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ARTICLE

Health issues and nutrition in the elderly

Estimating total daily energy requirements in community-dwelling older adults: validity of previous predictive equations and modeling of a new approach

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Abstract

Background/objectives Accurate estimation of energy requirements is crucial for health maintenance and prevention of malnutrition in older adults. This study aimed to assess the accuracy of predictive equations for estimating energy requirements in older adults and to test the validity of new predictive equations for this age group.

Subjects/methods This is a cross-sectional study including 38 Brazilian community-dwelling older adults aged 60–84 years, who had their total energy expenditure measured by doubly labeled water (TEE_{DLW}). The energy expenditure was compared to the Institute of Medicine (Dietary Reference Intake (DRI)) and Vinken et al. previous predictive equations and three predictive models developed in a modeling sample. The agreement was assessed using intra-class correlation coefficient, Bland–Altman plots, and Lin's concordance correlation. Accuracy was evaluated considering ±10% of the ratio between estimated and measured energy expenditure.

Results The mean (standard deviation) TEE_{DLW} was 2656.7 (405.6) kcal/day for men and 2168.9 (376.9) for women. Vinken et al. and both DRI equations presented moderate to good degree of agreement, while the developed models vary from fair to very good agreement in comparison to DLW. The accuracy rate was the same for both DRI equations and Vinken et al. equation (60.53%). The new equations developed in this study had accuracy in predicting TEE for Brazilian older adults varying from 43.11% to 73.68%.

Conclusions The results corroborate the use of previous predictive equations for estimating energy requirements in Brazilian older adults. Further studies have the potential to explore the use of the developed models to assess energy needs in this population.

Introduction

Aging is a multicomponent process, with important physiological and psychological changes in which adequate nutrition is essential to maintain health [1, 2]. There is a decline in lean body mass and basal metabolic rate with age, associated with an increase in body fat. Such changes lead to a reduction in energy requirements and reflect on nutrient needs. Meeting dietary needs is therefore crucial for the maintenance of health, quality of life, and particularly important to prevent malnutrition in older adults [3]. Thus, better understanding and accurate estimating daily energy expenditure and requirements are critical to minimize negative energy balance, in an attempt to mitigate declines in the health status of older people [4, 5].

Doubly labeled water (DLW) is the gold-standard technique for measuring total energy expenditure (TEE) in

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free-living individuals, but due to its cost and analytical complexity, it is not widely available. It is mainly used as a research tool rather than as a method in clinical practice [4, 6]. Given the unpractical use of DLW on a daily basis, predictive equations based on age, gender, weight, height, and physical activity level (PAL) for TEE estimation have been used [7, 8]. However, during these predictive equations development, older adults were not considered as a stand-alone category. Considering the changes in energy metabolism associated with the aging process, the accuracy of these equations may be affected when applied to older adults [9]. Therefore, selecting the most accurate predictive equation for this age group is important to avoid over or underestimation of energy requirements.

To address this knowledge gap, the present study aimed to assess the accuracy of previous predictive equations for estimating energy requirements in Brazilian older adults by using the DLW as the reference method. In addition, this study developed and tested new models for energy requirements considering the specificity of this population.

Methods

Study sample and design

Thirty-eight free-living older adults aged 60–84 years were included in this study. A convenient sample was recruited from the 2015 Health Survey of São Paulo (ISA-Capital 2015), a cross-sectional, population-based survey that used stratified, multistage sampling to create a representative sample of urban residents of São Paulo, Brazil [10]. Participants had their energy expenditure assessed by the DLW technique (TEE_{DLW}). Weight was tracked along the period of DLW administration to guarantee that the participants were not losing weight. Individuals with health conditions known to modify energy requirements such as fever and cancer were not included in the study. Participants were asked about chronic diseases and medications use, and inclusion criteria considered only those with no interference in DLW analysis and energy expenditure.

