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Original articles

Reported energy intake versus estimated energy requirements of Portuguese adolescents and young adults

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Summary.
Abstract
Introduction/objective: Predictive equations are commonly used to estimate basal metabolic rate/resting metabolic rate and determine energy requirements, with the Harris-Benedict equation being amongst the most study equations. However, if this formula effectively addresses basal metabolic rate/resting metabolic rate in individuals living in contemporary societies is still unclear. In the present study we compared the energy intake of Portuguese adolescents/young adults with their energy requirements by gender, age and Body Mass Index category. **Methods:** This was a cross-sectional study that included 287 participants from the 9th to the 12th grade, that recorded their food intake for at least 3 days in an online platform and had complete anthropometric data. The Harris-Benedict equations were used to estimate the energy requirements of adolescents/young adults. **Results:** Overall energy intake of adolescents/young adults was significantly lower than their requirements (1898.6 kcal versus 2047.1 kcal, p<0.001; Cohen's d= -0.42). The same was observed for both genders, with girls having a reported energy intake (REI) of 1847.9 kcal and estimated energy requirements (EER) of 1912.5 kcal (p=0.011; Cohen's d= -0.18); and boys a REI of 2002.6 kcal and an EER of 2323.5 kcal (p<0.001; Cohen's d= -1.09). Additionally, REI was significantly lower than EER for adolescents (1896.4 kcal versus 2052.9 kcal, p <0.001; Cohen's d= -0.45), normal weight (1896.8 kcal versus 2014.3 kcal, p <0.001; Cohen's d= -0.33), overweight (1912.5 kcal versus 2214.1 kcal, p<0.001; Cohen's d= -1.03), obese adolescents/young adults (1964.1 kcal versus 2362.2 kcal, p<0.001; Cohen's d= -2.14) and in all school grades. **Conclusion:** The energy intake of adolescents/young adults was significantly lower than their requirements for both genders, adolescents, normal weight, overweight and obese individuals and in all school grades (p<0.05).

Keywords: energy intake, energy requirements, adolescents, Body Mass Index

Introduction

Energy balance is defined as the biological homeostasis of energy in living systems and its basic components comprise energy intake, energy expenditure and energy stored(1,2). Energy balance is achieved when energy intake equals energy expenditure and body weight is stable. However, when energy intake exceeds energy expenditure, a state of positive energy balance occurs, that if sustained over time, will promote obesity(2,3).

Humans take in energy in the form of macronutrients (carbohydrates, protein and lipids) and alcohol; and expend it through: (i) resting metabolic rate

(RMR) – which is the energy required by the body in a resting condition, (ii) the thermic effect of food (TEF) – which is the energy allocated for absorbing and metabolizing the food ingested and (iii) the energy expended through physical activity(2,4). RMR is the largest component of daily energy expenditure and can range from 50% of the total energy expenditure in physically active individuals and 70% in sedentary individuals(5,6). Some controversy in the literature exists about the distinction between RMR and basal metabolic rate (BMR), and in this study the two terms will be used reciprocally. However, one should bear in mind that BMR is slightly lower than RMR, since BMR is measured shortly after participants wake up, succeeding an overnight stay in a research facility or metabolic chamber, while RMR is obtained when participants arrive at the research facility in the morning(7). TEF magnitude varies with the individual and type of food consumed, however in a typical mixed diet, TEF comprises 8 to 10% of the total energy ingested(2,8). Physical activity energy expenditure is the most variable component of energy expenditure(9) and can be further divided into exercise and non-exercise activity-induced thermogenesis(10). Non-exercise activity-induced thermogenesis comprises a combination of energy spent on the daily living physical activities, fidgeting, spontaneous muscle contraction and maintaining posture when not recumbent(11). Nevertheless, it should be noted that the relative contribution of each component to total energy expenditure is largely dependent on the interindividual variability of each component(12).

