PRECISION OF ANTHROPOMETRIC EQUATIONS TO ESTIMATE TOTAL ENERGY EXPENDITURE OF OLDER ADULTS WITH SARCOPENIA: A CROSS SECTIONAL STUDY

Precisão de equações antropométricas para estimar o gasto energético total de idosos com sarcopenia: um estudo transversal

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Key summary points

- Aim: To assess which anthropometric equation are relevant to measure total energy expenditure in sarcopenic seniors.
- Findings: for accurate estimation of total energy expenditure in sarcopenic seniors is need to consider their smaller body dimensions. Only the predictive equation of Escott-Stump with low caloric margin was precise.
- Message: The Escott-Stump equation with low caloric margin predicts total energy expenditure without overestimating daily energy requirements, increasing the chance of adherence to dietary planning.

ABSTRACT

Purpose: The accuracy and errors of prediction of equations that estimate energy expenditure are unknown to seniors with sarcopenia. This study assessed the precision of predictive equations to estimate energy needs of sarcopenic seniors. **Methods:** Ninety-four community-dwelling older adults (female: 66; mean age: 75.9[5.7]) were tested for body dimensions derived from DXA. Performance tests and diagnosis of sarcopenia were performed. The total energy expenditure (TEE) of sarcopenic seniors (n=10) was measured by accelerometry and compared with three anthropometric equations: DRIs, Escott-Stump with upper (Escott-Stumpupp) and low energy margin (Escott-Stumplow). **Results:** Except for height, all other variables of body dimensions of sarcopenic seniors were smaller than non-sarcopenic ones ($p<0.05$). The slightly lower TEE values in the Escott-Stumplow equation were not different from accelerometry (-53kcal; $t=0.606$; $p=0.560$) but were overestimated by the DRIs (+358kcal; $t=-3.163$; $p=0.011$) and Escott-Stumpupp (+240kcal; $t=-5.817$; $p<0.001$), confirmed due to lack of agreement (Bland-Altman) with measured TEE. **Conclusion:** Smaller body dimensions of sarcopenic seniors suggest that their energy needs should be estimated from specific resources. The TEE assessed by the Escott-Stumplow equation was similar to that measured by accelerometry and therefore may be a good alternative for sarcopenic seniors where direct measurement of TEE is not possible.

Keywords: energy metabolism; frailty; anthropometry; aged; frail elderly

RESUMO

Objetivo: A precisão e os erros de predição de equações que estimam o gasto energético são desconhecidos para idosos com sarcopenia. Este estudo avaliou a precisão de equações preditivas para estimar as necessidades energéticas de idosos sarcopênicos. **Métodos:** Noventa e quatro idosos (sexo feminino: 66; idade média: 75,9 [5,7]) foram testados quanto às dimensões corporais derivadas da DXA. Testes de desempenho e diagnóstico de sarcopenia foram realizados. O gasto energético total (GET) de idosos sarcopênicos (n=10) foi medido por acelerometria e comparado com três equações antropométricas: DRIs, Escott-Stump com margem calórica superior (Escott-Stumpsup) e inferior (Escott-Stumpinf). **Resultados:** Exceto a estatura, todas as demais variáveis das dimensões corporais dos idosos sarcopênicos foram menores que os não sarcopênicos ($p<0,05$). Os valores de GET foram ligeiramente mais baixos na equação de Escott-Stumpinf mas não foram diferentes da acelerometria (-53kcal; $t=0,606$; $p=0,560$), porém foram superestimados pela DRIs (+358kcal; $t=-3,163$; $p=0,011$) e Escott-Stumpsup (+240kcal; $t=-5,817$; $p<0,001$), confirmado por falta de concordância (Bland-Altman) com o GET medido. **Conclusão:** As dimensões corporais menores dos idosos sarcopênicos sugerem que suas necessidades energéticas devem ser estimadas a partir de recursos específicos. O GET avaliado pela equação de Escott-Stumpinf foi semelhante ao medido por acelerometria e, portanto, pode ser uma alternativa adequada para idosos sarcopênicos quando não for possível a medição direta do GET. **Palavras-chave:** metabolismo energético; fragilidade; antropometria; envelhecimento; Idoso frágil

