Abstract

Purpose: The aim of this study was to develop predictive equations to estimate stature from knee height in elderly female in Nagoya. Design: Cross sectional study, convenient sample. Methods: Height, weight, and knee height were measured (knee height was taken from the top of the patella with the knee flexed at 90°). The predictive equations were fixed according to a stepwise linear regression analysis. Results: Knee height was highly correlated with stature. A linear regression analysis revealed the equation (Predicted stature(cm)=69.8+2.0×knee height(cm)-0.13×Age. $R^2=0.669$)

Conclusion: Knee height is useful for estimating stature when height measurement is not possible.

Key words: height, knee height, elderly, linear regression analysis

Introduction

Height and weight are important anthropometric measurements for the assessment of health conditions in people. Ideal body weight is based on height. Body mass index (BMI), which is calculated from height and weight (expressed in kg/m²), is used to judge the level of obesity. Energy expenditure is measured from basal energy expenditure (BEE), which is estimated from the Harris-Benedict’s equation (for male; $BEE=664.7+(13.75\times weight)+(5.0\times height)+(6.76\times age)$). Creatinine height index, which shows protein nutrition, also requires a measurement of height. However, the measurement of height in the elderly who are confined to bed or in wheelchairs or who have spinal deformities can be difficult. Miyazawa 1) reported that there were 76 % of admitted patients who could not have their height and weight measured. In order to avoid these difficulties, alternative methods of estimating height from other anthropometric measurements have been developed. Generally, the knee height method is most common now. At present, the formula devised by Miyazawa 1) and Chumlea 2) are often used in Japan. However, whereas Miyazawa’s formula was developed from the data of people aged from 21 to 97 from various locations of Japan and Chumlea’s formula was developed from the data of people in the US. The ratio of knee height to height changes in time, and varies across age, races and regions In this paper, we attempt to create a height estimated formula to concentrating on the elderly living in Aichi Prefecture. We also try to assess the formula.

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Methods

1, Participants
All participants were female and were over 60 years old. They were healthy people who lived in the residential area in Nagoya city and participated in this study with informed consent.

2, Measurements
The participants were requested to stand straight, with heels together, and stature was measured with a stature meter with a handle moving (Yagami Co.). Weight was measured on scales (weight meter). Knee height was measured with a knee height caliper (Ross Co.). Knee height is the distance from the sole of the foot to the anterior surface of the thigh with ankle and knee each flexed to a 90 degree angle.

3, Statistics
Linear regression analysis was used to derive equations on knee height (independent variable) to predict height (dependent variable), using SPSS (Version 15.0J for Window).

Results

1, Participants’ characteristics
There were 133 female participants. The average year was 71.5, and the number of people was 55 in the age group of 60-69 years, 65 in the age group of 70-79 years, and 18 in the age group of 80 years old and over.

The mean height and its standard deviation (ST) was 150.6±5.4. The mean weight and its ST was 52.1±8.0. The mean knee height was 44.2±2.2 as shown in Table 1.

2, Actual height, knee height and weight
The scatter diagram for actual height and knee height was shown in Fig. 1. People who were taller in stature had a higher knee height. The Pearson’s correlation coefficient was 0.85 (p<0.01). The scatter diagram for actual height and age was shown in Fig. 2. The Pearson’s correlation coefficient was -0.23 (p<0.01). The scatter diagram for actual height and weight was shown in Fig. 3. The Pearson’s correlation coefficient was 0.53 (p<0.01).

3, Habit of exercise
The average height of participants who had a habit of exercise was 151.2±5.2. The average height of participants who did not have a habit of exercise was 148.8±5.7.

4, A model for the prediction of stature
An estimation equation for stature was developed according to a multiple regression analysis. $y_i = a_i + b_1x_1 + b_2x_2 + b_3x_3$. In this equation, $y_i$ represented stature (dependent) and $x_i$ represented independent factors, $x_1$: knee height, $x_2$: age, $x_3$: weight, and $a_i$ was the intercept, and $b_1$, $b_2$, $b_3$ represented the regression coefficients (slops) of knee height, age and weight. $R^2$ is called the coefficient of determination which is interpreted as the proportion of the total variation in height accounted for by factors (factors “explains” $R^2$ of the variability of stature). A model for the prediction of stature using parameters knee height, age and weight was shown as follow:

