Nutrition 28 (2012) 773–778

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigations

The BASA-ROT table: An arithmetic–hypothetical concept for easy BMI-, age-, and sex-adjusted bedside estimation of energy expenditure

Luzia Valentini Ph.D. [a,*], Erich Roth Ph.D. [b], Klara Jadrna Ph.D. [c], Elisa Postrach M.Sc. [a], Jörg Dieter Schulzke M.D., Ph.D. [a]

[a] Charité-Universitätsmedizin Berlin, Centrum 13, Med. Clinics of Gastroenterology, Infectiology und Rheumatology, Division of Nutritional Medicine, Berlin
[b] Medical University Vienna, University Clinics for Surgery, Surgical Research Laboratories, Vienna, Austria
[c] Hanusch Hospital Vienna, Pharmacy, Vienna, Austria

ARTICLE INFO

Article history:
Received 16 June 2011
Accepted 17 November 2011

Keywords:
Calorie requirements
Resting energy expenditure
Simple estimates
Intensive care
Artificial nutrition
Parenteral nutrition
Enteral nutrition

ABSTRACT

Objective: The rule of thumb (ROT) method is used to estimate energy expenditure (EE) at bedside. ROTs are fixed numbers of calories given daily per kilogram of body weight. Textbooks nevertheless indicate that age and body mass index (BMI) affect EE. This should also affect ROTs. We thus scrutinized the impact of BMI, age, and sex on ROTs, compared the results to the often used 25 kcal/kg ROT, and calculated a BMI-, age-, and sex-adjusted ROT table containing calories per kilogram in the basal state.

Methods: We based calculations on the Harris–Benedict equation corrected for systematic error in women and obesity obtained in previous validation studies and used age, weight, and height of 676 consecutively admitted patients from five hospitals.

Results: The calculated ROTs continuously decreased from normal weight (20.8 ± 2.2 kcal/kg) to overweight (18.9 ± 1.8 kcal/kg) and obese patients (15.5 ± 1.6 kcal/kg, $P < 0.001$). However, not only BMI but also increasing age reduced the ROT significantly within each BMI category ($P < 0.01$ except for BMI > 35 kg/m^2), resulting in a BMI- and age-adjusted ROT spectrum of 12-27 kcal/kg in the total population. The 25-kcal ROT, even when used with normal ("ideal") body weight, overestimated calculated ROTs in more than 95% of patients.

Conclusion: We found that both BMI and age significantly impacted ROT estimates. Thus, using one single fixed ROT for all patients independent of age and BMI does not seem appropriate. We consequently suggest a calculated table of BMI-, age-, and sex-adjusted ROTs where the results of resting EE were multiplied with 1.1, 1.2, and 1.3 and separately listed in the table to account for activity/stress factors.

Introduction

The estimation of energy expenditure (EE) is a pivotal first step in clinical nutritional therapy. It is most important in enteral and parenteral nutritional therapy, when the amount of provided calories and nutrients can be tightly controlled by the caregiver and the exact delivery is assured by technical equipment independent of the patient's appetite, disease-associated restrictions, and free will. Recent evidence and guidelines strongly suggest that both too few and too many calories can be detrimental to the patient and thus affect clinical outcome [1,2]. This is especially true for critically ill patients, where calorie delivery is a tightrope walk between doing good and potentially causing harm [2]. However, it also impacts other patient groups.

Although indirect calorimetry has been continuously recommended for over 30 years, it has not gained ground in the clinical setting [3,4], except for research purposes. The commonly accepted and recommended [5–7] bedside method is the rule of thumb (ROT) estimate. A ROT is one distinct quantity of kilocalories that is to be administered per kilogram of body weight and thus requires only one simple calculation (i.e., the multiplication with body weight), which is key to its acceptance in clinical practice. Traditionally, resting EE (REE) in mobile patients and total EE (TEE) in immobile patients are estimated with the 25 kcal/kg body weight (BW)/d ROT. The 25 kcal ROT is also recommended as a conservative estimate for TEE in

* Corresponding author. Tel.: 0049-(0)30-450 514 113; fax: 0049-(0)30-450 514 923.
E-mail address: luzia.valentini@charite.de (L. Valentini).