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INTRODUCTION

Sarcopenia is a muscle disorder (CID M62.84) ^[1] characterized by low muscle strength and low skeletal muscle mass ^[2]. It is associated with an increased likelihood of adverse outcomes, including fractures, motor dependence and mortality ^[2]. Additionally, there is a three times higher risk of falls compared to healthy seniors ^[2, 3] and the length of hospitalization stay for Medicare places a heavy burden on public health systems ^[4]. Sarcopenia has a higher prevalence in the aged population ^[5], with a prevalence of 16% in older adults in Brazil (12% for men; 20% for women) and 10% for the world population ^[6, 7]. Sarcopenia can occur exclusively due to aging or additional causes, such as: systemic diseases - especially those that cause inflammatory and neurodegenerative processes; diseases that alter the levels of growth hormone (GH) and its respondents (IGF-1); dysfunction of the thyroid gland; sedentary lifestyle; physical disability or immobility caused by illness or inadequate nutrition ^[2]. In the case of the latter, nutritional factors related to insufficient energy or protein intake caused by anorexia, malabsorption, limited access to healthy foods or even limited ability to eat are antecedents of sarcopenia ^[2]. A caloric intake below daily needs, when the expenditure is greater than the energy intake, leads to neoglycogenesis (use of amino acids for energy generation) ^[8]. These amino acids may come from contractile skeletal

muscle proteins in a greater or lesser extent, depending on the relative rates of available macro nutrients ^[9]. Even with adequate protein consumption, the process of neoglycogenesis continues to occur ^[9], with considerable impact on the reduction of skeletal muscle mass, favoring the diagnosis of sarcopenia ^[2]. Thus, properly estimating energy expenditure is necessary for accurate dietary prescription to attenuates the stimuli of the mechanisms that trigger sarcopenia (i.e., insufficient energy consumption).

The energy expenditure by the human organism for 24 hours is called total energy expenditure (TEE), when quantified. TEE is characterized by energy expended to maintain life, being composed of basal metabolic rate (BMR), dietary induced thermogenesis (DIT) and energy expenditure of physical activity (PA) ^[10, 11]. BMR represents 60 to 80% of total TEE; and DIT results from the energy needed to digest, absorb and convert food into nutrients, which represents 10% of TEE. PA represents another 15-30% of TEE ^[10, 11], being the component of greatest variability depending on the person's physical activity level ^[12].

Doubly labeled water, based on the quantification of hydrogen and oxygen isotopes ^[13], is the method considered as the gold standard for measuring TEE. It can be administered without interfering in the person's daily life, as it does not require modification of

daily activities or habitual PA, as occurs when using gas analyzers ^[14]. However, it is a high cost method and involves technical complexity to obtain the results ^[15]. As a consequence other, more time and labor economical alternatives have been to quantify TEE have been examined. One alternative measure for estimating TEE are accelerometers (devices used to measure the acceleration of a system). These devices which also does not interfere with patients' daily lives, are capable of measuring the frequency, duration and intensity of body movements ^[16]. They records counts which can be converted to the metabolic equivalent of the task (MET), unit equivalent to 3.5 ml O₂·kg⁻¹·min⁻¹ ^[17]. The estimated MET is multiplied by BMR and increased by 10% for DIT [18], resulting in TEE ^[19]. However, accelerometer use in daily clinical practice does not seem feasible, as accelerometers themselves can be costly (approx. \$300 per unit) and they present some technical-operational complexity which generally dietitians do not receive training in. Although data collection is relatively easy, accelerometry data interpretation requires the use of specific software, discarding long periods of physical inactivity and sleep, converting counts to METs and comparing the results with appropriate benchmarks ^[20]. Furthermore, accelerometer TEE estimates show a high degree of agreement with doubly labeled water in older adults, with greater accuracy when compared, i.e., to heart rate and PA records ^[21],

^[22]. They thus represent a valid reference for recording human energy expenditure ^[17].

The 'equilibrium' between energy intake and the use of daily energy (energy balance) can prevent the additional requisition of builders' macronutrients (proteins) as energy source. As a consequence, since seniors with this disease have lower TEE compared to healthy ones ^[23-25], having reliable tools to estimate the TEE of sarcopenic seniors with low predictive errors and easy clinical application is essential for widespread use in public health nutrition and related settings. In addition, aging alone impacts on the physiology of the digestive system, causing a series of losses that, among many other consequences, culminate in reduced appetite and protein intake ^[26]. Thus, an imprecise dietary prescription with an overestimation of the amount of caloric intake can decrease adherence to dietary planning, given the greater intolerance to the ingestion of large food volumes with aging ^[26].