Indirect calorimetry is considered the "gold standard" to measure metabolic rate, however its associated costs (purchase and maintenance of the equipment and training personnel) make its widespread use challenging(7,13). Therefore, predictive equations are commonly used as an easy and cost-effective alternative to estimate BMR/RMR and determine energy requirements(7). One of the earliest and most studied prediction equations is the Harris-Benedict equation that was derived in 1919(7,13). This equation takes into account gender, body weight, height and age. Then to obtain the total daily energy requirements in free-living individuals, the calculated BMR/RMR must be multiplied by an activity factor(14). However, if this formula effectively addresses BMR/RMR in individuals living in contemporary societies is unclear, as it has been reported that this formula might overpredict or underestimate BMR/RMR (15). Furthermore, the Harris-Benedict equation does not appear to permit a valid estimation of BMR/RMR in obese subjects(15).

Hence, the objective of this study was to determine the energy intake of Portuguese adolescents/young adults and compare it with their energy requirements by gender, school grade, age and Body Mass Index (BMI) category.

Material and methods

Participants

This cross-sectional study was conducted in six schools across Portugal (Lisboa, Palmela, Portalegre, Santo Tirso, Olhão and Tomar) and included participants from the 9th to the 12th grade. Only participants that had recorded their food intake for at least 3 days and had complete anthropometric data were included. Subjects were excluded from the study if they were undergoing nutritional counseling. In addition, a severe outlier was excluded from the analysis, leaving a final sample of 287 participants. Ethical approval was received from the Ethical Committee of Centro Hospitalar da Cova da Beira (Covilhã, Portugal) and written informed consent was obtained from all participants.

Dietary assessment, physical activity and demographic variables

Reported energy intake (REI), physical activity and self-reported demographic variables (such as age and gender) were collected using Obesidata, which is a self-administered health studies online platform. The platform is designed to allow the digital recording of all food and beverages consumed (in grams or milliliters or unit sizes) divided in six meals (breakfast, midmorning snack, lunch, midafternoon snack, dinner and supper). The amount of food and beverages consumed is estimated by selecting the closest portion size among three different options. Food composition data was derived from the Portuguese Food Composition Table developed by the National Health Institute

Doctor Ricardo Jorge, which is the national reference document for the composition of foods consumed in Portugal, and provides information about 42 components/nutrients in 962 foods(16). Moreover, product data from accredited manufactures was also included. Therefore, overall Obesidata includes 1200 food items. Data regarding physical activity was inserted by the participants in the platform during the physical education classes and the intensity of the exercise was evaluated in conjunction with the physical education teacher. Participants were classified as: (i) sedentary if they did little or no exercise; (ii) lightly active if they did light exercise 1-3 times a week; (iii) moderately active if they did moderate exercise 3-5 times a week and (iv) active if they did intense exercise 6-7 times a week(17).

Energy Requirements

The Harris-Benedict equations were used to estimate BMR/RMR (kcal/day) and can be found in Table 1.

Then to obtain the estimated energy requirements (EER) of each participant, the previously calculated BMR/RMR was multiplied by the physical activity level (PAL). PAL was defined as sedentary (PAL = 1.2), lightly active (PAL = 1.375), moderately active (PAL = 1.55)and very active (PAL = 1.725)(17). EER was calculated using participants' actual weight.

Anthropometry

Body weight was measured to the nearest 0.1kg with light clothes and no shoes, using a SECA 803 scale. Height was measured to the nearest 0.1 cm, using a SECA 213 stadiometer. BMI was calculated as weight divided by height squared (kg/m2). If participants were 19 years of age or younger, BMI was converted into age and gender specific BMI z-scores using the World Health Organization 2007 growth reference and categorized as underweight (<-2SD), overweight (between +1SD and <+2SD) and obese (>+2SD) (19). For participants over 20 years old, standard BMI categories of less than 18.5 (underweight), 18.5–24.9 (normal weight), 25.0–29.9 (overweight), and 30.0 or more (obese) were used(20).

