	0.111	±5.616	$S=134.683+2.686RFB$	0.077	±4.994
	30–39	$S=140.735+1.436RHL$	0.131	±5.707	$S=135.418+1.202RHL$	0.097	±4.912
		Men ( $n=1,386$ )	$S=132.311+4.191RHB$	0.086	±5.855	$S=125.628+4.093RHB$	0.092
	Women ( $n=1,535$ )	$S=86.462+3.335RFL$	0.394	±4.769	$S=90.586+2.941RFL$	0.379	±4.073
		$S=135.811+3.274RFB$	0.113	±5.768	$S=129.747+2.997RFB$	0.109	±4.880
	40–49	$S=133.855+1.740RHL$	0.218	±5.541	$S=130.447+1.452RHL$	0.136	±4.997
		Men ( $n=1,499$ )	$S=137.005+3.411RHB$	0.061	±6.069	$S=120.344+4.671RHB$	0.119
	Women ( $n=1,613$ )	$S=86.570+3.271RFL$	0.407	±4.822	$S=89.937+2.934RFL$	0.362	±4.294
		$S=129.504+3.748RFB$	0.148	±5.783	$S=131.502+2.704RFB$	0.084	±5.143
	50–59	$S=134.437+1.632RHL$	0.145	±5.804	$S=128.132+1.491RHL$	0.130	±5.074
		Men ( $n=1,442$ )	$S=116.142+5.835RHB$	0.160	±5.754	$S=116.809+4.906RHB$	0.128
	Women ( $n=1,595$ )	$S=87.588+3.186RFL$	0.386	±4.920	$S=85.324+3.071RFL$	0.396	±4.227
		$S=131.340+3.440RFB$	0.125	±5.872	$S=146.830+2.186RFB$	0.109	±5.135
	60+	$S=135.000+1.498RHL$	0.122	±5.790	$S=128.641+1.315RHL$	0.096	±5.546
		Men ( $n=1,457$ )	$S=116.721+5.587RHB$	0.151	±5.693	$S=107.418+5.871RHB$	0.147
	Women ( $n=1,520$ )	$S=87.784+3.119RFL$	0.362	±4.934	$S=78.148+3.309RFL$	0.384	±4.578
		$S=131.838+3.174RFB$	0.119	±5.800	$S=120.112+3.561RFB$	0.139	±5.414
Southern Han total	$S=138.587+1.494RHL$	0.116	±6.265	$S=133.321+1.254RHL$	0.085	±5.545	
Men ( $n=7,379$ )	$S=134.643+3.792RHB$	0.062	±6.456	$S=134.674+2.702RHB$	0.037	±5.687	
Women ( $n=7,814$ )	$S=82.335+3.464RFL$	0.386	±5.222	$S=86.651+3.068RFL$	0.330	±4.743	
	$S=138.921+2.818RFB$	0.073	±6.416	$S=146.830+2.186RFB$	0.060	±5.619	
Han Chinese	Han Chinese total	$S=144.333+1.220RHL$	0.096	±6.252	$S=133.712+2.409RHL$	0.066	±5.683
	Men ( $n=13,221$ )	$S=140.718+3.147RHB$	0.057	±6.385	$S=139.013+2.196RHB$	0.031	±5.788
	Women ( $n=13,706$ )	$S=88.522+3.225RFL$	0.363	±5.251	$S=89.811+2.941RFL$	0.320	±4.850
		$S=141.529+2.630RFB$	0.072	±6.337	$S=135.253+2.305RFB$	0.059	±5.705

a) S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; R<sup>2</sup>, coefficient of determination; SEE, standard error of estimate.

**Table 4** Stepwise regression models and multiple regression models for stature estimation (cm) from right hand/foot measurements in men<sup>a)</sup>