In this sense, anthropometric predictive equations of TEE that use information from the body dimensions are presented as effective tools with low operational cost and ease use in clinical practice for estimation of the necessary energy demands in humans. The classic literature on nutrition-related care and diagnostics presents dozens of equations for seniors ^[27], however, they predominantly estimate BMR. The exclusive options for estimating TEE in clinical practice appear to be the DRI ^[28] and

Escott-Stump equations ^[29]. To use the DRIs proposal is necessary to consider sex, age, body weight, height and physical activity level from pre-established physical activity coefficients (PAC). PAC allows classifying the patient's physical activity level into "sedentary", "low active", "active" or "very active" ^[28]. PAC is subjectively selected by the professional based on the report of habits, type and intensity of daily physical activities (<https://www.nal.usda.gov/fnic/dri-calculator/>).

The alternative option for estimating TEE is the Escott-Stump equation, also called "pocket formula". This nomenclature derives

from the ease of use in the field, since to estimate the patient's TEE just multiplying body weight by a determined coefficient (Chart 1). This coefficient is derived from the classification of body mass index (BMI) and associated factors, considered in two energy margins (lower and upper). The choice of coefficient between the margins is subjective, which takes into account age, physical activity level, body dimensions, pre-existence of diseases, among other factors that influence the TEE.

Chart 1 Escott-Stump anthropometric equation to estimate total energy expenditure (TEE)

BMI (kg·m ⁻²)	Kcal·kg ⁻¹ of current weight	
	Lower energy margin (Escott-Stump _{low})	Upper energy margin (Escott-Stump _{upp})
< 15	35	40
15 a 19	30	35
20 a 29	20	25
> 30	15	20

Source: adapted from Escott-Stump (2008).

To the best of our knowledge the anthropometric equations of the DRIs and Escott-Stump ^[28, 29] of recurrent use in clinical practice ^[30] have not yet been compared with any referential methods in sarcopenic seniors ^[31]. The accuracy of these estimates and possible prediction errors are unknown. Without quantifying the effectiveness of such prediction equations, dieticians, nutritionists, nutrologists and other health professionals may be at risk of making erroneous conclusions for practice. Thus, our objective was to verify the agreement between TEE referenced by

accelerometry and the values estimated by anthropometric equations in sarcopenic older adults.

METHODS

In this cross-sectional descriptive study, an intentional convenience sample was consisted of 94 older people of both sexes (66 women) aged 60 to 88 years. The older adults were regulars of three projects: Health services for seniors at Hospital of Ribeirao Preto School of Medicine, University of Sao Paulo, Brazil (HC-FMRP-USP); Physical Education Program for the seniors at Ribeirao Preto School

of Physical Education and Sport (EEFERP-USP); and Fragility Project developed by FMRP-USP. The study took place between July and October 2017. The inclusion criteria comprised: not having cancer, uncontrolled chronic diseases (heart or kidney failure), not having sequelae from stroke or unintentional weight loss greater than three kg in the last three months. The exclusion criteria were: not completing the tests or measures of the study, any impairment in health deterioration that limited participation, address change, giving up voluntary participation in the study or death. This study was conducted according to the legal recommendations in the Declaration of Helsinki and approved by the Research Ethics Committee of the HC-FMRP-USP (CAAE: 54345016.6.3001.5440). All subjects signed a Free and Informed Consent forms.

Body dimensions

Assessment of body dimensions was performed at HC-FMRP-USP and at the Laboratory of Kinanthropometry and Human Performance (LACiDH) of EEFERP-USP. From the height (m) and body weight (kg), the BMI in $\text{kg}\cdot\text{m}^{-2}$ (36) and body surface area in m^2 [32] were calculated. Other body measurements were obtained from dual energy X-ray absorptiometry (DXA) by Hologic® model Discovery CI/WI (software version 11.2, Bedford, MA, USA). Fat mass, fat-free mass, appendicular lean soft tissue (ALST) used

to calculate the skeletal muscle index ($\text{SMI} = \text{ALST}\cdot\text{height}^{-2}$) were obtained, according to previously described procedures [33].

For performance tests, we initially applied the Mini-Mental State Examination [34] to guarantee that seniors enjoyed full cognitive abilities and understanding of the tests. Dementia was considered who reached ≤ 12 points from the possible maximum score (19 points). Muscle strength was measured from a handgrip test in kg, using a manual dynamometer (Jamar® - modelo 5030J1, OH, USA) [35]. The highest measure of three attempts of the dominant hand was employed [36,37]. Gait speed was determined by 4-m usual walking speed test [38]. The course was monitored with photocells (FE Sistemas® - FSpeed Standard model, São Paulo, Brazil) [38]. The average speed ($\text{m}\cdot\text{s}^{-1}$) of two attempts was recorded.

