《Original Article》

Estimating Stature from Knee Height for Elderly females aged 60-80 years old in Aichi Prefecture, Japan

Katsumi Yamanaka*, Shizuno Ishida*, Hisashi Susaki*, Chiaki Kojima*, Natsuyo Omine*, Yuuki Itoh*, Yoshihiro Hirata*, Kiwako Okada*, Aya Sumiya* and Mika Toba*

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/m^2), 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×weight)+(5.0×height)+(6.76×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.

* School of Nutritional Sciences, Nagoya University of Arts and Sciences, Nisshin, Aichi, Japan

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 statue 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_n 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 1 Actual height and predicted height

	Mean	S.D.	Mini.	Max.
Actual stature (cm)	150.6	5.4	139.5	171.0
Predicted stature [1] (cm)	150.9	4.5	141.1	162.5
Difference	-0.3		-1.6	
Weight (kg)	52.1	8.0	34.2	75.0
Knee height (cm)	44.2	2.2	39.8	50.5

1) Stature was predicted from knee height and age

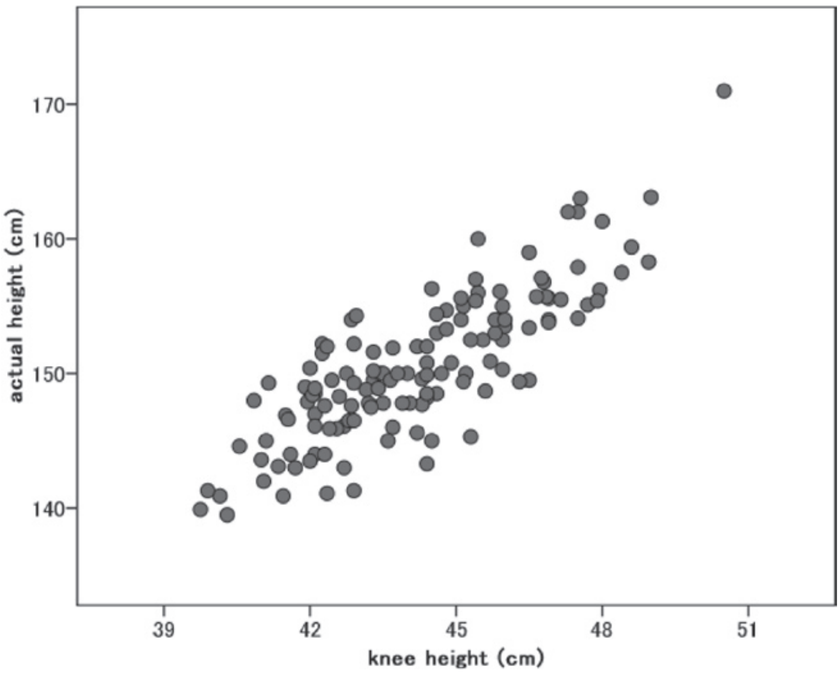

Fig. 1 Scatter diagram for actual height and knee height. n=133
The Pearson's correlation coefficient=0.85, p<0.001