This study was approved by the Ethics Committee on Research of the School of Public Health, University of São Paulo (CAAE no. 01349218.2.0000.5421). Written informed consent was signed by all participants.

Modeling sample

A sample of 41 individuals aged 62–77 years was used as a modeling database to develop new equations for TEE. Participants were also community-dwelling older adults, who had their TEE measured by DLW. The individuals were recruited in a public ambulatory from the Family Health Program (primary health care of Ribeirão Preto, SP, Brazil) and had their TEE measured by DLW as a part of the study protocol [11]. Inclusion criteria also considered the absence of health conditions with no interference in DLW analysis and energy expenditure.

Total energy expenditure (TEE) and predicted energy requirements

In both samples TEE was determined by DLW according to the multi-point method over a 14-days period [12]. The doses were prepared with a proportion of 2 g of oxygen-18 (^{18}O) at 10% and 0.11 g of deuterium oxide at 99.8% ($^{2}H_2O$) per kilogram of estimated total body water. On the first visit, after the collection of a basal urine sample, participants ingested the DLW dose. Urine samples were collected from days 1–14 after oral dose administration. Hydrogen (H_2) and oxygen-18 isotope enrichments in urine samples were analyzed in triplicate using isotope ratio mass spectrometry (IRMS-GLS: ANCA 20–20, Europe Scientific, UK and ANCA 22–20, Sercon, UK) at the Isotope Ratio Mass Spectrometry Laboratory of the Ribeirão Preto Medical School—University of São Paulo, Brazil. Dilution spaces for H_2 and ^{18}O were calculated according to Coward [13], which reflects carbon dioxide (CO_2) production to determine TEE.

In the present study, previous equations proposed by the Institute of Medicine—IOM (Dietary Reference Intake (DRI)) [8] and by Vinken et al. [7] were used to predict TEE (Supplementary 1). Besides, three models were developed in a modeling sample and tested for validity in our sample. DRI_{mixed} equations are suitable for the prediction of energy requirements in mixed groups containing normal-weight and overweight adults. $DRI_{stratified}$ are used to predict TEE stratified by sex and nutritional status [8]. Vinken et al. [7] equation was developed considering individuals between 18–81 years old and it is based on age, weight, height, and sex of participants. In order to convert megajoule (MJ) in kilocalories (kcal) the estimated TEE was multiplied by 238.85 (1 MJ = 238.85 kcal).

Anthropometric measurements and physical activity level

Trained interviewers obtained weight (in kilograms) and height (in centimeters). Body mass index (BMI) was calculated and classified according to the cutoffs for older people recommended by the Pan American Health Organization-[14] underweight: ≤23 kg/m^2, normal-weight: 23–28 kg/m^2, pre-obesity: 28–30 kg/m^2 and obesity: ≥30 kg/m^2.

PAL was defined as the ratio between TEE obtained from the DLW and RMR by using indirect calorimetry (RMR_{Cal}) (Cortex®—MetaLyzer 3B® Leipzig, Germany).

Table 1 Demographic and anthropometric characteristics of 38 community-dwelling older adults stratified by sex. São Paulo—Brazil.

Demographic and anthropometric characteristics	All ($n = 38$)		Men ($n = 22$)		Women ($n = 16$)		
	Mean	SD	Mean	SD	Mean	SD	p value
Age (years)	68.05	5.80	69.23	6.29	66.44	4.77	0.146
Weight (kg)	77.34	18.09	83.01	17.31	69.55	16.59	0.021*
Height (m)	1.62	0.10	1.68	0.08	1.54	0.05	0.000***
BMI (kg/m^2)	29.22	5.20	29.14	3.89	29.34	6.76	0.908
PAL (TEE/RMR)	1.68	0.36	1.53	0.26	1.89	0.38	0.001**
RMRCal (kcal)	1527.72	451.07	1782.15	388.43	1177.87	255.25	0.000***
TEE_{DLW} (kcal)	2451.30	457.79	2656.66	405.56	2168.94	373.85	0.001***