Sarcopenia

Sarcopenia was classified based on the current criteria established by the European Working Group on Sarcopenia in Older People (EWGSOP) [2]. The diagnosis is confirmed when the older adults does not reach minimum values of the first two criteria, which consist of: 1) Low muscle strength - determined when the handgrip strength was ≤ 30 or 21.7 kg for men and women, respectively [39]; 2) low muscle quantity – determined when SMI was ≤ 7.1 $\text{kg}\cdot\text{m}^{-2}$ for men [40] or ≤ 6.8 $\text{kg}\cdot\text{m}^{-2}$ for women [41]; and 3) Low physical performance

- confirmed when the gait speed was ≤ 0.8 m·s⁻¹ [2], characterizing severe sarcopenia, as 3rd criteria.

Measured total energy expenditure(TEE)

The measured TEE was determined using accelerometry (wGT3X-BT, Actigraph, Pensacola, FL; USA) fixed to the waist (dominant side), worn continuously for a period of seven days, including the weekend. A sampling frequency of 30 hertz, epoch length of 60 seconds, sleep time filter [42] and exclusion of inactive intervals ≥ 10 min [43] were employed. Counts were initially converted to MET using the equation [44]:

$$\text{METs} = 1.439008 + (0.000795 * \text{counts} \cdot \text{min}^{-1})$$

The determination of TEE in kcal was given by the equation [19, 18]:

$$\text{TEE} = (\text{MET} * \text{BMR}) * 1.10$$

BMR was calculated from the classic Harris and Benedict model [45].

Predicted total energy expenditure(TEE)

The predicted TEE was calculated using the anthropometric equations of DRIs [28], Escott-Stump based on the lower (Escott-Stumplow) and upper energy margin (Escott-Stumpupp) [29]. The TEE estimate in kcal using

the DRIs equation followed the specificity by sex:

$$\text{TEE (men)} = 662 - (9.53 * \text{age [years]}) + \text{PAC} (15.91 * \text{body weight [kg]} + 593.6 * \text{height [m]})$$

$$\text{TEE (women)} = 354 - (6.91 * \text{age [years]}) + \text{PAC} (9.36 * \text{body weight [kg]} + 726 * \text{height [m]})$$

The PAC for each sex was considered from the closest value to the calculated MET.

Nutritional status

Nutritional status was determined from BMI intervals, proposed for older adults [46]: underweight (≤ 22), eutrophy ($22 < \text{BMI} < 27$) and overweight (≥ 27).

Statistical analysis

Descriptive statistics and confidence interval (CI 95%) were calculated. Normality of data was tested by Kolmogorov-Smirnov for non-sarcopenics ($n > 30$) and Shapiro-Wilk for sarcopenics ($n \leq 30$). The t-test for independent samples was used to compare the variables of body dimensions, performance tests and BMR. Paired t-test was used to compare measured TEE (accelerometry) with that predicted by anthropometric equations. The degree of agreement between TEE measured and predicted was checked using Bland-Altman plots [47]. All analysis was performed using SPSS v. 23.0 and MedCalc v. 15.2 statistical packages, with a previously

established level of significance ($\alpha = 5\%$).

RESULTS

The recruitment, screening and evaluation protocol of the participants is shown in Figure 1.

Fig 1 Flowchart of participation and measures taken in older adults in the present study

Descriptive statistics of body dimensions, performance tests, energy expenditure and comparisons between seniors with and without sarcopenia are summarized in Table 1. The number of sarcopenic seniors ($n = 10$) was 10.64% of the total sample versus non-sarcopenic ($n = 84$). The distribution for sex among sarcopenics (female = 6; male = 4) was more equitable than non-sarcopenics (female = 60; male = 24). The age of sarcopenics (75.9[5.7]) was also statistically higher ($t = -3.143$; $p < 0.001$) than non-sarcopenics (69.5[6.1]). With the exception of height, all variables of body dimensions of sarcopenics were statistically lower ($p < 0.05$) than the