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Actual height and predicted height</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Actual stature (cm)</td>
<td>150.6</td>
</tr>
<tr>
<td>Predicted stature $^1$ (cm)</td>
<td>150.9</td>
</tr>
<tr>
<td>Difference</td>
<td>-0.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>52.1</td>
</tr>
<tr>
<td>Knee height (cm)</td>
<td>44.2</td>
</tr>
</tbody>
</table>

$^1$) Stature was predicted from knee height and age
1) Predicted stature from knee height

\[
\text{Predicted stature (cm)} = 59.1 + 2.1 \times \text{knee height (cm)}
\]

\[R^2 = 0.648\]

2) Predicted stature from knee height and age

\[
\text{Predicted stature (cm)} = 69.8 + 2.0 \times \text{knee height (cm)} - 0.13 \times \text{Age}
\]

\[R^2 = 0.669\]

The inclusion of age into the equation above 1) improved the value of \(R^2\).

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**Fig. 1** Scatter diagram for actual height and knee height. \(n=133\)

The Pearson’s correlation coefficient = 0.85, p<0.001

**Fig. 2** Scatter diagram for actual height and age. \(n=133\)

The Pearson’s correlation coefficient = -0.23, p<0.01
3) Predicted stature from knee height, age, and weight

Predicted stature(cm)
= 59.1 + 2.1×knee height(cm) - 0.13×Age
+ 0.08×weight(kg) 

The addition of weight to the regression above 2) reduced only 0.01 of R².

For the weight group, and the group with a habit of physical exercise, a model for the prediction of stature using the parameters of knee height, age and weight was shown as follows:

4) Predicted stature from knee height and age according to the weight group (less than 50 kg, and 50 kg and over)

(1) Less than 50 kg,

Predicted stature(cm)
= 82.3 + 1.9×knee height(cm) - 0.26×Age

R² = 0.59

(2) 50 kg and over

Predicted stature(cm)
= 63.0 + 2.0×knee height(cm) - 0.04×Age

R² = 0.68

5) Predicted stature from knee height, age, and weight according to the group of physical exercise habit

(1) Habit of physical exercise

Predicted stature(cm)
= 68.3 + 1.8×knee height(cm) - 0.06×Age
+ 0.11×weight(kg) 

R² = 0.70

(2) No habit of physical exercise

Predicted stature(cm)
= 83.7 + 1.9×knee height(cm) - 0.26×Age
+ 0.02×weight(kg) 

R² = 0.70

6) Predicted stature from knee height and age according to weight and habit of physical exercise.
Estimating Stature from Knee Height for Elderly females aged 60–80 years old in Aichi Prefecture, Japan

(1) Less than 50 kg and habit of physical exercise
Predicted stature(cm)
= 79.1 + 1.9 × knee height(cm) - 0.17 × Age
R² = 0.64

(2) Less than 50 kg and no habit of physical exercise
Predicted stature(cm)
= 95.8 + 2.0 × knee height(cm) - 0.50 × Age
R² = 0.54

(3) 50 kg and over, and habit of physical exercise
Predicted stature(cm)
= 63.0 + 2.0 × knee height(cm) - 0.02 × Age
R² = 0.66

(4) 50 kg and over, and No habit of physical exercise
Predicted stature(cm)
= 68.8 + 2.0 × knee height(cm) - 1.5 × Age
R² = 0.81

The R² value in the regressions of stature on knee height and age was the highest in the group 50 kg and over, and habit of physical exercise. However, The value of R² did not improved in the other group.

5. Actual stature and predicted stature

Difference between actual stature and calculated stature was very small (less than 2 cm) as shown in Table 1. The scatter diagram for actual height and predicted height was shown in Fig 4. The Pearson’s correlation coefficient was 0.84 (p<0.001).

Discussion

The estimation of stature from the measurement of the long bones (humerus, tibia, knee height) was
carried out in practicing. Within these long bone measurements, the estimation from knee height is higher correlated to the stature than other long bone measurements. There are many equations for estimating stature from knee height, which have been reported by Chumlea 2), Lera 3), Chumlea 4), Han 5), Chumlea 6), Palloni 7), Donini 8), Zhang 9), Myers 10), Shahar 11), Cockram 12), Knous 13) in various countries (Appendix 1). In Japan, the equations by Miyazawa and also by Chumlea are popular when estimating a person’s height from knee height.

