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Original article

Validity of predictive equations for resting metabolic rate in healthy older adults

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SUMMARY

Background & aims: Accurate estimation of energy expenditure in older people is important for nutritional support. The current literature contains controversial or inconsistent data regarding the resting metabolic rate (RMR, or basal metabolic rate) in older adults, including the relationship between the RMR and ethnicity. Little information about the RMR in healthy Asian older adults is available. This study was performed to examine the RMR in healthy Japanese older adults and compare it with previously established 16 equations.

Methods: Thirty-two community-dwelling, healthy, and active elderly Japanese adults were enrolled (age, 64–87 years; 14 men, 18 women; mean height, 154.9 ± 8.9 cm; mean weight, 53.5 ± 9.1 kg; mean body mass index, 22.2 ± 2.5 kg/m^2). The RMR was measured by indirect calorimetry. The measured RMR was compared among 16 equations. Correlation analysis, a paired t test, and a Bland–Altman plot were used to assess the agreement among the equations.

Results: The average RMR was 1132 ± 178 kcal/day with 2233 ± 437 kcal/day average total energy expenditure (TEE) measured by doubly labeled water (DLW). The smallest bias was established by De Lorenzo et al.'s equation as bias ±1.96SD = 4 ± 121 kcal/day. De Lorenzo et al. and Ikeda et al.'s equations had no significant average bias both in men and women ($P > 0.05$). The 1.96SD of bias in six equations was within 160 kcal/day. In contrast, residuals between the measured and predicted RMR were largely correlated with the RMR in four equations. A sex-related difference in the mean bias was observed in many equations.

Conclusion: Although the average Japanese healthy older adult has a shorter stature and lower weight than older adults in the Western population, the current data suggest that a similar predictive equation for the RMR can be applied to both Japanese and Western older adults. This study demonstrate that the De Lorenzo et al.'s or Ikeda's equation may be useful for estimating RMR in the community-dwelling, healthy, and active elderly Japanese adults without any systematic bias.

1. Introduction

Accurate assessment of energy requirements is necessary for effective nutritional support [1,2]. Malnutrition is an aspect of the frailty phenotype and may lead to sarcopenia, the need for long-term care, or mortality in the older population [3,4]. Measurement of the individual total energy expenditure (TEE) is a critical component of management in such patients [1,2,5–7], but measurement of the daily living TEE using the doubly labeled water

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method is complex and expensive. With few exceptions, the resting metabolic rate (RMR) is the largest single component of TEE [8] and can be accurately measured by indirect calorimetry. However, even measurement of the RMR requires special instruments and is time-consuming. Therefore, predictive equations based on demographic (age, sex, and ethnicity), anthropometric (weight and height), and/or body composition variables (fat-free mass, fat mass, and organ tissue mass) have been developed during the last century to allow quick estimation of the RMR [9–19].

Based on projections by the United Nations, the world population of older people has recently exceeded that of children aged <5 years, and more people are living longer and to more extreme ages than ever before [20]. Many Asian countries, including Japan, are undergoing rapid growth of the aged population. However, only a few studies have addressed the validity of predictive equations of the RMR in Japanese older adults.

On average, Japanese and other Asian older adults have a shorter stature, lower weight, and lower body mass index (BMI) than those of Western older adults [21–23]. Thus, the absolute RMR of Japanese older adults should be lower than that of the Western population [24]. However, most of the predictive equations of the RMR contain age, sex, height, and weight as predictive variables [9–19]. The hypothesis of the current study was that the RMR of Japanese older adults is not different from that of the Western population after adjustment for age, sex, height, and weight and that previously proposed predictive equations are applicable to both Japanese and Western older adults. The aim of the current study was to validate 16 equations previously established in various populations for Japanese healthy older adults.

2. Materials and methods

Thirty-two healthy older Japanese adults (64–87 years old) participating in an ongoing health study at Kyoto Prefectural University of Medicine were recruited for the study. The study cohort was the same as that in a previous study [23]. The participants were invited to attend an information meeting, and those interested in participating provided written informed consent. The inclusion criteria for the participants were no prescription medications that could interfere with the study and no personal history of alcohol abuse. The participants were evaluated by a physician to ensure they were in good health with no signs or symptoms of metabolic disease or endocrine disorders. The study protocol was approved by the Medical Ethics Committee at Kyoto Prefectural University of Medicine. Body mass was measured to the nearest 0.1 kg using an electronic scale. Stature was measured to the nearest 0.1 cm. Total body water was measured using the ^{2}H and ^{18}O dilution technique as previously described [23], and fat-free mass (FFM) was estimated as total body water/0.732 [25]. Physical activity (PA) was assessed by a previously validated and simplified PA record [26].