BMI body mass index, *TEE_{DLW}* total energy expenditure obtained by doubly labeled water, *PAL* (TEE/RMR) physical activity level (ratio between total energy expenditure and resting metabolic rate), *RMRCal* (kcal) resting metabolic rate obtained from indirect calorimetry, *SD* standard deviation.

p value for independent Student t test for comparison between sex—*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

The exam was performed under standardized conditions, after at least 2 h fasting and 30 min resting [15]. The data were collected for 25 min, but to eliminate the effects of habituation to the test procedure, the respiratory measurements during the first 5 min were discarded. The volumes of oxygen consumed (VO_2) and carbonic gas produced (VCO_2) were used to determine RMR. PAL values were estimated, and individuals classified as sedentary, low active, active, or very active according to the IOM guidelines [8]. PAL was included in the DRI equations, and to generate the new models.

Statistical analyses

Descriptive statistics

Normality was tested using the Kolmogorov–Smirnov test. All variables were normally distributed, and quantitative variables presented as mean (standard deviation (SD)). Paired *t*-test was used to examine the difference between measured and predicted TEE. Chi-Square and independent *t*-test were used to compare characteristics between sexes. Comparisons were also made between the study sample and the modeling database.

Modeling of new approaches

Linear regression analysis was used to develop new equations to predict TEE in the modeling sample. Predictive variables were added in the models to evaluate their contribution to estimated TEE_{DLW} (dependent variable). The independent variables were selected for multiple linear regression analyses when p value < 0.20 in univariate models. Age, sex, anthropometric variables, resting metabolic rate, and PAL were included through stepwise process. Multicollinearity was assessed by Pearson correlation coefficient and homoscedasticity by analyzing residuals.

Validity and reproducibility

Intra-class correlation (ICC) coefficients were used to evaluate the reproducibility between TEE predicted by each equation (previous and developed in this study) and TEE measured by DLW. ICC less than 0.4 were classified as poor reproducibility, values between 0.4 and 0.75 were classified as moderate reproducibility, and values above 0.75 were classified as good reproducibility [16]. Lin's concordance correlation coefficients (CCC) were also determined and classified according to Altman [17]. Bland–Altman plots with 95% limits of agreement were constructed to evaluate the agreement between methods. Accuracy was determined as the percentage deviation of the estimated values (ratio between estimated and measured TEE, multiplied by 100), considering for classification the proportion of participants with the predicted TEE within ±10% of the measured TEE.

Statistical analyses were conducted in Stata Statistical software (version 14.0, StataCorp, College Station, Texas, USA) and two-tailed p value of <0.05 was considered significant. Bland–Altman plots were analyzed using the integrated development environment RStudio (version 1.2.5019).

Results

The study included 38 older adults, 57.9% men, aged 68.1 (SD = 5.8 years). Demographic, anthropometric, and nutritional status of participants are shown in Table 1. Men were significantly taller ($p < 0.001$), had a higher weight ($p = 0.021$), RMR_{Cal} (1782.2 (388.4) kcal/day vs. 1177.9 (255.3) kcal/day; $p < 0.001$) and TEE_{DLW} (2656.7 (405.6) kcal/day vs. 2168.9 (376.9) kcal/day; $p = 0.001$) than women. There was no significant difference in BMI between sex. There was no significant difference in

Table 2 Comparison of anthropometric characteristics of community-dwelling older adults between study sample and modeling sample. São Paulo/Ribeirão Preto—Brazil.