0899-9007/$ - see front matter
doi:10.1016/j.nut.2011.11.020

intensive care unit (ICU) patients to avoid overfeeding [5,8]. Thus, we used this 25-kcal ROT exemplary to test the impact of body mass index (BMI) and age on calculated ROT estimates.

We aimed at testing in an arithmetic-hypothetical concept to what extent BMI and age affects a ROT estimate and, if significantly so, to construct a suggestion for an easy applicable bedside method to estimate energy expenditure, which takes obesity, aging, sex, and activity/stress into account.

Methods

Patients and participating institutions

The project was organized by the Scientific Service Center of the Austrian Society for Clinical Nutrition. A total of 676 consecutively admitted patients were evaluated for 1 mo in three internal wards ($n = 424$) and 2 surgical wards ($n = 252$) of five different general hospitals in Austria. The hospitals in Guessing, Grieskirchen, and Tulln are rural district hospitals with 158, 265, and 231 beds, respectively. The Rudolfstiftung Hospital is a major Viennese Community hospital with 798 beds and the Vienna General Hospital is a university medical center with 2000 beds. Patients admitted to ICUs were not included.

The patients were weighed on a calibrated scale and the body height was measured with a stadiometer. The BMI is defined as weight in kilogram divided by body height in meters squared. Ideal body weight (normal body weight) was calculated using the Broca Index (body height in cm–100).

Calculation of the BMI-, age-, and sex-adjusted ROTs (BASA-ROTs)

Step 1: Identifying the most appropriate formula

The literature was screened for well-investigated formulas that could be used in most patient groups. The Schofield formula, Mifflin formula, and Harris-Benedict equation (HBE) were identified.

The predictive value of the Schofield formula is poor with 36% for people older than 60 y of age [9]. Also, the Mifflin St Jeor equation [10] seems not to perform well in older individuals with general trends for underestimation and only 40% of cases with ±10% of measured REE in one study [11]. Thus, we decided to use the HB formula (HBE) [12]. HBE contains weight, height, age, and sex as variables and the determination coefficient (r^2) lies at 75% [12]. Also, other estimation formulae can reach this level at maximum. HBE is validated for adults up to 90 y of age [13,14], and in older people recently performed best of four formulae with 72% of cases within ±10% of measured REE and a mean difference of –40.0 kcal/d between measured and calculated REE [11].

Step 2: Optimizing the results of HBE

The original equation for the HB formula is: female: 655.1 + 9.6 (w) + 1.85 (h)–4.68 (y); male: 66.47 + 13.74 (w) + 5 (h)–6.76 (y), where w = body weight (kg); h = height (cm); y = age in years [12]. Despite known systematic errors in women [15] and obese individuals [16], the HBE formula was never corrected.

HBE overestimates EE in obese patients [16]. Thus, in individuals with BMI $\geq$30 kg/m^2, we used adjusted body weight equal to ideal body weight plus 50% of the excess body weight for the calculation [16]. Actual body weight was used up to a BMI of 30 kg/m^2. In women, HBE systematically overestimates REE for 5-10% [15]. Therefore, calculated REE was corrected for −5% in all women. We calculated the REE for all patients using the mentioned corrections.

Step 3: Calculating the per kg REE value for all patients (HB-ROTs)

The optimized REE was divided by the actual weight of each patient to receive the per kilogram REE estimate (HB-ROT). This was done in foresight to the final development in step 4 because division by the actual weight allows caregivers to use HB-ROTs with the actual weight in all patients, even in overweight and obese patients.

Step 4: Developing the final BASA-ROTs

The HB-ROTs of step 3 were grouped in age classes (18-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80-100) and within the age classes grade in BMI groups (18.5-19.9, 20-24.9, 25.0-29.9, 30-34.9, $\geq$35) and separated for sex. The mean group values are shown in Table 1 and were the cornerstone for the final BASA-ROT table (Table 2).