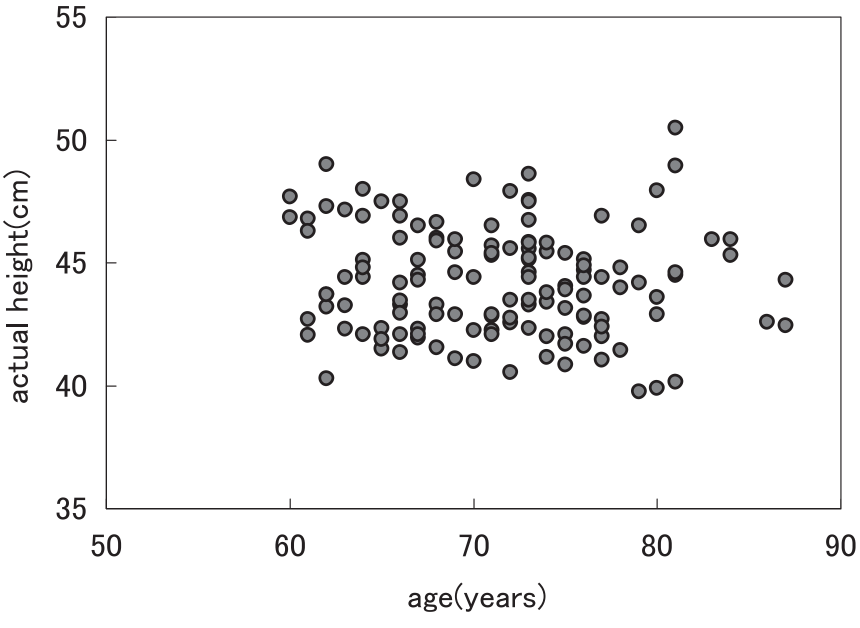

Fig. 2 Scatter diagram for actual hight and age. n=133
The Pearson's correlation coefficient=-0.23, p<0.01

1) Predicted stature from knee height

Predicted stature(cm)

=59.1+2.1×knee height(cm) R^2=0.648

2) Predicted stature from knee height and age

Predicted stature(cm)

=69.8+2.0×knee height(cm)-0.13×Age

R^2=0.669

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

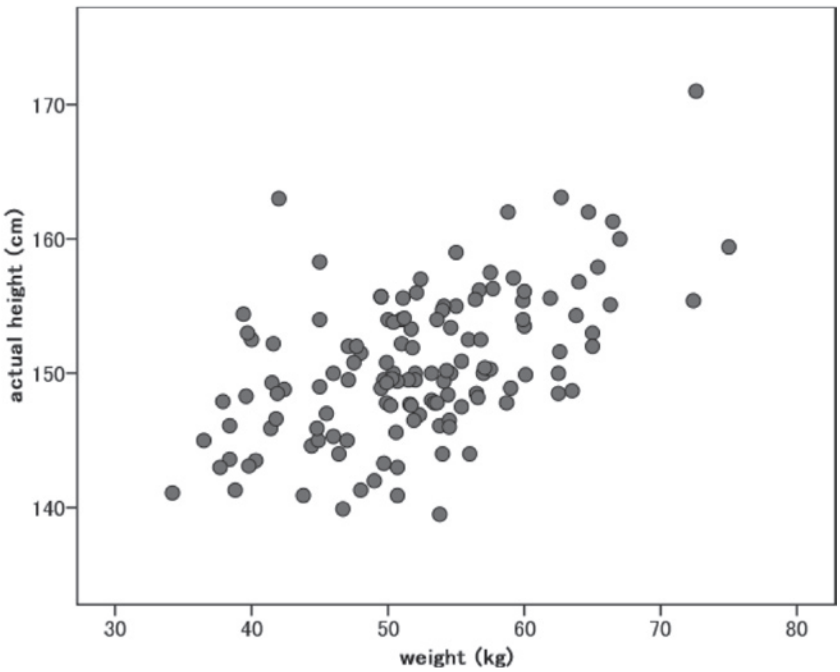

Fig. 3 Scatter diagram for actual height and weight
The Pearson's correlation coefficient=0.53, $p<0.01$

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) $R^2=0.68$

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

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
$R^2=0.59$

(2) 50 kg and over
Predicted stature(cm)
=63.0+2.0×knee height(cm)-0.04×Age
$R^2=0.68$

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) $R^2=0.70$

(2) No habit of physical exercise
Predicted stature(cm)
=83.7+1.9×knee height(cm)-0.26×Age
+0.02×weight(kg) $R^2=0.70$

6) Predicted stature from knee height and age according to weight and habit of physical exercise.