seniors without disease. Statistically significant differences between groups were confirmed both in measured (Weight, body surface area, fat mass, fat free mas, ALST) and derivative (BMI, SMI) variables. In performance tests, the average score on Mini-Mental State Examination was close to the maximum possible for both groups: sarcopenics (18.0[0.9] points) and non-sarcopenics (17.3[1.8] points). There was no difference between mean scores ($p > 0.05$), showing that in the cognitive status both groups were equally capable. The same competence was also observed in the usual gait speed, with average performance values statistically similar for sarcopenic (1.31[0.31] m·s⁻¹) and

non-sarcopenic ($1.25[0.35] \text{ m}\cdot\text{s}^{-1}$). However, in regard to muscle strength (handgrip) the groups differed ($t = 2.154$; $p < 0.05$), where the mean value for sarcopenics ($22.5[5.2] \text{ kg}$) was 8% lower than non-sarcopenics ($28.4[8.5] \text{ kg}$).

The normality tests showed greater homogeneity of age and physical characteristics among sarcopenic seniors (values 0.910 to 0.966 ; $p > 0.05$). Whereas, the group of non-sarcopenic seniors showed greater variability (values 0.077 to 0.212 ; $p < 0.05$) in most age and physical characteristics, except for fat mass, BMI and SMI. The nutritional status showed that half of the non-sarcopenics had eutrophy, with BMI between 22 and $27 \text{ kg}\cdot\text{m}^{-2}$ (Table 1). About 49% were overweight (BMI $> 27 \text{ kg}\cdot\text{m}^{-2}$) and only one case (1%) was classified as underweight (BMI $< 22 \text{ kg}\cdot\text{m}^{-2}$). Among sarcopenic seniors, there was a predominance of underweight (50%) followed by eutrophy (40%). There was only one case of overweight (10%). No participant had severe sarcopenia, as gait speed was always above $0.8 \text{ m}\cdot\text{s}^{-1}$ (4).

For the sarcopenic seniors, TEE (accelerometry) did not show statistically significant differences between the sexes ($t = -1.136$; $p = 0.289$). Thus, in all subsequent comparisons, the sarcopenic seniors were considered as a single sample. It is important to mention that the metabolic energy demand for the daily activities of these sarcopenic older adults was very low (MET = 1.03). That

is, the average daily metabolic expenditure was very close to the consumption unit at rest ($1 \text{ MET} = 3.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). Thus, in the PAC classification, 90% of these seniors were sedentary and only one case was low active. When comparing the reference TEE (accelerometry) with the Escott-Stumpflow equation (Figure 2), the mean value did not differ statistically from the accelerometry ($t = 0.606$; $p = 0.560$), with a negligible percentage delta ($\Delta = -4\%$). The agreement plot (Bland-Altman) between methods (Figure 3a) confirms this small bias in the mean of the differences (-53.0 kcal), which does not exceed the recommended variation for dietary prescription (between 90 and 110 %) of the expected daily energy requirement [48]. On the other hand, there was a statistically significant difference (Figure 2) for the DRIs ($t = -5.817$; $p < 0.001$) and Escott-Stumpflow equation ($t = -3.163$; $p < 0.05$), as also indicated by the differences (t-paired test) between the true values in Table 1 (*, †). The overestimated values are in the order of 18 and 27% ($\Delta\%$) for the Escott-Stumpflow and DRIs equations, respectively. The Bland-Altman plots (Figure 3: panel b, c) confirm these biases in comparisons between TEE measured by accelerometry and the highest values predicted in the Escott-Stumpflow (240 kcal) and DRIs equations (358 kcal), respectively.

Table 1. Descriptive statistics and comparisons of the variables of body dimensions, performance tests, energy expenditure of older adults (n = 94).