Statistical Analysis

Statistical analysis was conducted with SPSS, version 24.0 (IBM® Corp., Armonk, NY, USA). Standard statistical methods were used for the descriptive statistics (mean ± Standard Deviation (SD), median and frequencies (%)) and statistical significance was set at $p<0.05$. In the present study we used parametric tests when the sample size was greater than 30 and assumed that the sampling distribution of the mean was normal based on the Central Limit Theorem. The previous theorem states that "given random and independent samples of N observations each, the distribution of sample means approaches normality as the size of N increases, regardless of the shape of the population distribution" (21). If the sample size was smaller than 30, the Shapiro-Wilk test was used to assess the normality. To test for statistical differences between REI and EER means, we computed a new variable that resulted from the difference between REI and EER and then compared its mean to zero applying a One Sample *t* Test. To test for statistical differences between REI/EER/REI-EER means across age and gender categories an independent t-test was used. The one-way analysis of variance (ANOVA) was used to determine whether there were statistically significant differences between REI/EER/REI-EER means across

BMI categories and school grades. Effect size was estimated using Cohen's d(22).

Results

The characteristics of the study participants stratified by gender are summarized in Table 2. The sample comprised 287 individuals of each 193 (67.2%) were

Table 1. Harris-Benedict equations used to estimate BMR/RMR (kcal/day).

	Boys	Girls
Harris-Benedict equation(18)	66 + 13.7 x W + 5.0 x H – 6.8 x A	655 + 9.6 x W + 1.8 x H – 4.7 x A
W = Weight (kg); H = Height (cm); A = Age (years)		

Table 2. Descriptive characteristics of the sample (n=287) stratified by gender.

	Girls (n=193)		Boys (n=94)	
	Mean±SD	Median	Mean±SD	Median
Age (years)	17.8 ± 1.3	18.0	17.9 ± 1.2	18.0
Weight (kg)	56.9 ± 10.5	54.2	66.9 ± 12.6	66.6
Height (cm)	161.4 ± 6.6	161.0	173.7 ± 8.4	174.5
BMI (kg/m^2)	21.8 ± 3.6	21.1	22.1 ± 3.5	21.9
		Frequencies (%)		
BMI Category				
Underweight	1.0		5.3	
Normal weight	84.5		78.7	
Overweight	9.8		11.7	
Obese	4.7		4.3	
PAL				
Sedentary	37.3		42.6	
Lightly Active	42.0		34.0	
Moderately Active	16.1		21.3	
Very Active	4.7		2.1	

girls and 94 (32.8%) were boys. The age of the participants ranged from 15 to 22 years and the mean age was 17.8 and 17.9 years among girls and boys, respectively. The mean BMI for girls was 21.8 kg/m^2 and for boys 22.1 kg/m^2. The majority of the girls (84.5%) and boys (78.7%) had normal weight, while the percentage of overweight boys (11.7%) was slightly higher than the percentage of overweight girls (9.8%). Obesity prevalence was 4.7% and 4.3% for girls and boys, respectively. Regarding PAL, most girls (79.3%) and boys (76.6%) were either sedentary or lightly active.

Overall REI was significantly lower than EER (1898.6 kcal versus 2047.1 kcal, p<0.001; Cohen's d= -0.42). The same was observed for both genders, with girls having a REI of 1847.9 kcal and an EER of 1912.5 kcal (p=0.011; Cohen's d= -0.18) and boys a REI of 2002.6 kcal and an EER of 2323.5 kcal (p<0.001; Cohen's d= -1.09). Furthermore, REI was significantly higher among boys (p=0.003). (Table 3) When EER and REI were stratified by school grade (Table 4) REI was significantly lower than EER in all grades and REI did not differ across school grades. In Table 5 we find the mean and SD of EER and REI stratified by age and we observed that REI was significantly lower than EER in the adolescents' category (1896.4 kcal versus 2052.9 kcal, p <0.001; Cohen's d= -0.45). We also found that REI was significantly lower than EER for normal weight (1896.8 kcal versus 2014.3 kcal, p <0.001; Cohen's d= -0.33), overweight (1912.5 kcal versus 2214.1 kcal, p<0.001; Cohen's d= -1.03) and obese adolescents/young adults (1964.1 kcal versus 2362.2 kcal, p<0.001; Cohen's d=

Table 3. Mean and SD of total EER and REI and stratified by gender.