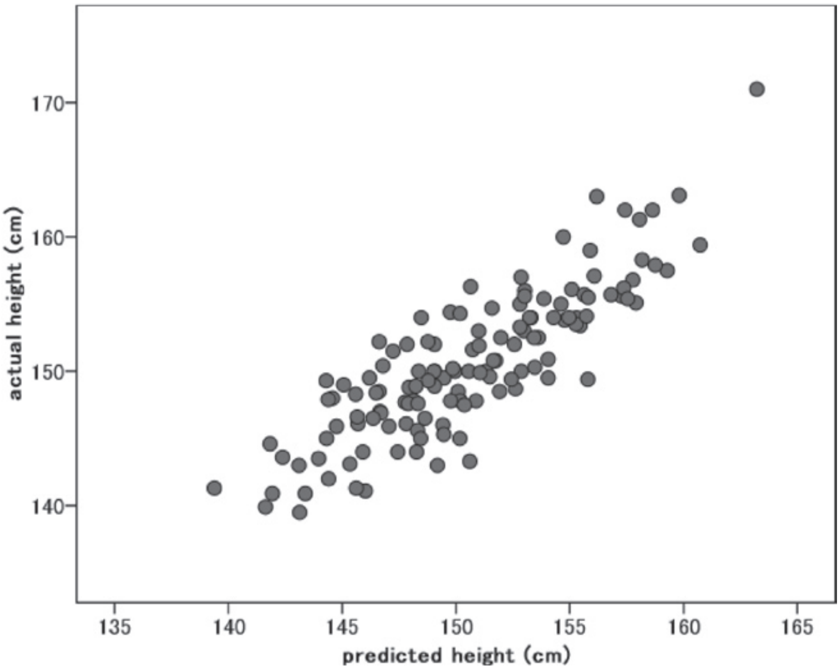

Fig. 4 Scatter diagram for actual height and predicted height
The Pearson's correlation coefficient=0.99, p<0.001
Predicted height was calculated from the equation
Predicted stature(cm)=69.8+2.0×knee height(cm)-0.13×Age.

(1) Less than 50 kg and habit of physical exercise

Predicted stature(cm)
=79.1+1.9×knee height(cm)-0.17×Age
R^2=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
R^2=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
R^2=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
R^2=0.81

The R^2 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 R^2 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".

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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 $y=64.19+2.02\times KH-0.04\times age$ $R^2=0.67$
N=130 women $y=84.88+1.83\times KH-0.24\times age$ $R^2=0.65$

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

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 $y=70.25+1.87\times KH-0.06\times age$ $R^2=0.66$
N=402 mean age 41.4 black women $y=68.10+1.86\times KH-0.06\times age$ $R^2=0.67$

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

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

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 $y=78.31+1.94\times KH-0.14\times age$ $R^2=0.69$
N=1,472 mean age 69.9 Non-hispanic black men $y=79.69+1.85\times KH-0.14\times age$ $R^2=0.70$
N=474 mean age 68.9 Mexican-American men $y=82.77+1.83\times KH-0.16\times age$ $R^2=0.67$
N=481 mean age 71.8 Non-hispanic white women $y=82.21+1.85\times KH-0.21\times age$ $R^2=0.67$
N=497 mean age 70.5 Non-hispanic black women $y=89.58 +1.61\times KH-0.17\times age$ $R^2=0.67$
N=457 mean age 68.3 Mexican-American women $y=84.25+1.82\times KH-0.26\times age$ $R^2=0.67$

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

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

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 $y=71.16+2.61\times KH-0.56\times age$ $R^2=0.84$
N=39 mean age 68.0 women $y=64.19+2.02\times KH-0.04\times age$ $R^2=0.73$

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×KH-0.12×age
N=2135	Black women	y=112.6+1.09×KH-0.17×age
N=85	Mestizo men	y=73.17+1.89×KH-0.08×age
N=160	Mestizo women	y=97.97+1.43×KH-0.21×age
N=206	Mexican men	y=67.00+1.92×KH-0.10×age
N=315	Mexican women	y=75.57+1.78×KH-0.11×age
N=136	Mulatto men	y=123.4+1.02×KH-0.15×age
N=256	Mulatto women	y=110.33+1.00×KH-0.09×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×KH-0.07×age
N=505	women	y=77.88+1.77×KH-0.10×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=67.2+1.96×KH-0.08×age	R^2=0.69
N=944	mean age 72.1	women	y=69.87+1.85×KH-0.11×age	R^2=0.58

Santiago, Chile

N=389	mean age 70.6	men	y=64.88+2.09×KH-0.10×age	R^2=0.70
N=615	mean age 71.3	women	y=75.17+1.78×KH-0.10×age	R^2=0.54

Mexico city

N=388	mean age 69.5	men	y=63.88+1.99×KH-0.06×age	R^2=0.67
N=607	mean age 70.0	women	y=73.09+1.87×KH-0.19×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.

和文抄録

高齢者女性の下肢長から身長推定式について

山中　克己*　石田　静乃*　須崎　　尚*　小島　千明*
大峰　夏世*　伊藤　勇貴*　平田　芳浩*　岡田希和子*
角谷　亜矢*　鳥羽　美香*

背景：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

＊名古屋学芸大学管理栄養学部