A Practical Equation to Predict Resting Metabolic Rate in Older Men

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The accuracy of previous equations for predicting resting metabolic rate (RMR) in healthy older men is questionable because they are based on limited sample sizes and the absence of cross-validation procedures. The purposes of this study were to (1) examine biological predictors of RMR in healthy older men; (2) develop a practical equation to predict RMR from easily measured variables and examine its accuracy using cross-validation procedures; and (3) test the validity of existing equations in the literature to predict RMR in older men by comparison with measured RMR values. RMR, body composition, anthropometric measurements, leisure time activity (LTA), maximal aerobic power (VO2max), energy intake, and plasma thyroid hormone levels were determined in 89 healthy older men aged 50 to 78 years. Stepwise regression analysis showed that RMR was best predicted by fat-free weight ([FFW] \( R^2 = 85 \% \)), free 3,5,3'-triiodothyronine (T3) level (\( R^2 = 1 \% \)), and VO2max (\( R^2 = 1 \% \)); these variables predicted RMR with a residual error of \( \pm 30 \text{ kcal/d} \). A practical equation was developed in a randomly selected subsample (N = 61) using easily measured variables as potential predictors, and was successfully cross-validated in a random subsample of older men (N = 28). The pooled equation to predict RMR is as follows: RMR (in kilocalories per day) = 9.7 (weight in kilograms) - 6.1 (chest skinfold thickness in millimeters) - 1.8 (age in years) + 0.1 (leisure time activity [LTA] in kilocalories per day) + 1.060. These variables accounted for 76% \( (R^2) \) of the variation, and predicted RMR with a residual error of \( \pm 42 \text{ kcal/d} \). When four previously published equations were applied to predict RMR in our sample of older men, individual predicted values deviated -19% to +14% from measured values. We conclude that variations in FFW account for the greatest source of variation in RMR in older men. Current equations to predict RMR are generally imprecise on an individual basis when applied to older men. We offer a practical and successfully cross-validated equation to predict RMR in healthy older men based on measures of body weight, LTA, and chest skinfold thickness.

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DUE TO THE INADEQUACIES of measuring energy intake in older individuals,\(^{1,3} \) it has been proposed that energy needs are more accurately predicted by measuring energy expenditure in healthy individuals.\(^{2,3} \) Resting metabolic rate (RMR) has served as the basis on which estimates of total energy needs have been developed.\(^{4} \) RMR can be either determined directly by calorimetry or estimated from a prediction equation in clinical settings. The measured or predicted RMR value is then multiplied by an activity factor to estimate daily energy requirements.\(^{2} \)

Energy requirements decrease with advancing age due to a decrease in resting and daily energy expenditure\(^{6,7} \) as well as to a decline in physical activity\(^ {1} \) and deleterious changes in body composition.\(^{5,7,8} \) At present, the most frequently used regression equations to predict RMR in older individuals are extrapolated from those for younger individuals\(^ {9} \) and are based on small sample sizes.\(^ {10} \) Furthermore, existing equations have not been tested for accuracy using cross-validation procedures in an independent sample population.\(^{9,10,11} \) Thus the ability of existing equations to accurately predict RMR in older men remains doubtful.

Therefore, the purposes of this study were to (1) examine biological predictors of RMR in healthy older men; (2) develop an age-specific equation to predict RMR from easily measured variables and cross-validate it in an independent sample; and (3) compare our measured RMR values with previously used generalized and age-specific prediction equations.

SUBJECTS AND METHODS

Subjects

Eighty-nine healthy older men aged 50 to 78 years participated in this study. Subjects were excluded from participation for the following reasons: (1) clinical evidence of coronary heart disease (eg, ST segment depression > 1 mm at rest or exercise) or cardiomyopathy; (2) hypertension (blood pressure > 140/90 mm Hg); (3) medications that could affect cardiovascular function or metabolic rate; (4) medical history of diabetes or obesity; (5) instability of body weight during the preceding year (a change of > 2 kg); and (6) exercise-limiting noncardiac disease (arthritis, peripheral vascular disease, cerebral vascular disease, etc.). Procedures used in this study were approved by the Committee on Human Research for the Medical Sciences at the University of Vermont; written informed consent was obtained from each subject before investigation.