Variables	Study sample ($n = 22$)		Modeling sample ($n = 16$)		
	Mean	SD	Mean	SD	p value
Age (years)	68.05	5.80	67.54	3.96	0.6434*
Weight (kg)	77.34	18.08	71.97	12.53	0.1268*
Height (cm)	162.10	10.01	162.00	10.68	0.9658*
BMI (kg/m^2)	29.22	5.20	27.53	4.71	0.1317*
PAL (TEE/RMR)	1.68	0.36	1.61	0.33	0.3482*
RMRCal (kcal)	1527.7	451.07	1478.66	213.91	0.5339*
TEE_{DLW} (kcal)	2451.30	457.79	2363.92	553.27	0.4487*
Sex	*n*	%	*N*	%	
Male	22	57.89	20	48.78	0.417**
Female	16	42.11	21	51.22	

BMI body mass index, *TEE_{DLW}* total energy expenditure obtained by doubly labeled water, *PAL* (*TEE/RMR*) physical activity level (ratio between total energy expenditure and resting metabolic rate), *RMRCal* (kcal) resting metabolic rate obtained from indirect calorimetry, *SD* standard deviation.

*p value for independent Student t test for comparison between samples.

**p value for Chi-Square test for comparison between samples and categorical variables.

participant's characteristics when comparisons were made between the study sample and the modeling sample (Table 2).

A significant correlation was found between estimated TEE_{DLW} in the modeling sample and weight ($r = 0.43$; $p < 0.01$), RMR_{Cal} ($r = 0.48$; $p < 0.01$), PAL ($r = 0.77$; $p < 0.001$), and sex ($r = 0.38$; $p < 0.05$). Weight, PAL, RMR_{Cal}, and sex were significant predictors of TEE_{DLW} in univariate linear regression models (Table 3). In multiple linear regression models, TEE_{DLW} was positively associated with PAL and RMR_{Cal} in model 1. However, considering the biological plausibility in energy expenditure, age, and sex were used to adjust the model. In model 2, weight, PAL, and sex were significant predictors of TEE_{DLW}, whereas age was also included as an adjustment variable. In model 3, significant predictors of TEE_{DLW} included BMI, age, sex, and PAL.

Accuracy and reproducibility measurements of predictive equations for TEE (DRIs, Vinken et al., and the new developed equations) compared to TEE_{DLW} in the study sample were presented in Table 4. No significant differences were observed for TEE estimated by DLW both DRI equations, Vinken et al. equation, and developed model 3. However, models 1 and 2 tended to overestimate energy requirements when compared to TEE_{DLW} (2552.2±511.6 kcal/day for model 1 and 2694.4 ±457.3 kcal/day for model 2 vs. 2451.3±457.8 for TEE_{DLW}). Considering ±10% of TEE_{DLW} as a threshold for accuracy, both DRI equations and Vinken et al. had the same proportion of accurate TEE compared to TEE_{DLW} (60.53%). However, Vinken et al. tended to underestimate more than DRI equations (21.05 vs. 18.42%). Developed models 2 and 3 were 43.11% and 55.26% accurate, respectively, while model 1 presented the best proportion of accurate estimation (73.68%). Developed model 2 had the highest proportion of overestimation of energy requirements (44.74%), while developed model 3 equation was the equation with highest underestimation of energy requirements (23.68%). On the other hand, model 1 did not underestimate the TEE of any individual. Vinken et al. was the equation with the lowest proportion of overestimation of energy needs (18.42%).

The ICC for most equations were indicative of a moderate degree of reproducibility with TEE_{DLW}. However, model 2 presented an ICC with poor degree of reproducibility, while model 1 was the only predictive equation with a good degree of reproducibility ($r = 0.92$, $p < 0.01$). The ICC observed for both DRI equations ($r = 0.69$; $p < 0.01$) were similar to Vinken et al. ($r = 0.68$; $p < 0.01$) and higher than models 2 and 3 ($r_{model2} = 0.39$ and $r_{model3} = 0.42$; $p < 0.01$). When Lin's concordance coefficients were used, both DRI equations and Vinken et al. equation were classified as good agreement with TEE_{DLW}. However, the developed models showed different results for CCC. While model 2 presented a fair agreement when compared to DLW ($r = 0.39$; $p < 0.01$), model 3 obtained a moderate agreement ($r = 0.42$, $p < 0.01$). Furthermore, model 1 was the only predictive equation to present a very good agreement using CCC ($r = 0.92$, $p < 0.01$).