To receive the final BASA-ROTs (Table 2), groups containing less than 10 patients were filled by subtracting or adding 10 kg body weight from patients of the adjacent BMI classes in the same sex and age class and applying the calculation steps 1 to 4.

In our patient population, only 11 patients had a BMI less than 18.5 kg/m^2, ranging from 14.7 to 18.5 kg/m^2. This was considered too small a sample size to calculate or extrapolate data. Additionally, HBE is not validated for underweight individuals [17]. We excluded these patients from the analysis.

Statistical analysis

Statistical analysis was carried out using PASW 18 (SPSS Inc., Chicago, IL, USA). According to the Kolmogorov-Smirnov test, data on energy expenditure were normally distributed within the individual BMI and age group. Thus the parametric test was used for statistical analysis (Student t test for paired and unpaired samples). Values were considered statistically significant when the probability value was less than 0.05.

Results

Figure 1 depicts the HBE-based ROTs (= HB-REE per kilogram BW) stratified according to sex, age, and BMI. All BMI-specific results significantly differed within the three age groups (all <0.001). Additionally, in men and in women the mean HB-ROTs significantly decreased along the age classes in all BMI categories (all $P < 0.01$), except for patients in the highest BMI category ($\geq$35 kg/m^2), where no age-related decline could be observed (women: $P = 0.913$; men: $P = 0.490$).

Although the HB-ROTs and BMI were negatively related, the absolute REE values continuously increased from the lowest to highest BMI class ($P < 0.05$ for all age groups), reflecting the absolute small increase of metabolically active mass with increasing weight. The BMI class-specific HBE-based absolute REE values were 1218 ± 200 kcal/d (BMI 18.5-19.9 kg/m^2), 1340 ± 234 kcal/d (20.0-24.9 kg/m^2), 1462 ± 260 kcal/d (25.0-29.9 kg/m^2), 1438 ± 233 kcal/d (30.0-24.5 kg/m^2), and 1493 ± 297 kcal/d ($\geq$35 kg/m^2).

As expected, the absolute REE significantly decreased with increasing age in all BMI classes (all $P < 0.05$). The absolute age-group-related REE values were 1601 ± 246 kcal/d (18-39 years), 1490 ± 232 kcal/d (40-69 years), and 1253 ± 191 kcal/d (70-100 years).

Table 1 shows the mean values and standard deviations for the HB-ROTs for each age and BMI category. As consecutively admitted patients were included, the group size in each category represents the natural group force. The dark gray area refers to 57% of patients, demonstrating that the average patient was older and overweight with a HB-ROT significantly less than the 25 kcal ROT ($P < 0.001$). The mean age of patients was 62.3 ± 17.4 y (range: 18 to 97 y) and 60.2% of the patients were older than 60 y. The mean BMI was 26.8 ± 5.9 kg/m^2. Only 4.4% ($n = 29$) had a BMI between 18.5 and 19.9 kg/m^2. However, 61.1% patients were either overweight (BMI $\geq$ 25 kg/m^2, $n = 245$, 36.9%) or obese (BMI $\geq$ 30 kg/m^2, $n = 161$, 24.2%).

Figure 2 depicts the overestimation of REE (or TEE in immobile patients) when the 25 kcal ROT is calculated either with actual weight (A) or with ideal weight (B) compared to the respective HB-ROT. The 25 kcal ROT significantly overestimated REE in all BMI/age groups ($P < 0.001$) except for patients up to 39 y in the lowest BMI range for actual weight and in the highest BMI range for ideal weight.