Timing of Measurements

All volunteers were admitted to the Clinical Research Center on the afternoon before their metabolic testing between 2:00 and 4:00 pm. Subjects were fed dinner and then given practice with the ventilated hood to reduce any concern or apprehension about testing conditions. The Minnesota Leisure Time Physical Activity (LTA) questionnaire\(^ {13} \) was administered, and instructions for measuring 3-day dietary intake were provided. After an overnight fast in which volunteers slept in the Clinical Research Center, the following evaluations were performed the next morning: RMR.
blood sampling for hormone assessment, underwater weighing for body composition determination, anthropometric measurements, and testing of maximal aerobic power (V\text{O}_\text{max}). All testing procedures were standardized for all subjects and performed by the same individual (E.T.P.). These methods and their reproducibility in our laboratory have been previously described in detail\textsuperscript{13-15} and thus will only be briefly described in this report.

**RMR**

RMR was established for each subject with indirect calorimetry for 45 minutes using a ventilated-hood technique. RMR was determined at least 48 hours after the last exercise bout, since this delay has been shown to eliminate residual effects of exercise on metabolic rate.\textsuperscript{16} Energy expenditure (kcal/min) was calculated from the Weir equation.\textsuperscript{17}

**Body Composition**

Body fat content was estimated from body density as measured by underwater weighing, with simultaneous measurement of residual lung volume by the helium dilution method using the formula of Keys and Brozek.\textsuperscript{18} Fat-free weight (FFW) was estimated as total body weight minus fat weight.

**Skinfolds**

Skinfold measurements were taken from the triceps, chest, abdomen, and thigh with a Lange skinfold caliper (Cambridge Scientific, Cambridge, MD). All skinfold measurements were taken on the right side of the body and were measured to the nearest 0.5 mm. Each skinfold value represents the mean of three consecutive measurements, and all skinfold measurements were taken by the same investigator according to recent recommendations.\textsuperscript{19}

**LTA and V\text{O}_\text{max}**

The level of physical activity within the past year was assessed in a structured interview using the Minnesota LTA Questionnaire.\textsuperscript{12} We have previously shown that this questionnaire is correlated with energy expenditure of physical activity as derived from the doubly labeled water method.\textsuperscript{20} V\text{O}_\text{max} was measured by a progressive and continuous treadmill test to volitional fatigue. The highest oxygen uptake for 1 minute during the test was recorded as the maximal V\text{O}_\text{max}.

**Energy Intake**

Energy intake was recorded from 3-day food diaries. Briefly, each subject was asked to weigh and record intakes of all food and beverages for 2 weekdays and 1 weekend day. Particular emphasis was placed on the importance of maintaining typical eating habits and describing foods and methods of preparation in accurate detail. A 5-lb metabolic scale was sent home with each subject to aid in measurement. The Nutritionist III computer program (4.0 version, N-Squared Computing, Silverton, OR) was used to analyze all diets for energy intake and macronutrient composition.

**Plasma Hormone Determinations**

Plasma levels of thyroxine (T\textsubscript{4}), free T\textsubscript{4}, and 3,5,3'-triiodothyronine (T\textsubscript{3}) were measured using clinical assay kits (Baxter, Cambridge, MA), and free T\textsubscript{3} concentration was measured using an analogue assay (Diagnostic Products, Los Angeles, CA).

**Statistical Approach and Analyses**

Assessment of linearity of data. It is important to first examine the linearity or nonlinearity of RMR data relative to other independent variables. Thus linear and quadratic regression equations were generated for the total group and within the validation group for the prediction of RMR. Semipartial F tests were performed to determine whether quadratic models explained a significantly greater amount of variance in RMR above that explained by linear regression models.\textsuperscript{20} No curvilinear function was found to contribute significantly to the model above that accounted for by linear function. Pearson Product-Moment Correlation Coefficients were used to assess degree of association between variables.