	REI (kcal)	EER (kcal)	REI-EER (kcal)	P-value	Cohen's d†
Gender					
Girls (n=193)	1847.9 ± 418.52	1912.5 ± 248.3	-64.6 ± 351.5	**0.011**	-0.18
Boys (n=94)	2002.6 ± 385.5	2323.5 ± 295.2	-320.9 ± 293.9	**<0.001**	-1.09***
P-value	**0.003**	**<0.001**	**<0.001**	---	---
Total (n=287)	1898.6 ± 413.8	2047.1 ± 327.2	-148.6 ± 354.3	**<0.001**	-0.42*

†Classification of Cohen's d effect sizes: trivial (Cohen's d ≤ .2); * small (Cohen's d > .2); ** moderate (Cohen's d > .5); *** large (Cohen's d > .8); **** very large (Cohen's d > 1.3)(22)

Table 4. Mean and SD of total EER and REI and stratified by school grade.

	REI (kcal)	EER (kcal)	REI-EER (kcal)	P-value	Cohen's d†
School Grade					
9th(n=63)	1855.73 ± 373.19	2047.41 ± 324.30	-191.69 ± 433.03	**0.001**	-0.44*
10th(n=96)	1898.51 ± 468.03	2057.60 ± 335.40	-159.09 ± 347.62	**<0.001**	-0.46*
11th(n=73)	1934.55 ± 405.22	2018.17 ± 294.51	-83.63 ± 344.86	**0.042**	-0.24*
12th(n=55)	1900.10 ± 372.29	2067.00 ± 361.83	-166.90 ± 264.63	**<0.001**	-0.63*1
P-value	0.748	0.833	0.307	---	---

†Classification of Cohen's d effect sizes: trivial (Cohen's d ≤ .2); * small (Cohen's d > .2); ** moderate (Cohen's d > .5); *** large (Cohen's d > .8); **** very large (Cohen's d > 1.3)(22)

Table 5. Mean and SD of EER and REI stratified by age.

	REI (kcal)	EER (kcal)	REI-EER (kcal)	P-value	Cohen's d†
Age					
15-19 years (n=267)	1896.4 ± 408.7	2052.9 ± 327.4	-156.5 ± 350.1	**<0.001**	-0.45*
20-22 years (n=20)	1928.2 ± 487.9	1970.8 ± 323.0	-42.6 ± 401.7	0.641	-0.11
P-value	**0.740**	**0.288**	**0.166**	---	---

†Classification of Cohen's d effect sizes: trivial (Cohen's d ≤ .2); * small (Cohen's d > .2); ** moderate (Cohen's d > .5); *** large (Cohen's d > .8); **** very large (Cohen's d > 1.3)(22)

-2.14), with the difference between REI and EER being greater for overweight (-301.6 kcal) and obese individuals (-398.1 kcal). (Table 6) REI was not significantly different across age (p=0.740) and BMI categories (p=0.811).

Discussion and conclusion

In the present study we compared the energy intake of Portuguese adolescents/young adults with their energy requirements by gender, school grade, age and BMI category.