For actual weight, mean overestimations were 134 ± 113 kcal/d (18.5-19.9 kg/m^2), 288 ± 132 kcal/d (20-24.9 kg/m^2), 464 ±132 kcal/d (25-29.9 kg/m^2), 814 ± 129 kcal/d (30-34.9 kg/m^2), and 1161 ± 261 kcal/d ($\geq$35 kg/m^2). For ideal weight, the mean overestimations were 452 ± 114 kcal/d (18.5-19.9 kg/m^2), 371 ± 121 kcal/d (20-24.9 kg/m^2), 232 ± 127 kcal/d (25-29.9 kg/m^2), 258 ± 99 kcal/d (30-34.9 kg/m^2), and 110 ± 120 kcal/d ($\geq$35 kg/m^2).

Table 2 presents the final BASA-ROTs derived from the HB-ROTs for use in clinical practice. As most hospital patients, especially intensive care patients, need total calorie requirements ranging from 1.0 to 1.3 times REE [18], we calculated the BASA-ROTs times 1.0, 1.1, 1.2, and 1.3 of basal BASA-ROT to consider stress/activity factors and to facilitate use at bedside.

Table 1
HB-ROTs differ according to sex, BMI, and age

BMI kg/m^2	18.5-19.9		20-24.9		25.0-29.9		30-34.9		≥35.0	
Age, y	W	M	W	M	W	M	W	M	W	M
18-29	—	27.1	22.6	25.6	20.3	22.7	16.4	19.6	—	—
SD			±0.67	±0.82	±0.86	±0.62	±0.50			
n		1	9		6	5	4	1		
30-39	23.7	25.5	21.8	23.6	19.2	22.5	16.8	18.9	13.4	15.8
SD	±0.81	±0.71	±0.67	±0.86	±0.42	±0.47	±0.83	±0.57	±1.41	
n	3	2	10	12	2	11	3	3	2	1
40-49	23.0	24.6	20.5	23.0	18.5	21.3	15.4	17.8	14.1	16.6
SD	±0.46	±0.07	±1.32	±0.69	±0.81	±0.42	±0.44	±0.42	±0.55	±0.14
n	4	2	6	12	10	14	6	5	3	2
50-59	21.4	23.2	19.8	21.9	18.2	20.5	15.5	17.7	13.2	15.8
SD		±0.36	±0.80	±0.70	±0.63	±0.48	±0.55	±0.47	±1.00	±0.58
n	1	4	13	21	11	26	11	13	5	4
60-69	21.5	22.8	19.2	21.1	17.8	19.8	14.8	16.6	13.2	14.7
SD			±0.71	±0.66	±0.78	±0.46	±0.83	±0.44	±0.54	±1.6
n	1	1	13	20	26	32	19	13	6	4
70-79	20.8	—	18.8	19.9	17.2	18.9	14.5	16.1	13.3	15.0
SD	±0.59		±0.87	±0.42	±0.75	±0.28	±0.51	±0.56	±0.56	±0.78
n	3		22	31	42	23	18	19	10	2
80-100	20.2	19.6	18.2	19.0	16.8	18.3	14.5	—	—	—
SD	±0.66	±0.83	±0.71	±0.53	±0.69	±0.41	±0.43			
n	4	3	29	22	26	11	7			

n, group size; SD, standard deviation; W, women; M, men
The table shows the mean value of the sex-, BMI-, and age-adjusted ROTs per actual weight based on the Harris-Benedict equation using body data from 335 female and 330 male patients. The dark gray area refers to the BMI and age range with the highest group sized (or n = 376 = 57% of all patients).