**Prediction of RMR.** Stepwise multiple regression analysis and all-possible-subsets regression analysis were used to predict RMR from laboratory and easily measured variables. These two statistical procedures yielded similar results, and thus only results of stepwise regression analysis are presented. Potential laboratory predictors of RMR were standing height, body weight, body surface area, body mass index, fat mass, FFW, four skinfold measurements, V\text{O}_\text{max} (L/min), LTA, daily energy and macronutrient intake, age, and plasma thyroid hormone levels. A second practical equation was derived in which easily measured variables were considered, and included the following variables: body weight, standing height, age, skinfold measurements, and LTA. The number of subjects selected to generate the practical equation was based on a favorable subject to variable ratio (30:1). Thus the practical model contains only three or four independent variables and diminishes the capitalization on chance.\textsuperscript{21}

**Cross-validation of practical equation.** There are two acceptable methods to perform cross-validation procedures.\textsuperscript{20} The first method involves collecting the validation group independently of the cross-validation group; the second method is an a posteriori division of the sample of subjects. The present study chose the latter of the two procedures, which involves randomly splitting the sample into two subsamples. To test the accuracy of the practical equation in an independent sample, subjects were randomly assigned into either a validation group (N = 61) or a cross-validation group (N = 28). The success of cross-validation procedures was determined by the following procedures: (1) measured and predicted means of RMR of the cross-validation group were compared using a dependent t test; and (2) the sample correlation coefficient (r) between predicted RMR and measured RMR was compared with the multiple correlation coefficient (R\textsuperscript{2}) obtained from the regression equation of the validation group by an independent z test.\textsuperscript{22} These statistical procedures have been recommended in cross-validation studies.\textsuperscript{12,23} When cross-validation procedures are successful, data from validation and cross-validation groups can therefore be pooled to generate a prediction equation of RMR with the largest sample size possible. Statistical significance was set at P less than .05; values are expressed as means ± standard deviation and/or standard error of the estimate (SEE).

**RESULTS**

Table 1 shows physical, metabolic, and hormonal characteristics of the total group of older men. These healthy older male volunteers represent a broad range of body composition, V\text{O}_\text{max}, physical activity level, and nutritional status.

Table 2 shows Pearson Product-Moment Correlation Coefficients among physical characteristic, body composition, and hormonal variables assessed in the present study.

**Biological Equation**

Stepwise regression analyses were used to estimate the best predictors of RMR in older men. FFW was shown to
be the strongest predictor of RMR, as it explained 85% of the total variance. Fig 1 shows the significant linear relationship between RMR and FFW in the total group of 89 older men \( (r = .92, P < .01) \). The regression equation for predicting RMR with FFW was as follows: RMR (kcal/d) = 14 (FFW in kilograms) + 804 \( (R^2 = .85; \text{SEE} = 32 \text{ kcal/d}) \).

Table 3 shows the stepwise regression analysis in 89 healthy older men, with RMR as the dependent variable. After FFW, the next variables to enter the equation were \( V_o_{max} \) and free \( T_3 \) level, with the latter two variables each contributing a small but significant 1% of unique variance \( (total R^2 = .87) \). The complete biological equation is as follows: RMR (kcal/d) = 12.6 (FFW in kilograms) + 31.8 \( (V_o_{max} \text{ in liters per minute}) + 26 \) (free \( T_3 \) level in picograms per milliliter) + 728 \( (r = .93, R^2 = .87, \text{SEE} = 30 \text{ kcal/d}, P < .01) \).