Overall the energy intake of adolescents/young adults was lower than their requirements. Boys compared to girls had a higher gap between their energy intake and requirements, as they were consuming on average 320.9 kcal less than their requirements. Girls were consuming less 64.6 kcal than their requirements. As expected, boys had a higher energy intake than girls. When the sample was stratified by school grade, results pointed in the same direction, with the energy intake of the adolescents/young adults being lower than their requirements in all grades. Regarding age category, adolescents had a higher gap between their energy intake and requirements. No differences in en-

Table 6. Mean and SD of EER and REI by BMI category.

BMI category	REI (kcal)	EER (kcal)	REI-EER (kcal)	P-value	Cohen's d†
Underweight (n=7)	1777.2 ± 190.9	1859.1 ± 241.4	-81.9 ± 258.0	0.433	-0.32*
Normal weight (n=237)	1896.8 ± 428.2	2014.3 ± 318.9	-117.5 ± 361.3	**<0.001**	-0.33*
Overweight (n=30)	1912.5 ± 385.2	2214.1 ± 320.5	-301.6 ± 294.1	**<0.001**	-1.03***
Obese (n=13)	1964.1 ± 290.2	2362.2 ± 233.8	-398.1 ± 185.7	**<0.001**	-2.14****
P-value	0.811	**<0.001**	**0.002**	---	---

†Classification of Cohen's d effect sizes: trivial (Cohen's d ≤ .2); * small (Cohen's d > .2); ** moderate (Cohen's d > .5); *** large (Cohen's d > .8); **** very large (Cohen's d > 1.3)(22)**Discussion and conclusion**

ergy intake were found between the two age groups. The gap between energy intake and requirements was higher for overweight and obese adolescents/young adults, as they were consuming less 301.6 and 398.1 kcal than their requirements, respectively. And, lastly no significant difference in energy intake was observed between BMI categories, which is in accordance with Ortega et al(23) that found no differences in energy intake between overweight/obese and normal weight adolescents.

Our findings are in agreement with Tazhibi and Bahraini(1) study that assessed the energy intake of 400 students aged 14 to 18 years and compared it with their energy requirements derived from a modified Harris-Benedict equation. The authors found that the energy intake of young students was lower than their requirements, with the energy intake and requirements of boys being 2155 kcal/day and 1670 kcal/day, respectively and of girls being 2700 kcal/day and 2300 kcal/day, respectively.

Prediction equations for BMR/RMR continue to be the most common tool for diet prescription in the clinical setting(5), with the Harris-Benedict equations being amongst the most widely used for calculating BMR/RMR(24). However, the Harris-Benedict equations are the oldest of the equations(25) and used participant groups whose body size, body composition and race/ethnicity are not representative of the present-day population(6), which increases the chance of bias. These equations were validated to be within 5% of measured BMR/RMR in the 1950's(26), nonetheless Daly et al(27) in 1985 using a direct gradient-layer calorimeter and two different indirect calorimeters in a sample of 201 healthy men and women, showed that the Harris-Benedict equations overestimated BMR/RMR by about 10 to 15%. Additionally, a systematic review found that in non-obese healthy adults, the accurate prediction of BMR/RMR using the Harris-Benedict equations across all validation studies occurred in 45% to 80% of the subjects, and errors tend to be overestimates (error range: maximal underestimation by 23% to overestimation by 42%)(25). Similar findings in adolescents have been reported by Fonseca et al(28) that analyzed the validity of several prediction equations for BMR/RMR in 51 girls between 10 to 17 years of age. The authors found that the Harris-Benedict equations overestimated BMR/RMR by more than 5% (6.4%). In 76 non-obese Korean children and adolescents the Harris-Benedict equation had 9% bias, an accurate prediction of 53%, and 4% and 43% of under and overprediction, respectively(29). However, the previous findings have not been consistent(30).The Harris-Benedict equation only takes into consideration body weight, age, height and gender to predict RMR/BMR and does not consider other factors, such as body composition(1). However, it is well recognized that fat-free mass – and not body weight – is the major determinant of BMR/RMR. The brain and internal organs account for approximately 70-80% of RMR/BMR, but only constitute 5% of the body weight, while skeletal muscle accounts for approximately 15% of RMR/BMR but has a much larger contribution to body weight(31). Additionally, fat mass has also been shown to be an independent factor that impacts RMR/BMR, even though its contribution to total RMR/BMR variability is small when compared to fat-free-mass(32). For obese children, equations based on body weight are likely to overpredict energy requirements since the extra weight is largely fat mass – a less metabolically active tissue in comparison to fat free-mass(30). Furthermore, the Harris-Benedict equations were developed using mostly normal weight individuals(18), which might also limit its applicability to obese individuals. However the literature is ambiguous regarding the validity of Harry-Benedict equations for obese adolescents, with studies reporting that the equations are valid(33), overestimate(34) or underestimate RMR/BMR(34,35).