Bland–Altman plots revealed no specific pattern for systematic bias in models 2 and 3, and Vinken et al. equation (Fig. 1). However, both models 2 and 3 presented the largest limits of agreement, showing the worst agreement compared to TEE_{DLW}. Vinken et al. equation on the other hand presented the lowest bias in comparison to DLW (1.3 kcal), considering the three previous predictive equations. No relevant differences were found between both DRI equations (mixed and stratified). Bias and limits of agreement were very similar. Furthermore, the pattern revealed a tendency for energy overestimation with higher TEE_{DLW} measurements. In comparison to the previous equations, developed model 1 presented the lowest range of limits of agreement, which indicates a better agreement with TEE_{DLW} measurements. The plots also indicate that model 1 is more likely to overestimate the energy requirements of the individuals. All tested equations presented a wide dispersion, showing that the differences between measurements varied considerably. Few outliers were detected in both DRI equations and Vinken et al. equation.

Table 3 Predictive models for estimating energy expenditure in a modeling sample of 41 community-dwelling older adults. Ribeirão Preto—Brazil.

Variables	Crude model		Model 1[a] Adj. $R^2 = 0.9835$	Model 2[b] Adj. $R^2 = 0.8488$	Model 3[c] Adj. $R^2 = 0.8043$
	β (95% CI)	R^2	β (95% CI)	β (95% CI)	β (95% CI)
Constant (β_0)[§]	–	–	−2357.01 (−2867.97; −1846.05)	−139.91 (−1478.80; 1198.98)	472.31 (−989.89; 1934.51)
Weight (kg)	18.90 (5.98; 31.83)	0.18	–	17.42 (11.56; 23.27)	–
Height (m)	1229.75 (−400.98; 2860.48)	0.06	–	–	–
PAL (TEE/RMR)	1285.51 (939.55; 1631.47)	0.59	1486.86 (1415.57; 1558.15)	1318.45 (1108.34; 1528.55)	1226.95 (987.36; 1466.54)
RMR (kcal)	1.23 (0.50; 1.97)	0.23	1.67 (1.54; 1.81)	–	
BMI (kg/m²)	28.19 (−8.76; 65.14)	0.06	–	–	39.14 (21.38; 56.89)
Male sex[d]	410.49 (82.27; 738.99)	0.14	−23.99 (−79.21; 31.24)	235.22 (91.35; 379.09)	491.37 (326.34; 656.39)
Age (years)	−10.08 (−55.25; 35.09)	0.01	−1.95 (−7.97; 4.06)	−14.56 (−32.27; 3.15)	−20.69 (−40.63; −0.74)

β, coefficient of linear regression.

95% *CI* 95% confidence intervals, *BMI* body mass index, *RMRCal* (kcal) resting metabolic rate obtained from indirect calorimetry, *PAL (TEE/RMR)* physical activity level (ratio between total energy expenditure and resting metabolic rate), *Adj. R^2* adjusted R^2. § Constant for the crude model was not presented as it was different for each tested variable.

[a]Model 1: covariates: RMR and PAL adjusted for age and sex.

[b]Model 2: covariates: weight, sex, and PAL adjusted for age.

[c]Model 3: covariates: BMI, age, sex, and PAL.

[d]Reference—female.

Discussion

We assessed the validity of previous predictive equations for TEE in community-dwelling, independent older adults. In summary, this study showed that the accuracy of TEE predictive equations did not vary substantially among the tested equations. To the best of our knowledge, this is the first study to evaluate the validity of these equations in Brazilian older adults in comparison to DLW, the gold-standard method [18]. We emphasize that efforts should be made to develop less biased more individually accurate equations for this specific population.