**Practical Equation**

Due to the difficulty in measuring FFW, \( V_o_{max} \), and free \( T_3 \) level in a clinical (or nonresearch) setting, we focused our attention on generating a practical equation for predicting RMR in healthy older men. Table 4 shows physical characteristics of older men in validation \( (N = 61) \) and cross-validation \( (N = 28) \) groups. The cross-validation group represented a randomly selected group of older men in our data set. There were no significant differences between groups for all variables measured. Using stepwise multiple regression with RMR as the dependent variable, the following variables were generated as the best set of predictors of RMR from validation group data \( (N = 61) \): weight (kg), chest skinfold thickness (mm), \( L_T \) (kcal/d), and body mass index \( (r = .90, R^2 = .81, \text{SEE} = 37 \text{ kcal/d}, P < .01) \).

**Cross-Validation of Practical Equation**

To test predictive accuracy of the practical regression equation from the validation group, we applied the equation to the cross-validation group as described in the Methods. Several statistical criteria were satisfied that indicated cross-validation procedures were successful. First, no significant differences were found between the means of measured and predicted RMR for the practical equation \( (1,644 \pm 87 \neq 1,642 \pm 69 \text{ kcal/d}) \). Second, the correlation coefficient between the measured and predicted value of RMR in the cross-validation group \( (r = .85) \) approximated the correlation coefficient of the regression equation derived from the validation group \( (r = .90) \). These findings show that the regression equation is robust to sample-
Arciero-Poehlman Practical Equation

On successful cross-validation, the data of validation and cross-validation groups were pooled and a new equation was generated using the total sample size ($N = 89$). Pooling of data of the two groups is recommended when cross-validation procedures are successful.20 Table 5 shows stepwise multiple regression analysis using pooled data from easily measured variables to predict RMR. Body weight alone accounted for 54% of total variance in RMR. The relationship between RMR and body weight is shown in Fig 2. After body weight, chest skinfold thickness was the next variable to enter the equation, explaining an additional 35% of variance in RMR. LTA and age were the next variables to enter into the equation, contributing an additional 4% and 3% unique variance, respectively (total $R^2 = .76$). Thus, based on results presented in Table 5, the new Arciero-Poehlman practical equation in our pooled sample of older men is RMR (kcal/d) = 9.7(weight in kilograms) - 6.1(chest skinfold thickness in millimeters) + 1.4(age in years) + 0.38(LTA) + 1.060 ($R^2 = .76$, SEE = 42 kcal/d, $P < .01$).

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Variable step</th>
<th>Independent Variable</th>
<th>$R^2$ (%)</th>
<th>$P$</th>
</tr>
</thead>
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<tr>
<td>RMR</td>
<td>1</td>
<td>FWV</td>
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<td>&lt;.01</td>
</tr>
<tr>
<td>RMR</td>
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<td>VO2max</td>
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<td>&lt;.05</td>
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<td>RMR</td>
<td>3</td>
<td>LTA</td>
<td>97</td>
<td>&lt;.06</td>
</tr>
</tbody>
</table>

Table 3. Stepwise Multiple Regression Analysis for Biological Equation in 89 Healthy Older Men Aged 50 to 78 Years

Table 4. Physical, Metabolic, and Hormonal Characteristics of Older Men in Validation and Cross-Validation Groups

Table 5. Stepwise Multiple Regression Analysis for Practical Equation in 89 Healthy Older Men (Aged 50 to 78 Years)

Comparison With Applicable Equations In the Literature

We examined the predictive accuracy of several commonly used equations for predicting RMR in older men because of (1) their age-specificity and/or (2) their reporting of statistical information that made direct comparison with the present study possible. Cross-validation procedures were performed between the measured RMR in our study with estimates from the equations of WHO/FAO/UNU,2 Harris-Benedict,3 Fredrix et al,10 Mifflin et al,11 and with the Arciero-Poehlman equation.

Table 6 shows the original prediction equation from the four studies chosen for cross-validation analysis and the Arciero-Poehlman practical equation derived from the present study.