We must bear in mind that in current study the gap observed between the EER and REI, could arise due to the bias of the equation used, but it also can result from the use of self-reported energy intake, or a combination of both. When one self-assesses energy intake, mis-reporting (under- or over-reporting) of consumption may occur, which is a well-known and serious problem in nutrition and health studies(36,37). Consistent with previous findings in adults(38), one of the most robust findings in dietary studies of children and adolescents is the positive association between low-energy reporting and increased body fatness, especially in adolescents(39). A cross-sectional study with 96 post pubertal adolescents (47 normal weight and 49 obese) found that energy intake misreporting was identified in 65.6% of adolescents (64.6% of under-reporting and 1% over-reporting) and obese adolescents were 5 times more likely to under-report energy intake (95% CI: 2.0, 12.7) than their normal-weight counterparts(40). However, only speculation regarding this matter can be done as no analysis was made in that sense.

Our findings should be interpreted with several caveats in mind. Firstly, EER was based on a prediction equation – and prediction errors are inherent when using any estimated equations(37) – and self-reported physical activity data. Secondly, the use of self-reported dietary data and the limitations of the method used, such as limited food composition data and portion size estimation. However, Obesidata allows the recording of the food and beverages consumed in real time and therefore it is not memory dependent. Additionally, a higher preference for digital methods for collecting dietary data when compared with conventional methods has been reported(41). Another limitation lies in the fact that only BMI was used to assess the adolescents' weight status, as BMI is an indirect measure of body fat and is unable to differentiate between fat and lean mass(42). Its use to assess adiposity is of concern in the pediatric population, since the contributions of fat mass and lean body mass to weight vary by gender, age, ethnic origin and maturational status(43). And lastly, the sample might not be representative of the adolescent population due to the fact that 67.2% of the participants were girls, as girls were more likely to record their food intake for at least 3 days. This has been a recurrent issue in studies that evaluate electronic dietary intake assessment tools(41,44). This might arise from the fact that adolescent girls are more likely to report dieting and to be less satisfied with their bodies than boys(45–47), which could result in a higher interest in recording their food intake. Therefore, future research should implement additional strategies (e.g. additional reminders) to improve males' response rates(48).

In conclusion, energy intake of adolescents/young adults was significantly lower than their requirements. Energy intake was significantly lower than EER in the following groups: boys, girls, 9th, 10th, 11th and 12th grades, adolescents, normal weight, overweight and obese individuals ($p<0.05$). This study was only descriptive, and we cannot say that results observed here are related with the accuracy of the prediction equation used. However, we believe that it is important to study the validity of the Harry-Benedict equation for Portuguese adolescents based on the results obtained here.

The ability to estimate daily energy requirements and, consequently BMR/RMR accurately is of extreme importance in public health nutrition, as underestimation or overestimation of BMR/RMR could result in errors of the population energy allowances or the calculation of an individuals' energy requirements(49). However, the Harris-Benedict equations and other commonly used equations ignore important factors such as lean body mass, fat mass or fat-free mass(50). Therefore, new equations that take into account body composition are needed.

Conflict of interest

No potential conflict of interest relevant to this article was reported by the authors.

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