Ethnic groups	Age groups (Years)	Men		
		Equation	R <sup>2</sup>	SEE
Northern Han	19–29	$S=103.689+2.758RFL$	0.334	±4.925
	Men (n=1,131)	$S=98.987+2.538RFL+0.554RHL$	0.365	±4.812
	Women (n=1,121)	$S=135.732+0.911RHL+2.341RHB$	0.149	±5.572
		$S=102.477+2.609RFL-0.516RFB$	0.337	±4.917
		$S=94.764+2.363RFL+0.262RFB+0.550RHL+0.756RHB$	0.371	±4.792
	30–39	$S=101.351+2.761RFL$	0.345	±4.587
	Men (n=1,149)	$S=96.084+2.592RFL+0.513RHL$	0.371	±4.498
	Women (n=1,193)	$S=137.402+0.800RHL+1.982RHB$	0.114	±5.337
		$S=102.346+2.880RFL-0.410RFB$	0.347	±4.582
		$S=94.174+2.655RFL-0.449RFB+0.487RHL+0.622RHB$	0.375	±4.487
	40–49	$S=96.222+2.911RFL$	0.367	±4.741
	Men (n=1,212)	$S=90.475+2.724RFL+0.563RHL$	0.395	±4.636
	Women (n=1,224)	$S=128.804+0.867RHL+2.721RHB$	0.152	±5.487
		$S=95.938+2.880RFL-0.109RFB$	0.367	±4.743
		$S=88.149+2.618RFL+0.045RFB+0.555RHL+0.558RHB$	0.397	±4.630
	50–59	$S=94.392+2.948RFL$	0.349	±5.201
	Men (n=1,170)	$S=90.116+2.734RFL+0.516RHL$	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
		$S=87.181+2.620RFL-0.033RFB+0.489RHL+0.787RHB$	0.372	±5.112
	60+	$S=99.632+2.695RFL$	0.303	±4.933
	Men (n=1,180)	$S=95.914+2.516RFL+0.438RHL$	0.320	±4.876
	Women (n=1,158)	$S=127.416+0.756RHL+2.885RHB$	0.153	±5.441
		$S=97.740+2.548RFL+0.569RFB$	0.306	±4.924
	$S=91.317+2.244RFL-0.322RFB+0.422RHL+1.020RHB$	0.331	±4.841	
Northern Han total	$S=99.220+2.809RFL$	0.309	±5.198	
Men (n=5,842)	$S=94.988+2.643RFL+0.453RHL$	0.326	±5.136	
Women (n=5,892)	$S=136.892+0.809RHL+1.942RHB$	0.099	±5.937	
	$S=100.146+2.899RFL-0.327RFB$	0.310	±5.194	
	$S=94.650+2.709RFL-0.422RFB+0.447RHL+0.349RHB$	0.328	±5.129	
Southern Han	19–29	$S=86.182+3.439RFL$	0.439	±4.462
	Men (n=1,595)	$S=83.585+3.286RFL+0.350RHL$	0.446	±4.437
	Women (n=1,551)	$S=123.070+1.051RHL+3.437RHB$	0.144	±5.513
		$S=85.321+3.377RFL+0.252RFB$	0.440	±4.462
		$S=79.492+3.182RFL+0.068RFB+0.332RHL+0.787RHB$	0.448	±4.429
	30–39	$S=86.462+3.335RFL$	0.394	±4.769
	Men (n=1,386)	$S=82.187+3.033RFL+0.642RHL$	0.417	±4.679
	Women (n=1,535)	$S=118.045+1.241RHL+3.208RHB$	0.179	±5.550
		$S=85.744+3.265RFL+0.258RFB$	0.394	±4.768
		$S=79.403+2.949RFL+0.017RFB+0.626RHL+0.604RHB$	0.418	±4.676
	40–49	$S=86.570+3.271RFL$	0.407	±4.822
	Men (n=1,499)	$S=82.121+2.756RFL+0.937RHL$	0.460	±4.603
	Women (n=1,613)	$S=109.470+1.694RHL+3.063RHB$	0.267	±5.365
		$S=85.340+3.133RFL+0.478RFB$	0.409	±4.817
		$S=78.441+2.600RFL+0.245RFB+0.951RHL+0.588RHB$	0.463	±4.595
	50–59	$S=87.588+3.186RFL$	0.386	±4.920
	Men (n=1,442)	$S=83.218+2.864RFL+0.666RHL$	0.406	±4.839
	Women (n=1,595)	$S=102.426+1.269RHL+4.695RHB$	0.242	±5.469
		$S=85.810+3.039RFL+0.557RFB$	0.388	±4.911
		$S=74.883+2.536RFL+0.214RFB+0.618RHL+1.829RHB$	0.420	±4.786
	60+	$S=87.784+3.119RFL$	0.362	±4.934
	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
	$S=75.683+2.574RFL+0.023RFB+0.443RHL+2.080RHB$	0.392	±4.823	
Southern Han total	$S=82.335+3.464RFL$	0.386	±5.222	
Men (n=7,379)	$S=78.835+3.202RFL+0.542RHL$	0.399	±5.166	
Women (n=7,814)	$S=117.913+1.333RHL+2.895RHB$	0.151	±6.141	
	$S=83.648+3.570RFL+0.409RFB$	0.387	±5.217	
	$S=78.337+3.286RFL-0.567RFB+0.539RHL+0.480RHB$	0.401	±5.158	
Han Chinese	Han Chinese total	$S=88.522+3.225RFL$	0.363	±5.251
	Men (n=13,221)	$S=84.618+3.000RFL+0.514RHL$	0.378	±5.188
	Women (n=13,706)	$S=126.137+1.089RHL+2.513RHB$	0.132	±6.128
		$S=89.630+3.323RFL-0.368RFB$	0.364	±5.247
	$S=84.128+3.073RFL-0.500RFB+0.508RHL+0.439RHB$	0.380	±5.179	