Variable	unit	Descriptive statistics										Comparisons				
		Sarcopenics (n=10)					Non-sarcopenics (n=84)									
		range	mean	Standard deviation	f	Shapiro-Wilk	range	mean	Standard deviation	f	Kolmogorov-Smirnov	t value	p			
		(min; max)	value	CI (95%)		value	p		(min; max)	value	CI (95%)					
Age	years	(69.0; 84.0)	75.9	71.8 to 80.0	5.7	0.910			(60.0; 85.0)	69.5	68.1 to 70.8	6.1	0.100	<0.05	-3.143	<0.01
Body dimensions																
Height	m	(1.5; 1.7)	1.6	1.5 to 1.6	0.1	0.966			(1.5; 1.9)	1.6	1.6 to 1.6	0.1	0.106	<0.05		
Weight	kg	(39.9; 83.1)	58.6	48.4 to 68.8	14.2	0.96			(45.6; 109.9)	69.8	67.2 to 72.5	12.1	0.099	<0.05	2.727	<0.01
BMI	kg·m ⁻²	(18.3; 27.7)	22.9	20.3 to 25.5	3.6	0.898			(17.5; 39.9)	27.3	26.4 to 28.2	4.2	0.078	<0.05	3.210	<0.01
Body surface area	m ²	(1.3; 2.0)	1.6	1.4 to 1.8	0.2	0.938			(1.4; 2.4)	1.8	1.7 to 1.8	0.2	0.115	<0.01	2.577	<0.05
Fat mass	kg	(10.0; 31.0)	21.1	15.1 to 27.1	8.4	0.884			(7.6; 47.9)	26.6	24.9 to 28.2	7.6	0.077	<0.05	2.126	<0.05
Fat free mass	kg	(25.8; 47.8)	36.6	31.4 to 41.8	7.3	0.941			(29.9; 80.8)	43.3	41.3 to 45.3	9.1	0.126	<0.01	2.228	<0.05
Appendicular lean soft tissue	kg	(9.2; 19.4)	13.6	11.2 to 16.0	3.4	0.883			(11.1; 32.5)	16.7	15.8 to 17.7	4.3	0.135	<0.01	2.262	<0.05
Muscle mass index	kg·m ⁻²	(4.29; 6.61)	5.35	4.79 to 5.91	0.78	0.913			(4.19; 9.41)	6.47	6.23 to 6.72	1.14	0.088	<0.01	3.024	<0.01
Nutritional status																
Underweight	%				50										1	
Eutrophy	%				40										50	
Overweight	%				10										49	
Performance variables																
Mini-mental score	0-19 points	(17.0; 19.0)	18.0	17.3 to 18.7	0.9	0.769	<0.05		(13.0; 19.0)	17.3	17.0 to 17.7	1.8	0.212	<0.001		
Handgrip strength	kg	(17.0; 30.0)	22.5	18.8 to 26.2	5.2	0.838	<0.05		(12.0; 56.0)	28.4	26.6 to 30.3	8.5	0.139	<0.001	2.154	<0.05
Gait speed (4m)	m·s ⁻¹	(0.95; 2.00)	1.31	1.09 to 1.54	0.31	0.920			(0.63; 2.51)	1.25	1.17 to 1.32	0.35	0.109	<0.05		
Total energy expenditure (TEE)																
Accelerometry	kcal	(968.9; 1842.4)	1321.6	1136.6 to 1506.5	258.6	0.935										
Escott-Stump _{low}	kcal	(912.0; 1653.0)	1268.6	1117.1 to 1420.0	211.7	0.952										
Escott-Stump _{upp}	kcal	(1140.0; 1928.5)	1561.6*	1384.9 to 1738.2	246.9	0.962										
DRI _{ts}	kcal	(1265.9; 2582.2)	1679.2†	1386.0 to 1972.4	409.9	0.865										
Physical activity level (from PAC)																
Sedentary	f				90											
Low active	f				10											
Active	-				-											
Very active	-				-											

*p < 0.05 vs TEE Accelerometry of Sarcopenics

†p < 0.001 vs TEE Accelerometry of Sarcopenics

BMI=body mass index

low= lower caloric margin

upp=upper caloric margin

DRI_{ts}= Dietary Reference IntakesPAC=physical activity coefficient from DRI_{ts}

Fig 2 Comparison of the total energy expenditure measured by accelerometry with that estimated by anthropometric equations in sarcopenic seniors.

low= lower energy margin; upp= upper energy margin; Δ = delta% of the difference (vs. TEE accelerometry); DRIs=Dietary Reference Intakes.

In addition, the DRIs equation (Figure 3c) showed heteroscedasticity of data, as there was a high association between the x axis (mean) and the y axis (difference) in the Bland-Altman plot ($r = 0.792$; $p = 0.006$). Thus, the slope of the trend line of this regression suggests an increase in error as TEE increases. Conversely, there was no heteroscedasticity of data ($p > 0.05$) for the Escott-Stumpalow ($r = -0.208$; $p = 0.564$) and Escott-Stumpupp equations ($r = -0.055$; $p = 0.880$).

Fig 3 Degree of agreement between the total energy expenditure measured by accelerometry and that estimated by anthropometric equations (kcal) in sarcopenic seniors.

low= lower energy margin; upp= upper energy margin; DRIs=Dietary Reference Intakes.