Figure 3 shows the spread of residuals (predicted minus measured RMR) between the RMR predicted from the five equations when applied to the 89 subjects in this study with the measured RMR. The means of predicted RMR were underestimated by 3.5% (SD ± 5%),4 4% (SD ± 6%),6 and 5% (SD ± 5%).11 On the other hand, the equation of Fredrix et al10 overpredicted RMR by 3% (SD ± 5%). Of practical interest is the range of individual RMR values predicted by the aforementioned equations. The relative range of predicted RMR from measured values varied from −17% to 7%,4 −19% to 9%,2 −8% to 14%,10 and −18% to 5%,11 suggesting a loss of accuracy when applied on an individual basis.

![Graph showing linear relationship between RMR and body weight](image-url)

Fig 2. Linear relationship between RMR and body weight in 89 healthy men aged 50 to 78 years.

NOTE. $R^2$ is the fraction of explained variance; the last step provides the cumulative $R^2$. Other predictor variables that were considered in the analyses but were not entered into regression equation were body weight, height, age, percent body fat, fat weight, LTA, skinfold thicknesses, dietary intake data, body surface area, $T_d$, $T_a$, and free $T_d$.
Table 6. Comparison of Original Prediction Equations of the Four Studies Used for Cross-Validation Analyses and the Practical Equation From the Present Study

<table>
<thead>
<tr>
<th>Study</th>
<th>Original Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mifflin et al (n = 50) men &gt; 50 yr</td>
<td>RMR (kcal/d) = 10(W) + 6.25(H) - 5(A) + 5 ((R^2 = .71))</td>
</tr>
<tr>
<td>Harris-Benedict (n = 5) men &gt; 50 yr</td>
<td>RMR (kcal/d) = 5H + 13.7(W) - 6.8(A) + 66 ((R^2 = NA))</td>
</tr>
<tr>
<td>Fredrix et al (n = 18) men &gt; 50 yr</td>
<td>RMR (kcal/d) = (10.7[W] - 9[A] - 203) + 1,641 ((R^2 = .84))</td>
</tr>
<tr>
<td>WHO/FAO/UNU (n = 7) men &gt; 60 yr*</td>
<td>RMR (kcal/d) = 8.8(W) + 11.3(H) - 1,071 ((R^2 = .71))</td>
</tr>
<tr>
<td>Arciero and Poehlman (n = 89) men &gt; 50 yr</td>
<td>RMR (kcal/d) = 9.7(W) + 1.7(CSF) - 1.8(A) + 0.1(LTA) + 1,060 ((R^2 = .76))</td>
</tr>
</tbody>
</table>

*Number of men older than 60 years not available.

NOTE. Values in parentheses indicate number of subjects older than 50 years of age.

Abbreviations: W, weight (kg); H, height (cm); A, age (yr); CSF, chest skinfold (mm); NA, not available; \(R^2\), squared correlation coefficient from the original study.

DISCUSSION

The major purposes of the present study were to (1) examine the predictive capacity of several biological determinants of RMR in older men; (2) develop a prediction equation from easily obtained measurements and examine its accuracy and stability in an independent sample of older men; and (3) test the validity of several existing equations for predicting RMR in older men by comparison with our measured RMR values.

Biological Equation

Our results confirm earlier findings that FFW is the best predictor of RMR in older men, explaining 85% of the variance \((R^2 = .85)\). Based on measurement of FFW, we could predict RMR in older men within an error of ±32 kcal/d. Whether differences in FFW can fully account for age-related variation in RMR is a controversial issue. Tzankoff and Norris reported that changes in the amount of creatine-generating tissues, primarily skeletal muscle, are completely responsible for the decrease in RMR with age. Conversely, other investigators have found that differences in FFW do not fully account for the age-related decrease in RMR in older individuals.

A recent investigation from our laboratory showed that the decrease in \(V_O_2\)max was a significant contributor to the decrease in RMR in the elderly.