The DRI equations are the most commonly used in clinical and research practice. In our study, these equations showed a percentage of accurate estimation of energy requirements equal to 60.53%, with no statistically significant mean difference compared to $TEE_{DLW,}$ which indicates that these equations accurately predict TEE in this target group. Accuracy was similar for both $DRI_{stratified}$ and DRI_{mixed} equations. The proportion of accurate (60.53%), underestimated (18.42%), and overestimated (21.05%) individuals were the same. Besides, there was no difference in the ICC and CCC between $DRI_{stratified}$ and DRI_{mixed} equations ($p < 0.01$). The reproducibility of these equations in our study varies from moderate to good agreement, which is in accordance with findings from previous studies. According to the Observing Protein and Energy Nutrition study [19], although the equation appears to overestimate TEE, particularly in obese women, the results corroborate the use of the DRI equations for EER in middle-age men and women. The study also found a higher PALs in women than men using the same approach than our study (TEE/RMR ratio). The Bland–Altman plots in a longitudinal cohort [4] in the USA indicated an accurate range of agreement of the DRI equations with measurements of TEE_{DLW}, concluding that this equation was very comparable to DLW.

Regarding DRI_{mixed} equation, as far as we know, no studies have previously investigated the validity of this specific DRI equation in this age group. One hypothesis for the similar performance of these equations in our group is that our population included individuals in all nutritional status categories. In studies with heterogeneous samples or groups of individuals including only normal-weight or overweight/obese participants these equations might result in different outcomes and one equation stands out the other.

The Vinken et al. [7] equation was developed for healthy, free-living adults aged 18–81 years old, but it performs better in individuals with BMI between 18 and 31 kg/m². Although the Bland–Altman plot demonstrated wide limits of agreement, no proportional or systematic bias was detected, with the lowest mean difference bias in comparison to TEE_{DLW}. In addition, a moderate to good agreement and no significant differences were found compared to the

Table 4 Accuracy and reproducibility measurements of predictive equations for total energy expenditure compared to doubly labeled water in 38 older adults. São Paulo—Brazil.

Methods for TEE	TEE (kcal/day) Mean	SD	*p* value	ICC	CCC	Under <90%	Accurate 90–110%	Over >110%
TEE_{DLW}—Ref	2451.30	457.79	–	–	–	–	–	–
$DRI_{stratified}$	2395.03	331.54	0.2774	0.69	0.68	18.42	60.53	21.05
DRI_{mixed}	2399.77	339.40	0.3231	0.69	0.68	18.42	60.53	21.05
Vinken et al.	2449.98	466.70	0.9827	0.68	0.67	21.05	60.53	18.42
Model 1	2552.18	511.59	0.0007*	0.92	0.92	0.00	73.68	26.32
Model 2	2694.35	457.27	0.0034*	0.36	0.39	13.16	42.11	44.74
Model 3	2554.77	452.33	0.2007	0.41	0.42	23.68	55.26	21.05

TEE_{DLW}, Ref: reference method—total energy expenditure by doubly labeled water, *ICC* intra-class correlation coefficient, *CCC* Lin's concordance correlation coefficient, *CV*(%) coefficient of variance, *TEE* total energy expenditure, *SD* standard deviation.

DRI_{mixed}: DRI equation for energy requirements of mixed groups containing normal-weight and overweight adults.

$DRI_{stratified}$: DRI predictive equation for energy requirements of groups stratified by sex and nutritional status.

p value: paired *t*-test comparing predictive equations with reference method (TEE_{DLW}).

Model 1: dependent variable: energy expenditure by DLW. Covariates: RMR, PAL age, and sex.

Model 2: dependent variable: energy expenditure by DLW. Covariates: weight, PAL, age, and sex.

Model 3: dependent variable: energy expenditure by DLW. Covariates: BMI, PAL, age, and sex.

*$p < 0.01$.