a) S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; R<sup>2</sup>, coefficient of determination; SEE, standard error of estimate.

**Table 5** Stepwise regression models and multiple regression models for stature estimation (cm) from right hand/foot measurements in women<sup>a)</sup>

Ethnic groups	Age groups (Years)	Women		
		Equation	R <sup>2</sup>	SEE
Northern Han	19–29	$S=98.195+2.703RFL$	0.338	±4.443
	Men (n=1,131)	$S=93.009+2.620RFL+0.416RHL$	0.353	±4.394
	Women (n=1,121)	$S=137.010+0.612RHL+1.570RHB$	0.066	±5.281
		$S=99.390+2.818RFL-0.445RFB$	0.340	±4.438
		$S=94.512+2.736RFL-0.367RFB+0.416RHL-0.136RHB$	0.355	±4.391
	30–39	$S=101.452+2.491RFL$	0.270	±4.715
	Men (n=1,149)	$S=96.121+2.380RFL+0.459RHL$	0.291	±4.651
	Women (n=1,193)	$S=133.799+0.674RHL+1.613RHB$	0.073	±5.315
		$S=100.723+2.430RFL+0.240RFB$	0.271	±4.715
		$S=94.512+2.736RFL-0.367RFB+0.416RHL-0.136RHB$	0.291	±4.652
	40–49	$S=90.904+2.926RFL$	0.353	±4.650
	Men (n=1,212)	$S=85.647+2.730RFL+0.564RHL$	0.375	±4.574
	Women (n=1,224)	$S=121.777+0.996RHL+2.381RHB$	0.133	±5.385
		$S=90.241+2.850RFL+0.271RFB$	0.354	±4.650
		$S=85.445+2.677RFL+0.286RFB+0.564RHL-0.150RHB$	0.376	±4.575
	50–59	$S=99.961+2.464RFL$	0.301	±4.609
	Men (n=1,170)	$S=96.018+2.308RFL+0.433RHL$	0.316	±4.561
	Women (n=1,196)	$S=124.532+0.848RHL+2.146RHB$	0.114	±5.190
		$S=99.463+2.423RFL+0.161RFB$	0.301	±4.610
		$S=94.683+2.239RFL+0.100RFB+0.434RHL+0.262RHB$	0.316	±4.563
	60+	$S=91.659+2.752RFL$	0.317	±4.491
	Men (n=1,180)	$S=86.751+2.613RFL+0.462RHL$	0.332	±4.443
	Women (n=1,158)	$S=117.412+0.786RHL+2.910RHB$	0.127	±5.078
		$S=90.895+2.648RFL+0.353RFB$	0.318	±4.488
	$S=84.675+2.440RFL+0.317RFB+0.463RHL+0.418RHB$	0.335	±4.437	
Northern Han total	$S=95.546+2.706RFL$	0.291	±4.939	
Men (n=5,842)	$S=91.721+2.602RFL+0.360RHL$	0.301	±4.907	
Women (n=5,892)	$S=134.349+0.703RHL+1.314RHB$	0.057	±5.697	
	$S=96.368+2.788RFL-0.306RFB$	0.292	±4.936	
	$S=94.474+2.744RFL-0.122RFB+0.372RHL-0.685RHB$	0.305	±4.894	
Southern Han	19–29	$S=88.965+3.098RFL$	0.372	±4.120
	Men (n=1,595)	$S=84.968+2.785RFL+0.651RHL$	0.396	±4.044
	Women (n=1,551)	$S=120.332+1.324RHL+2.088RHB$	0.158	±4.771
		$S=88.968+3.099RFL-0.001RFB$	0.372	±4.121