2.1. Measurement of RMR

The RMR was calculated by indirect calorimetry (AE-300S; Minato Medical Science Co., Ltd., Osaka, Japan) [27–30]. Measurements were performed for 30 min between 05:00 and 07:00 AM, after an overnight stay in the facility based on a previous suggestion [17]. Each participant was familiarized with the procedures and equipment used for the RMR analysis before the study commenced. The RMR was measured under standardized conditions, including the requirement to fast for at least 12 h and remain at rest after waking in the facility [31]. After waking up, each participant rested for at least 20 min before beginning the RMR measurement and familiarization with the equipment. A VO_2 variation of <25 mL/min was used to determine whether the measurement was acceptable [31]. Each participant was monitored periodically to ensure that they remained awake. Data collection took place in a thermally regulated environment with minimal light and noise. Calibration of the calorimeter system with 2-L syringe and a known concentration of standard gas was performed prior to each measurement. Total energy expenditure (TEE) measured by doubly labeled water (DLW) as described previously [24,32].

2.2. Predicted RMR

The predictive equations for the RMR in the current study were selected based on a study by Siervo et al. [19], who recently examined the accuracy of predictive equations of the RMR in white Caucasian older adults at the University of Milan (13 men, 55 women; mean age, 74.4 ± 9.3 years; mean height, 158.4 ± 10.3 cm; mean weight, 66.4 ± 15.7 kg; and mean BMI, 26.3 ± 5.0 kg/m^2). Their research was chosen because it included many major previously established equations for older adults. The equations were established by Harris and Benedict [9], Owen et al. [12], Mifflin et al. [13], Bernstein et al. [10], the World Health Organization (WHO) [33], Fredrix et al. [34], Livingston and Kohlstadt [35], Müller et al. [16], Lührmann et al. [15], Schofield [11], the European Union (EU) [36], Henry [37], Korth et al. [38], and De Lorenzo et al. [14]. We also included an equation developed by Ganpule et al. [39], which is based on 20- to 70-year-old Japanese adults; an equation developed by Ikeda et al. [40], which is based on 19- to 78-year-old Japanese adults with type I and II diabetes; and the most currently established equation by Kruizenga et al. [41], which was established following the research on obesity performed by Weijs and Vansant [18]. Table 1 shows the predictive equations.

2.3. Statistical analysis

Results are presented as mean ± standard deviation (SD). The difference between the measured and predicted RMR (ΔRMR) is expressed as an absolute value (kcal/day, mean bias) and percentage (%, relative bias) [19]. Relative bias (%) was calculated as follows: $(\Delta RMR_{mean\ bias})/RMR_{measured} \times 100$. A measurement was considered inaccurate when the relative bias was greater than ±10% of the measured RMR, and the number of subjects with an inaccurate prediction was calculated [18]. The associations between the ΔRMR and age, BMI, FFM, percent body fat (%fat), and PA level were evaluated to indicate whether these factors had a significant influence on the estimation bias [19]. A Bland–Altman plot analysis [42] was performed to examine the agreement between the measured and estimated RMR. The paired t test was used to examine the mean difference between the measured and estimated RMR. Pearson's correlation analysis was conducted to evaluate whether age, BMI, or FFM was significantly associated with the mean bias. We tried to detect the mean difference of 50 kcal/day between measured RMR and estimated RMR. When standard deviation of repeated measure of RMR is 95 kcal/day, α error probability was set as 0.05, and β error probability was set as 0.8, the needed sample size was calculated as 31. We, therefore, measured 32 subjects. The between-sex difference was also examined. All analyses were performed using SPSS 22.0 for Windows (IBM Corp., Armonk, NY), and results were considered significant at $P < 0.05$.

3. Results

The participants' mean age was 73.9 ± 6.2 years, height was 154.9 ± 8.9 cm, weight was 53.5 ± 9.1 kg, and BMI was 22.2 ± 2.5 kg/m^2. The mean measured RMR was 1132 ± 178 kcal/day (Table 2) with 2233 ± 437 kcal/day of TEE. The RMR was significantly higher in men than women (1267 ± 160 vs. 1026 ± 107 kcal/day,

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