DISCUSSION

The present study, for the first time, presents data comparing the accuracy of TEE estimated from commonly used prediction equations and TEE, assessed using objective measures. As a consequence, the current study presents data with practical application for use in public health nutrition where direct assessment of TEE is not possible and proxy measures are needed. Our findings allowed us to evaluate the accuracy of the Escott-Stumpflow equation by predicting the TEE values measured by accelerometry in older adults with sarcopenia without statistically significant differences. The estimates of this equation also confirmed an adequate agreement between the methods (Bland-Altman plot), as the data did not present heteroscedasticity (Figure 3a). Obviously, this does not eliminate the lack of bias in the measured TEE (around 50 calories), but suggests consistency of the estimators, since this difference is not related to the magnitude of the observed dispersion. The other equations were not in agreement with the TEE measured by accelerometry. In addition, the DRIs equation presented heteroscedasticity of the data, with tendencies to growing prediction errors as the TEE increased. Our findings identify that in terms of body dimensions, sarcopenic seniors are physically smaller than non-sarcopenics (Table 1). The magnitude of these differences observed in body weight (-16%), body surface area (-11%),

fat mass (-20.7%), fat free mass (-15.5%) and SMI (-17.3%) was statistically significant for all these comparisons. Accordingly, the relative frequency of underweight in nutritional status was 50% among sarcopenics versus only 1% in non-sarcopenics. These results demonstrate that the energy and nutritional needs of sarcopenic seniors require precise estimates from accurate and reliable methods and inferring energy and nutritional needs from non-sarcopenic seniors may not be appropriate.

Previous studies have shown the accuracy of accelerometers to estimate TEE in older adults referenced in the doubly labeled water technique ^[21, 22]. In this way, the TEE estimates of the accelerometers were considered as a safe reference parameter to test the anthropometric equations in this study. A study ^[21] that measured TEE with doubly labeled water technique, in older women with frailty syndrome (physical characteristic close to sarcopenia) showed a similar mean (1.421 ± 274 kcal) to the values of the sarcopenic seniors in our study (1.322 ± 259 kcal). Two important points explain part of this similarity: 1) the largest number of females in our sample and; 2) similar body dimensions between our study (BMI: $23.2 \text{ kg}\cdot\text{m}^{-2}$) and the study analyzed (BMI: $22.4 \text{ kg}\cdot\text{m}^{-2}$). These are preponderant factors with predictive impact on TEE that support our decision to choose accelerometry as a comparative reference. That is, there is similar sensitivity to these methods

in measuring TEE in physically smaller seniors. The smaller physique of our elderly with sarcopenia in most variables of body dimensions ($p < 0.05$; Table 1) confirmed the morphological characteristics for the diagnosis of the disease^[2]. These sarcopenic seniors were more homogeneous than non-sarcopenic ones, when the normality of ALST (value = 0.883; $p = 0.140$) and SMI (value = 0.913; $p = 0.299$) did not exceed the normality criterion of Shapiro-Wilk (value < 0.938). This more homogeneous and physically smaller characteristic of seniors with sarcopenia results in less energy expenditure^[23-25]. Thus, the non-differentiated nutritional support and the use of imprecise equations to estimate TEE can generate gross errors in the dietary prescription, leading to the risk of overestimating the real caloric need of older adults. This type of error can reduce your adherence to the diet, since lack of appetite is typical in this age group^[26].

The frequency of sarcopenia in our older adults (10.6%) was similar to the prevalence found worldwide (10%) for people over 60 years old^[6]. However, the lower frequency in relation to the national prevalence (16% in Brazil), possibly can be explained by our study include only physically active and independent community-dwelling older adults, while the comparative study of national meta-analysis included seniors living in assisted living facilities, nursing home residents and community-dwelling older adults^[7]. In this

sense, the profile of habitual mobility and autonomy of older adults should be observed in these comparisons, with estimates of their physical activity habits and energy expenditure. The subjective choice of the PAC required to estimate the TEE by the DRIs equation, in our study was obtained in a more realistic way from the METs obtained via accelerometry. The mean obtained of PAC (1.01[0.04]) characterized a very low physical activity level, when 90% of older adults were classified as “sedentary” (PAC = 1.00) and only one case was classified as “low active” (PAC = 1.12). Throughout the weekly period observed, there was a predominance of intensity levels of sedentary activities (69.0%), followed by light activities (29.7%) and only 1.2% of moderate activities. There was no record of moderate to vigorous physical activity, indicating that none of the participants met the minimum weekly recommendations proposed by the World Health Organization, of 150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity^[49].