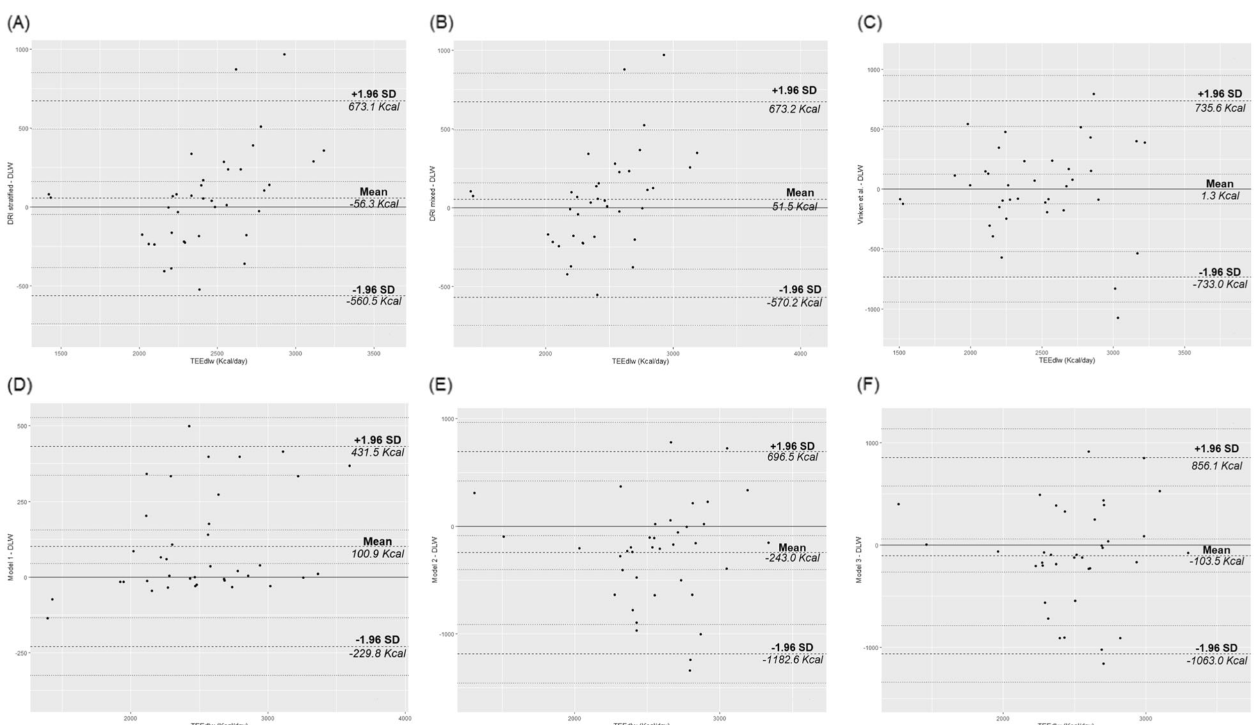

Fig. 1 Bland–Altman plots of energy expenditure measured by doubly labeled water (TEE_{DLW}) and predictive equations for energy requirements. a DRI for stratified groups. **b** DRI for mixed groups. **c** Vinken et al. **d** Predicted model 1. **e** Predicted model 2. **f** Predicted model 3. The lines represent the mean difference between each method and the DLW and 1.96 standard deviation (SD) of the mean (limits of agreement).

reference method (TEE_{DLW}). Accuracy and reproducibility were very similar to both DRI equations. The proportion of accurate individuals was also 60.54%. However, Vinken et al. [7] equation presented a lower proportion of overestimation and a higher proportion of underestimation than both DRI equations.