Table 2
BASA-ROTs for bedside estimation of energy requirements

BMI kg/m^2	18.5–19.9		20–24.9		25.0–29.9		30–34.9		≥35.0	
Activity/stress factor 1.0 = Resting Energy Expenditure										
Age, y	W	M	W	M	W	M	W	M	W	M
18–29	24	27	23	26	20	23	16	20	15	18
30–39	24	26	22	24	19	23	16	19	14	17
40–49	23	25	21	23	19	21	16	18	14	17
50–59	22	23	20	22	18	21	16	18	13	16
60–69	22	23	19	21	18	20	15	17	13	15
70–79	21	21	19	20	17	19	15	16	13	15
80–100	20	20	18	19	17	18	15	15	12	14
Activity/stress factor 1.1										
Age, y	W	M	W	M	W	M	W	M	W	M
18–29	26	30	25	28	22	25	18	22	17	20
30–39	26	28	24	26	21	25	19	21	16	18
40–49	25	27	23	25	20	23	17	20	16	18
50–59	24	26	22	24	20	23	17	20	15	18
60–69	24	25	21	23	20	22	16	18	15	16
70–79	23	23	21	22	19	21	16	18	15	16
80–100	22	22	20	21	19	20	16	17	13	15
Activity/stress factor 1.2										
Age, y	W	M	W	M	W	M	W	M	W	M
18–29	29	33	27	31	24	27	20	24	18	22
30–39	29	31	26	28	23	27	20	23	17	21
40–49	28	30	25	28	22	26	19	21	17	20
50–59	26	28	24	26	22	25	19	21	16	19
60–69	26	27	23	25	21	24	18	20	16	18
70–79	25	25	23	24	21	23	17	19	16	18
80–100	24	24	22	23	20	22	17	18	14	17
Activity/stress factor 1.3										
Age, y	W	M	W	M	W	M	W	M	W	M
18–29	31	35	29	33	26	30	21	25	20	23
30–39	31	33	28	31	25	29	22	25	18	22
40–49	30	32	27	30	24	28	20	23	18	22
50–59	28	30	26	29	24	27	20	23	17	21
60–69	28	30	25	27	23	26	19	22	17	19
70–79	27	27	24	26	22	25	19	21	17	19
80–100	26	26	24	25	22	24	19	20	16	18

The table presents the final BASA-ROTs for use in clinical practice. Most hospitalized patients have energy requirements ranging from 1.0 to 1.3 times REE, depending on activity and stress factors. All results are to be used with actual weight. W, women; M, men

Discussion

Our results revealed a significant impact of age and BMI on the per kilogram BW estimate of energy expenditure (ROTs). Consequently, current recommendations of using only one single ROT or only one single range of ROTs independent of age or BMI seem inadequate for use in all patients. We thus suggested calculated ROT values adjusted for age and BMI, the BASA-ROTs, for bedside use in clinical practice.

Energy expenditure is affected by sex, age, and body composition [19]. Expressed as ROT, REE decreases with increasing body weight [20,21], because tissue with low energy requirements, mainly fat mass (13 kcal/kg) [22], increases disproportionately to tissue with high energy requirements, like body organs (e.g., heart: 440 kcal/kg [22]). The aging-associated decrease of REE can be explained in similar terms. With increasing age under weight-stable conditions, the metabolically active body cell mass decreases relative to the fat mass, resulting in lower ROTs [23]. Additionally, it is hypothesized that mitochondrial aging adds to the reduction in energy expenditure [24]. In our population, the calculated HB-ROT for REE decreases over the adult lifespan between 15% and 26%.

Previous indirect calorimetry-based studies in the ICU showed that REE on a per kilogram weight basis varies considerably from as low as 10 kcal/kg to higher than 50 kcal/kg (e.g., 16) but only one study investigated the impact of BMI on the per kilogram REE value so far [25]. In this study, Zauner and colleagues found mean REE values of 24.8 ± 5.5 kcal/kg in normal-weight, 22.0 ± 3.7 kcal/kg in overweight, and 20.4 ± 2.6 kcal/kg in obese patients. The authors concluded that BMI-specific adaptation should be applied in clinical practice for estimating energy needs [25]. Zauners' measured results compare well to our calculated BASAROT table when age is neglected and when commonly used stress factors of 1.1 or 1.2 are applied. Still, aging additionally impacts the per kilogram REE results as shown by the marked drop of calculated age-adjusted values in the BASA-ROT table. Except for Zauners' study, we only