Addition of free \(T_3\) level and \(V_O_2\)max to the model significantly improved the prediction of RMR, although the additional variance accounted for by these variables was small (2%). Other body composition-related measurements (fat weight, skinfold thickness, body mass index), physical characteristics (age, height, weight), energy intake data, and LTA were not independent contributors to our biological predictive model. These findings confirm previous findings from our laboratory, in which \(V_O_2\)max was a significant predictor of RMR independent of FFW. Interestingly, we have not previously found an independent influence of plasma free \(T_3\) levels on RMR, although thyroid hormones have traditionally been considered important regulators of resting thermogenesis.

Taken together, our 3-variable biological equation would predict RMR within an error of ±30 kcal/d.

Arciero-Poehlman Practical Equation

The principal focus of the present analysis was to develop a simple and practical equation for predicting RMR, since variables in our biological equation are either impractical to measure or require the use of highly trained personnel. After removal of those variables deemed impractical or difficult to measure, body weight alone best predicted...
PREDICTION OF RMR IN OLDER MEN

RMR, accounting for 54% of the explained variance in RMR in older men (Fig 2). This finding is in agreement with other investigations that have shown a high correlation between body weight and RMR.10,25 The fact that body weight is closely related to RMR is not surprising, since it is also highly correlated with other measures of active protoplasmic tissue mass such as 1+FW (r = .82, P < .01). The use of body weight alone would permit an estimation of RMR within ±57 kcal/d. Of interest is the addition of chest skinfold thickness, energy expended in LTA, and age as independent factors influencing RMR in older men. These three variables increased the R² to 76%, which would permit an estimation of RMR within ±42 kcal/d.

We have previously shown that energy expenditure (and thus energy requirements) due to physical activity differ widely between older individuals, as measured from doubly labeled water.3 The LTA Questionnaire12 was found to accurately estimate energy expenditure from physical activity (r = .83, P < .01), providing support for the use of this tool as a valid instrument to estimate the energy expenditure of physical activity.3 Collectively, the independent contribution of LTA to the prediction of total energy expenditure3 and RMR in older men (present study) underscores the importance of physical activity as a determinant of daily energy requirements in free-living elderly individuals.

Our finding of age as a significant independent contributor to the variation in RMR in older men is interesting. A recent cross-sectional study from our laboratory5 involving 300 healthy males (17 to 78 years) has shown that the decrease in RMR with age is characterized by a curvilinear relationship, not a linear one as previously suggested. This study found no relationship between RMR and age in males up to 40 years. However, in men older than 40 years, a linear decrease in RMR and age was noted. Based on this finding, the development of a generalized equation with linear regression techniques across a wide age range would be less precise for use in older individuals, due to the curvilinear relationship between age and RMR. It is reassuring to note that our practical equation (SEE ± 42 kcal/d) compares favorably with the predictive capacity of our biological equation (SEE ± 30 kcal/d) and cross-validates on an independent sample. Thus we feel confident that the present investigation offers a practical and accurate equation to predict RMR in a population of healthy older men.

Accuracy of Comparable Equations

To determine the accuracy and stability of several commonly used prediction equations, we cross-validated equations of WHO/FAO/UNU,4 Harris-Benedict,9 Fredrix et al.10 and Mifflin et al11 with the measured RMR values from this study. We recognize that other equations to predict RMR are available in the literature6,25,26,27; however, we chose the aforementioned equations based on the following criteria: (1) age specificity, (2) reporting of easily measured variables, and (3) inclusion of statistical information that made direct comparison with the present study possible.

A brief discussion of these equations that are directly comparable to the Arciero-Pochman practical equation of the present study is warranted. The most commonly used prediction equation for RMR is the Harris-Benedict equation.9 This generalized equation is based on a wide age range (16 to 63 years), but includes only five men over the age of 50 years. During the past decade, several studies have indicated that the Harris-Benedict' equation significantly underestimates (7%)10,25 and overestimates (up to 15%)11,26 RMR in older and younger populations, respectively. In the present study, the Harris-Benedict equation resulted in a wide range of underprediction and overprediction of individual RMR values (~19% to 9%). The most plausible reasons for the error associated with the Harris-Benedict equation are differences in indirect calorimetry equipment (mouthpiece v hood), the brief measurement period (5 to 15 minutes), and the paucity of older individuals (N = 5 subjects > 50 years) in their data set. Moreover, it is likely that changes in nutritional intake and occupational energy expenditure have occurred over the 7 decades since the Harris-Benedict equation was developed.