In general, the results for the three previous predictive equations for TEE were similar and endorse the use of these equations in our sample of older adults. The decision about which equation to choose may rely on the researcher's hands, due to the study objectives, participants' characteristics, and available data. Aging is associated with a progressive reduction in lean body mass with a concomitant increase in body fat, both components being the main determinants of energy expenditure. Thus, older people are usually at risk of both undernutrition and overweight/obesity. The researcher should consider which issue is more determinant in the study sample, and which consequences prioritize. In situations where the main objective is to avoid underestimation of energy needs and prevent undernutrition, DRI equations may be more suitable, since they detect a lower proportion of underestimation. On the other hand, in situations aimed to avoid overestimation of energy needs to prevent overweight/obesity as a consequence of overfeeding, the Vinken et al. equation may be more adequate.

We found no other studies that have investigated the validity of Vinken et al. predictive equation for energy requirements in this age group. The equation is sex, age, weight, and height dependent, and no input of PAL is required. For this reason, we believe that the removal of an associated source of error, such as PAL, could enhance the accuracy of this equation. In our study, we used a reference method for the estimation of PAL. However, this parameter usually depends on subjective self-reported activity or relies on the population average, and that is why energy-requirement models that do not depend on a measurement of PAL are supported and encouraged [20]. Thus, in a situation where a PAL level is not available, Vinken et al. equation may also be applied.

In our study, we have also developed and tested the validity of new predictive equations to estimate TEE in older adults. We derived our models in a modeling database based on anthropometric measurements, PAL, and RMR data. The PAL was the most important predictor of TEE_{DLW} in the crude model. When adjusted for other variables, this measurement remained significant in all the three developed models. Model 1 considered RMR and PAL as significant predictors of TEE_{DLW}, adjusted for sex and age, due to their effect on energy expenditure. In our study, this equation was the most suitable to estimate TEE in older adults. It showed the lowest limits of agreement in the Bland–Altman plot. With this equation, the proportion of accuracy was 73.68% and it showed a very good agreement with TEE_{DLW} with the highest ICC and CCC. However, it tended to overestimate the energy requirements of the individuals.

Model 2 based on weight, PAL, and sex, adjusted for age was the worst among the three developed models. The proportion of accurate TEE_{DLW} estimation was only 44.11%. It also tended to overestimate the energy requirements of the individuals, with a significant mean difference in comparison to TEE_{DLW}. Model 3 was developed using BMI, which is a parameter that considers the ratio between weight and height, easily measured in routine practice. Besides, in this model, TEE_{DLW} was also significantly associated with PAL, sex, and age. The energy estimation using this model did not vary significantly in comparison to TEE_{DLW}. Also, the prevalence of the accuracy rate was 55.26%.

The expected explaining of variance (R^2) for equations for energy estimation is about 60% [7]. All three developed models obtained values above the recommended (model 1: 98.35%, model 2: 84.88%, model 3: 80.43%).

Limitations of this study include the small sample size and the use of a convenience sample. Thereby, our results cannot be generalized to the overall population. We highlight that the outstanding proportion of the variance explained by the developed models may be related to the gold-standard methods that were used in our study, not usually available in epidemiological settings. PAL and RMR were assessed with the reference methods for these measurements, and the results may not be reproducible in other situations where these approaches are not available. Additional external validation is required to establish the utility of the developed models, especially in studies using other methods to estimate the measurements. Nevertheless, a major strength of our study is that energy expenditure was measured with a highly accurate method, the DLW, which provides a comprehensive measure of total energy requirements. DLW requires standard methods and trained operators, and it is not frequently used in routine clinical practice. Therefore, the present study developed accurate predictive equations to estimate TEE based on this gold-standard method to predict TEE in older adults.

In conclusion, our results corroborate the use of the Vinken et al. and both DRI previous predictive equations for estimating energy requirements in this sample of older adults. The decision about the equation selection may rely on the study objectives, participants' characteristics, and available data. The equations developed and tested in this study also presented some potential for predicting the energy requirements of older adults. Further studies may explore the use of the developed models to assess the energy needs in a representative sample of this population.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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