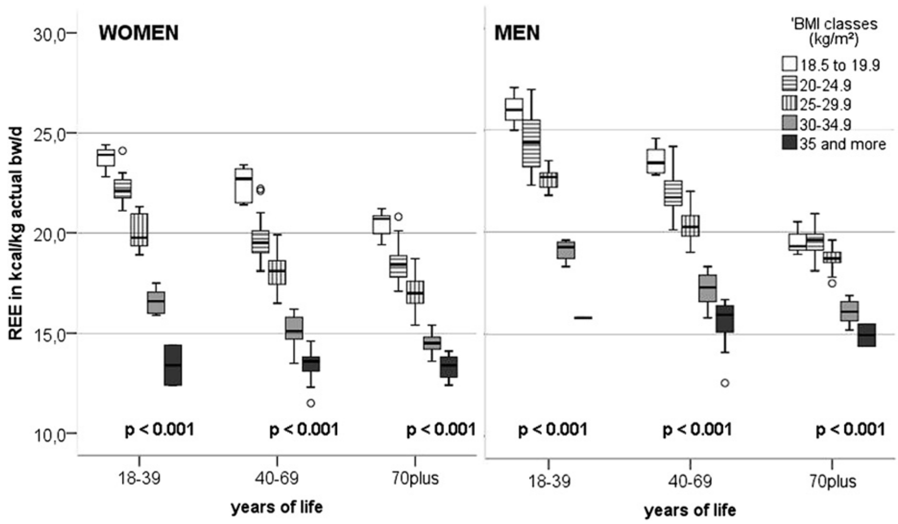

Fig. 1. Impact of BMI and age on per kilogram estimates for resting energy expenditure showing the descending calculated values for the per kilogram actual body weight value of HB-based REE (HB-ROTs) according to the BMI classes, age, and sex. The box plots present the median values and the quartiles with the whiskers ending at the maximum and minimum value.

found one other investigation on the impact of BMI on the EE per kilogram values performed in healthy Gambian women [20] and resulting in a significantly lower per kilogram value in heavier women compared to slimmer women.

The 25-kcal ROT overestimated REE in nearly all of our consecutively admitted patients compared to our calculated Harris-Benedict equation (HB)-based ROTs. Our patient population is representative of the majority of hospital populations in the Western world [26], with about 50% of patients being older than 65 y of age and the majority being overweight or obese [26]. Therefore, our results should be relevant to Western patients in general. The 25-kcal ROT calculated with actual body weight was adequate as REE only in young and lean patients (4.8% of the total population). It overestimated HB-REE in the remaining 95.5% of patients, who were older and/or had higher BMIs. The overestimation only confirmed previous findings, the results of which were transferred to practice by basically two strategies: first, some national and international nutrition societies now recommend the 25-kcal ROT as an estimate for total EE instead of REE (e.g., [27–29]). Second, in courses on clinical nutrition, sometimes ideal instead of actual weight is taught for calculation, although taking ideal weight is not generally recommended [30]. Nevertheless, new in our study is that using ideal body weight instead of actual body improved the mean deviation but still overestimated HB-REE significantly in nearly all patients ($n = 662$, 99.5%) except in young patients in the highest BMI category ($n = 3$). Thus, independent of whether actual or ideal weight is applied, we cannot consider the 25 kcal ROT sufficient to estimate adequately REE/TEE in a general Western hospital population like ours. Additionally, we question its general