To evaluate the relationship between stature and knee height or other factors, all authors who mentioned above used the simple or multiple linear regression models 1-12). In both models, the slopes for knee height were approximately 1.8 and the slopes for age ranged from -0.07 to -0.26. A negative association between height and age was observed in all authors. Concerning the decline of height, there is one report 14) in which the decline of height with age was seen amongst individuals 45 years and over, and the mean decline of height per year became larger according to age. In addition, another report by Chumlea 15) showed that the mean annual rate of decline was approximately the same (-0.5 cm/year) regardless of an individual’s age. Changes in body posture or thinning of vertebrae disc can contribute to a reduction in height in elderly females. In the model for simple linear regression, in which $y_1$ is height and $b_1$ is knee height, $R^2$ ranged from 0.56 to 0.71. The addition of age to the regression (multiple linear regression) did improve the value of $R^2$, which ranged around 0.60-0.80.

There is a report that estimation from arm length was less correlated to the stature than from knee height. We did not assess the estimation of the height from arm length. Arm length is easy to measure in the ambulatory patients, and changes little with age. Arm length may be used as a substitute for measurement of stature. However, at present, the measurement of knee height provides a simple, quick, and accurate means estimating stature for the elderly, whose height cannot be measured.

We propose that the estimation of the height for females, as “Predicted stature=69.8+2.0×knee height-0.13×Age”.

Reference


Appendix 1. Various equations (linear multiple regression model) developed to predict stature using knee height and age

Author, reference number, date of publishing
Characteristics of participants, ethics, age
Number of participants, gender, equations

**Chumlea WC 2) 1985**
Participants: American, age range 65-104 years old
N=106  men  \( y=64.19+2.02\times KH-0.04\times\text{age} \ R^2=0.67 \)
N=130  women  \( y=84.88+1.83\times KH-0.24\times\text{age} \ R^2=0.65 \)

**Cockram DB 12) 1990**
Participants: ambulatory patients, age range 64-83 years old in OH, USA
N=15  mean age 71.8  men  \( y=47.65+2.51\times KH-0.14\times\text{age} \ R^2=0.85 \)
N=25  mean age 41.4  women  \( y=95.0+1.79\times KH-0.32\times\text{age} \ R^2=0.83 \)

**Chumlea WC 4) 1994**
Participants: American, the data from National Health Examination Survey (1960-1970), age range 18-60 years old
N=2537  mean age 38.6  white women  \( y=70.25+1.87\times KH-0.06\times\text{age} \ R^2=0.66 \)
N=402  mean age 41.4  black women  \( y=68.10+1.86\times KH-0.06\times\text{age} \ R^2=0.67 \)

**Myers SA 10) 1994**
Participants: Japanese-American in USA, mean age 72 years old (62-86)
N=16  men  \( y=53.69+2.57\times KH-0.23\times\text{age} \ R^2=0.70 \)
N=16  women  \( y=69.10+2.11\times KH-0.22\times\text{age} \ R^2=0.78 \)

**Han TS 5) 1996**
Participants: in England, age range 17-70 years old
N=78  mean age 43.9  men  \( y=54.9+2.30\times KH-0.06\times\text{age} \ R^2=0.79 \)
N=82  mean age 43.1  women  \( y=71.3+1.91\times KH-0.10\times\text{age} \ R^2=0.72 \)

**Chumlea WC 6) 1998**
Participants: non-hispanic black, white and Mexican-American in USA, age 60 years old and over
N=1,369  mean age 70.6  Non-hispanic white men  \( y=78.31+1.94\times KH-0.14\times\text{age} \ R^2=0.69 \)
N=1,472  mean age 69.9  Non-hispanic black men  \( y=79.69+1.85\times KH-0.14\times\text{age} \ R^2=0.70 \)
N=474  mean age 68.9  Mexican-American men  \( y=82.77+1.83\times KH-0.16\times\text{age} \ R^2=0.67 \)
N=481  mean age 71.8  Non-hispanic white women  \( y=82.21+1.85\times KH-0.21\times\text{age} \ R^2=0.67 \)
N=497  mean age 70.5  Non-hispanic black women  \( y=89.58+1.61\times KH-0.17\times\text{age} \ R^2=0.67 \)
N=457  mean age 68.3  Mexican-American women  \( y=84.25+1.82\times KH-0.26\times\text{age} \ R^2=0.67 \)