To the best of our knowledge there are no other studies that have examined the accuracy of anthropometric predictive equations for TEE in sarcopenic older adults. The validity of using these tools in everyday clinical practice, called as ‘pocket formulas’, needed confirmation as without this health professionals may be more likely to draw

erroneous conclusions based on inaccurate proxy prediction equations. In this sense, the Escott-Stumprow equation was effective for sarcopenic seniors. The findings of our study initially highlight the distinction in the smaller body dimensions of older adults with sarcopenia and the need to have a different nutritional support for these individuals compared to non-sarcopenics. Then, the risk of inadequate equations generate gross prescription errors, reduces adherence to the necessary treatments with an appetite bias. Finally, despite the high use of DRI equations in clinical practice at all ages, the current study demonstrates that these are not accurate for sarcopenic older adults. Therefore, caution is needed when interpreting its results due to its greater potential for error in the prediction of TEE in sarcopenia profiles.

As limitations of our study we can point out: 1) the energy demand of the seniors in our study considered only a global approach in TEE, without directly measuring BMR and DIT. However, we identified the MET to obtain (more objectively) the PAC and classify the physical activity level of older adults; 2) we do not use the doubly labeled water technique, considered as a reference for TEE measurements, although its agreement with accelerometry seems well consolidated ^[21, 22]. Furthermore, this procedure has a high cost, is not without evaluation errors and is restricted to large research centers; 3) the sample size in

our study was small, which warns of caution when extrapolating these results in populations with characteristics similar to ours. Despite this, the frequency of sarcopenia in our sample was similar to the worldwide occurrence of sarcopenia. Future research could expand the investigation of the energy demands of sarcopenic older adults with other functional factors (i.e., physical activity, associated diseases) to better define the real dietary needs of sarcopenics. The accuracy of the anthropometric equation with the best estimate of TEE in our study still needs to be tested with reference methods such as doubly labeled water technique and in other populations, to make it widely recommended for use.

Nutritional factors and natural physiological changes of aging can cause sarcopenia ^[2], because insufficient energy consumption also called as negative energy balance can trigger the neoglycogenesis [8, 9]. The process involves degradation of the contractile proteins of the skeletal muscle and the subsequent removal of amino acids for energy generation ^[2, 8]. Thus, due to anatomical and functional changes in aging that affect the health of older adults, greater precision in the prescribed caloric quantity is required, especially in the case of the most debilitated. An overestimated dietary prescription is discouraging for seniors with reduced appetite due to aging itself, as in this condition it will be difficult to ingest the prescribed amounts^[50].

Reductions in BMR, TEE, percentage of lean mass and increase in adipose tissue are notable changes ^[51] that require attention and monitoring, as well observed in our seniors with sarcopenia (Table 1). Specifically, in the digestive system, several changes are noted that result in nutritional deficiencies, increased intolerance to food, constipation, reduced protein intake and loss of appetite, among other losses ^[26]. Therefore, there are important clinical implications of the results we present in the current study, principally the need for adequate selection of predictive instruments which accurately relate to the realistic energy demands in older adults with sarcopenia.

CONCLUSION

In conclusion, the accuracy of DRIs and Escott-Stumpupp predictive equations to estimate energy needs of sarcopenic older adults demonstrate significant inaccuracy. The smaller body dimensions of sarcopenic seniors indicate the need for specific equations to estimate their real energy needs. Only the TEE estimate using the Escott-Stumpflow equation was consistent with TEE assessed using accelerometry without presenting heteroscedasticity in the data. Therefore, using this equation to estimate the TEE of sarcopenic older adults seems to be the most viable alternative, when expensive and more sophisticated methods are not available.

Conflict of interest

No potential conflict of interest was reported by the authors.

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Code availability

Not applicable.

Author contributions

PPA: Conceptualization; Roles/ Writing - original draft; ASC: Data curation, Visualization; APS: Methodology, ACRV: Formal analysis; NCR: Software, JM: Funding acquisition, Supervision; JAGM: Investigation, MD: Writing - review & editing; DRLM: Validation and Project administration, Resources. All authors read and approved the final manuscript.

Ethics approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (of the HC-FMRP-USP CAAE: 54345016.6.3001.5440) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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