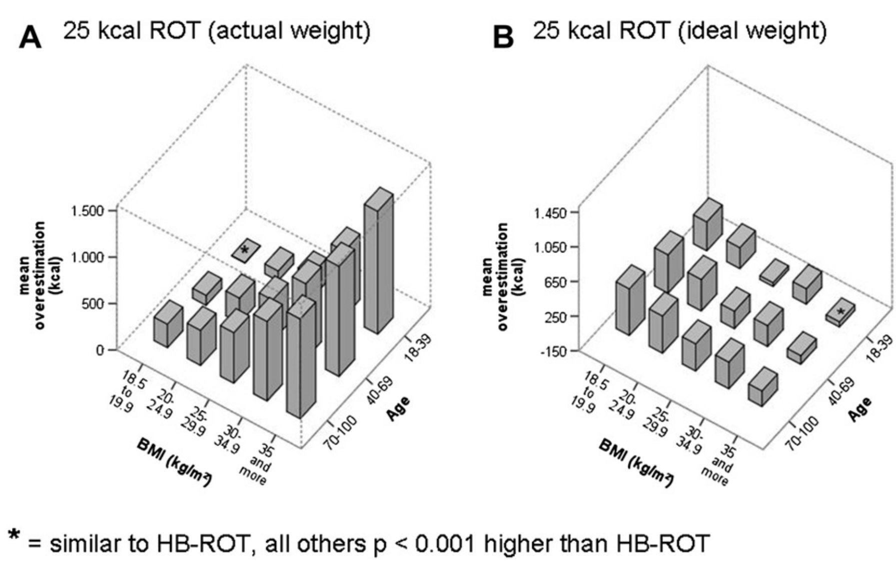

Fig. 2. Difference between HB-REE and REE calculated with 25 kcal ROT depicting the difference between HB-REE compared to the REE results calculated with 25 kcal ROT. The 25 kcal ROT overestimates HB-REE in most patients. More severely when actual weight was taken as a multiplier (left), but even with ideal weight, HB-REE was overestimated, particularly in the low BMI part (right). The ideal body weight was defined as the Broca Index (body height minus 100).

recommendation in ICU patients. Furthermore, based on our results with significant impact of BMI and age, we also consider any other fixed ROT estimates equally insufficient to estimate EE in all patients and strongly suggest using BMI- and age-adapted ROTs as suggested in our BASA-ROT table (Table 2) for use in clinical practice, especially in sensible patient groups.

One might question if the Mifflin equation [10] should have been preferred to HBE for calculation of BASAROTs, because 23.9% of our population was obese, and this formula was developed in a sample in which obesity was more prevalent than in the population underlying HBE. Furthermore, with Mifflin it would not have been necessary to correct for obesity (adjusted body weight for BMI >30 kg/m^2) and for females (−5%). We decided against using the Mifflin equation mainly because of poor evidence on its validity in older individuals [11] as mentioned in the METHODS section. Nevertheless, we calculated BASAROTs using the Mifflin formula in our population (data not shown) and found up to a BMI of 34.9 kg/m^2, an 89% agreement with the presented HBE-based BASAROTs. We defined "agreement" as 1 kcal/kg maximum discrepancy compared with the HBE-based value in the respective BMI, age, and sex category. In the highest BMI class (≥35 kg/m^2), Mifflin-based BASAROTs were significantly higher than our HBE-based BASAROTS with a mean difference of 2 kcal/kg. If one equation is superior to the other, it has yet to be tested in future studies.

Validation

The BASA-ROTs in Table 2 were previously validated by indirect calorimetry in 112 multimorbid elderly individuals with a mean age of 81.4 ± 6.8 y and mean BMI of 25.5 ± 4.4 kg/m^2 [31]. In this study, three estimation formulas (original HBE, WHO, FAO) and two different ROTs (BASA-ROTs and 20 kcal/kgBW/d ROT) were compared. All used formulas and ROTs overestimated the measured REE (mREE). However, the BASA-ROTs were the best to predict mREE with a precision of 95.4%. The other used formulas overestimated mREE between 8.2% (original HBE) and 20.1% (20 kcal ROT). Main diagnoses, multimorbidity, medication, mobility, or cognitive status did not impact mREE. The authors concluded that currently among the chosen methods the BASA-ROTs are best suited to estimate REE in multimorbid elderly patients.