**Zhang H 9) 1998**
Participants: Chinese in Melbourne, Australia, age range 30-90 years old
N=130  mean age 53.8  men  \( y=71.70+1.98\times KH-0.04\times\text{age} \ R^2=0.69 \)
N=117  mean age 42.0  women  \( y=78.46+1.79\times KH-0.07\times\text{age} \ R^2=0.72 \)

**Donini LM 8) 2000**
Participants: Italian, age 61 years and over
N=113  mean age 72.8  men  \( y=99.67+1.58\times KH-0.23\times\text{age} \ R^2=0.75 \)
N=172  mean age 73.4  women  \( y=94.87+1.58\times KH-0.23\times\text{age} \ R^2=0.75 \)

**Knous BL 13) 2002**
Participants: Japanese in Joetsu city, Japan
Age range, 65-74 years old in men, 65-75 years old in women
N=40  mean age 68.0  men  \( y=71.16+2.61\times KH-0.56\times\text{age} \ R^2=0.84 \)
N=39  mean age 68.0  women  \( y=64.19+2.02\times KH-0.04\times\text{age} \ R^2=0.73 \)
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Palloni A 7) 2005
Participants: Hispanics in Latin American countries, age 60 years old and over
N=1363 Black men $y=117.99+1.10\times KH-0.12\times age$
N=2135 Black women $y=112.64+1.09\times KH-0.17\times age$
N=85 Mestizo men $y=73.17+1.89\times KH-0.08\times age$
N=160 Mestizo women $y=97.97+1.43\times KH-0.21\times age$
N=206 Mexican men $y=67.00+1.92\times KH-0.10\times age$
N=315 Mexican women $y=75.57+1.78\times KH-0.11\times age$
N=136 Mulatto men $y=123.44+1.02\times KH-0.15\times age$
N=256 Mulatto women $y=110.33+1.00\times KH-0.09\times age$

Miyazawa Y 1) 2005
Participants: Japanese in nursing home
Age range, 21-88 years old in men, 21-97 years old in women
N=245 men $y=64.02+2.12\times KH-0.07\times age$
N=505 women $y=77.88+1.77\times KH-0.10\times age$

Lera L 3) 2005
Participants: people in San Paulo, Brazil, Santiago, Chile, Mexico city. Age: 60 years and over
San Paulo, Brazil
N=713 mean age 73.3 men $y=67.24+1.96\times KH-0.08\times age$ $R^2=0.69$
N=944 mean age 72.1 women $y=69.87+1.85\times KH-0.11\times age$ $R^2=0.58$
Santiago, Chile
N=389 mean age 70.6 men $y=64.88+2.09\times KH-0.10\times age$ $R^2=0.70$
N=615 mean age 71.3 women $y=75.17+1.78\times KH-0.10\times age$ $R^2=0.54$
Mexico city
N=388 mean age 69.5 men $y=63.88+1.99\times KH-0.06\times age$ $R^2=0.67$
N=607 mean age 70.0 women $y=73.09+1.87\times KH-0.19\times age$ $R^2=0.59$

In the equations, $y$ means predictive height in cm, $KH$ means knee height in cm, and $age$ means age in years, and $R^2$ means the multiple correlation coefficient of determination.
高齢者の栄養評価をする場合、身長や体重の値が必要になる。しかし、高齢者では寝たきり、脊椎の変形などにより身長の測定が出来ないことが多い。

目的：女性高齢者について、下肢長から身長を推定する式（重回帰式）を作る。

方法：名古屋市内に在住する健康な女性高齢者（60歳以上）133名について、身長、下肢長を測定して重回帰分析を行った。

結果：分析の結果、重回帰式 推定身長（cm） = 69.8 + 2.0×下肢長（cm）− 0.13×年齢（年）を得た。その寄与割合は $R^2 = 0.669$ であった。

結論：名古屋市在住の女性高齢者の身長を下肢長、年齢から推定できる。

キーワード：女性高齢者、身長、下肢長、重回帰式