The equation of Fredrix et al10 overestimated measured RMR in our group of older men by 5%, with a range of individual deviation of ~3% to 14%. The small sample size of older men (N = 18) tested and testing conditions used may have also contributed to the equation’s inaccuracy relative to our sample population. Regarding the latter point, in the study by Fredrix et al10 subjects transported themselves to the laboratory on the morning of testing. A recent study from our laboratory29 has shown that outpatient measurements of RMR are 7% to 8% higher than those measured under inpatient conditions, which could partially account for their overestimation of RMR.

Both the equations of Mifflin et al11 and the WHO/FAO/UNO4 equations were chosen for comparative purposes because of their relatively large sample sizes in the older age group. In comparison with the measured RMR in the present data set, the deviation of predicted RMR values obtained in the study by Mifflin et al11 ranged from ~18% to 5%, and in the WHO/FAO/UNU study deviations from measured RMR ranged from ~17% to 7%. To our knowledge, these equations have not been cross-validated in an age-specific independent sample of older men to test their accuracy and stability.

Several methodological considerations regarding the prediction of RMR in our large sample of older men should be considered. First, all measurement techniques were highly standardized to ensure optimal basal conditions. These experimental conditions included the assessment of RMR in an inpatient setting and 48 hours from the last exercise session. Second, to our knowledge, this study used the largest sample size of older men from which prediction equations of RMR have been derived and successfully cross-validated on an independent sample.

Clinical Implications

Clinical implications of our findings relate to the ability to predict energy requirements in older individuals. Information on RMR is of potential use since it is the major component of total energy expenditure, and is of clinical
importance in the determination of energy requirements. However, a recent investigation from our laboratory has shown that under free-living conditions, RMR explains less than 50% of individual variation in energy requirements because of wide interindividual variation in physical activity. This finding suggests that other markers of physical activity are required to optimize the prediction of individual energy requirements. We have identified $V_{O_2 \text{max}}$ and LTA by questionnaire as two potential markers of physical activity level. For example, the combination of RMR and LTA accounted for 83% of the variation in total energy expenditure in older individuals.

Our equation to predict RMR may be useful in predicting daily energy requirements in the elderly if it is used in combination with an activity questionnaire. A subsequent analysis was performed comparing total daily energy expenditure determined with the doubly labeled water technique in six older men with results obtained using the Arciero-Poehlman equation. Total daily energy expenditure was derived from our developed equation, the energy expenditure in physical activity (from questionnaire), and an estimated cost of 10% for the thermic effect of feeding. The measured total daily energy expenditure value (2,675 kcal/d) using the doubly labeled water technique was significantly related ($r = .79, P < .05$) to the predicted total daily energy expenditure value (2,407 kcal/d). These preliminary findings suggest that our equation and an easily derived measure of physical activity may be useful in predicting daily energy needs in older individuals.

The use of RMR for predicting daily energy requirements is also important in the clinical setting (eg, nonambulatory hospitalized patients). In this situation, the relationship between RMR and energy requirements is more clearly defined because the reduction in physical activity is greater and therefore more standardized. In a clinical setting, it is often of interest to know whether the injury or illness leads to a reduction or elevation in RMR. In these situations, the most common reference for comparisons is probably the Harris-Benedict equation; however, as discussed previously, this equation may not be specific for an aging population. Therefore, to determine whether energy expenditure is elevated in a clinical setting, we suggest comparing measured RMR with that predicted from our proposed equation. In summary, we offer an equation to predict RMR in older men that is both practical and accurate for use in the clinical or nonlaboratory setting.

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