		$S=84.369+2.767RFL-0.020RFB+0.647RHL+0.128RHB$	0.396	±4.046
	30–39	$S=90.586+2.941RFL$	0.379	±4.073
	Men (n=1,386)	$S=87.933+2.768RFL+0.385RHL$	0.388	±4.046
	Women (n=1,535)	$S=116.464+0.947RHL+3.164RHB$	0.147	±4.774
		$S=89.953+2.881RFL-0.227RFB$	0.379	±4.073
		$S=85.809+2.672RFL+0.132RFB+0.366RHL+0.466RHB$	0.389	±4.044
	40–49	$S=89.937+2.934RFL$	0.362	±4.294
	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	±4.808
		$S=89.204+2.884RFL+0.21RFB$	0.362	±4.294
		$S=79.143+2.483RFL-0.181RFB+0.554RHL+1.739RHB$	0.396	±4.179
	50–59	$S=85.324+3.071RFL$	0.396	±4.227
	Men (n=1,442)	$S=82.039+2.823RFL+0.516RHL$	0.409	±4.182
	Women (n=1,595)	$S=106.765+1.128RHL+3.683RHB$	0.194	±4.885
		$S=83.990+2.969RFL+0.412RFB$	0.398	±4.223
		$S=76.872+2.641RFL+0.131RFB+0.445RHL+1.241RHB$	0.416	±4.159
	60+	$S=78.148+3.309RFL$	0.384	±4.578
	Men (n=1,457)	$S=76.152+3.147RFL+0.327RHL$	0.389	±4.561
	Women (n=1,520)	$S=99.660+0.893RHL+4.864RHB$	0.187	±5.260
		$S=75.470+3.057RFL+0.947RFB$	0.392	±4.552
	$S=67.460+2.751RFL+0.639RFB+0.238RHL+1.799RHB$	0.407	±4.498	
Southern Han total	$S=86.651+3.068RFL$	0.330	±4.743	
Men (n=7,379)	$S=84.412+2.900RFL+0.351RHL$	0.336	±4.723	
Women (n=7,814)	$S=123.789+1.105RHL+1.636RHB$	0.097	±5.507	
	$S=87.598+3.148RFL-0.315RFB$	0.331	±4.740	
	$S=87.130+3.014RFL-0.181RFB+0.383RHL-0.573RHB$	0.338	±4.716	
Han Chinese	Han Chinese total	$S=89.811+2.941RFL$	0.320	±4.850
	Men (n=13,221)	$S=86.733+2.794RFL+0.373RHL$	0.328	±4.822
	Women (n=13,706)	$S=127.792+0.919RHL+1.597RHB$	0.081	±5.636
		$S=90.782+3.028RFL-0.335RFB$	0.321	±4.846
	$S=89.455+2.928RFL-0.183RFB+0.394RHL-0.603RHB$	0.330	±4.812	

a) S, stature; RHL, right hand length; RHB, right hand breadth; RFL, right foot length; RFB, right foot breadth; R<sup>2</sup>, 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

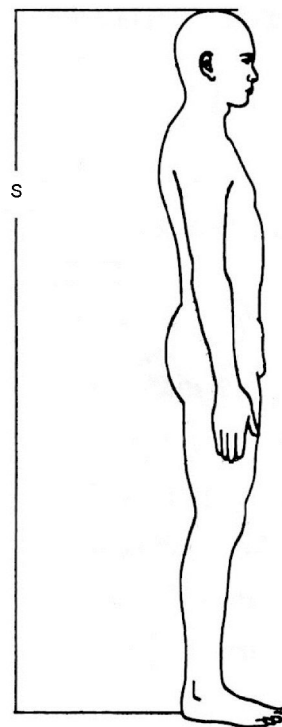
### Materials

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:  $45.1 \pm 16.3$  years, mean age of women:  $45.0 \pm 15.6$  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 ( $R > 0.9$ ;  $r_{TEM} < 5\%$ ) (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.*

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