Limitation

The current study is limited by relying on calculated and not on measured values. Another limitation is that BASA-ROTs require actual weight. With increasing availability of chair, hoist, and bed scales, it is possible to obtain a reliable weight in many hospitalized patients [3] but not in all. For instance, patients with ascites/edema or ICU patients have fluid retentions that increase body weight without increasing metabolically active tissue and therefore, where possible, "dry" weight should be recorded and used to calculate REE/TEE. Measurement of height is not required for calculating BASA-ROTS, but might be necessary to calculate the BMI. Models for the accurate estimation of height in bed-ridden patients were suggested recently [32]. Additionally, the use of activity or stress factors rely on clinical judgment, knowledge, and experience of the individual calculating the predicted requirements [3,33]. A rough guideline for use of activity factors and stress factors is provided in Table 3 and for detailed population-specific instruction a recent publication is recommended (e.g., [34]). The HB equation is reliable for BMI 18.5-50.0 [35], but not less than 18.5 kg/m^2 [17]. Thus, we did not extrapolate data below the 18.5 kg/m^2 threshold. Recently, however, ROTs of 30-32 kg/m^2 to calculate REE were suggested for this patient group [17].

Table 3
Suggested use of activity and stress factor

Activity factors	
In-house patient—bed bound, can sit, active arm movements	1.1
In-house patient—stands up for restroom, show	1.2
In-house patient—walks the aisle several time a day	1.3
Outpatient—mainly sitting activities, short walks	1.4
Stress factors	
Trauma, multiple	1.2–1.3
Sepsis or severe infection (e.g., peritonitis)	1.2–1.3
Surgery postoperative	1.0–1.2
Cancer	1.0–1.2
Fever	1.0

This table provides a rough overview over suggested activity and stress factors. For a more detailed summary, "Energy and nitrogen requirements in disease states" by Taylor SJ is recommended [40].
Stress factors should not be added when more than one condition applies. Here the condition with the highest stress factor should be chosen. If both activity factors and stress factors apply, total energy expenditure should be calculated by [BASAROT × (activity factor plus stress factor) × actual body weight].
Calculation with activity factors and stress factors underlies the model of normocaloric nutrition, in which energy expenditure equals energy requirements. Thus, corrections are needed when nutritional support aims at permissive underfeeding (e.g., intensive care patients) or permissive overfeeding (e.g., targeted weight gain). In regard to patients with fever, in contrast to former practice, increased energy supply is not recommended [18].

Conclusion

The most accurate method to determine energy expenditure is to measure it, but indirect calorimetry is rarely used [36]. With the current work, we attempted to transfer basic nutritional knowledge into concrete practice recommendations with precise instruction (e.g., to use actual weight instead of ideal weight) based on the background that there are sensible patients groups in which overfeeding is clearly detrimental. As shown in the present work, BMI and age impact the per kilogram values for EE considerably and one fixed ROT cannot provide the precision needed for individual treatment, especially in sensible patient groups, like ICU patients. By considering sex, age, BMI, and stress/activity factors, the suggested BASA-ROT table provides a simple and practical suggestion for a bedside tool to improve accuracy without increasing complexity and time requirements. The BASA-ROTs, however, introduced in the present publication are calculated and not measured and are based on an Austrian patient population. The current concept is pure arithmetic hypothesis and should be the starting point rather than the solution to discuss and find feasible and accepted methods to estimate EE more accurately at the bedside, until electronic solutions are fully developed and broadly available.

Acknowledgments

We thank Barbara Ernst, Markus Keinrad, Martin Traby, Nicole Oder, and Karin Schmeitzl, all former students of nutritional sciences, for evaluating the patients in the course of a 1-mo internship at the Austrian Society of Clinical Nutrition. We also thank Vera Tajmel, MD (Guessing Hospital), Christian Fadinger, MD (Grieskirchen Hospital), Andrea Wadsack, RD (Rudolfsstiftung Hospital), and Friedrich Rakowitz, MD (Tulln Hospital) for enabling and supporting the evaluations in their respective institution.

References

[1] Singer P, Pichard C, Heidegger CP, Wernerman J. Considering energy deficit in the intensive care unit. Curr Opin Clin Nutr Metab Care 2010;13:170–6.
[2] Dickerson RN. Optimal caloric intake for critically ill patients: first, do no harm. Nutr Clin Pract 2011;26:48–54.
[3] Elizabeth WC. Controversies in the determination of energy requirements. Proc Nutr Soc 2007;66:367–77.
[4] Schoeller DA. Making indirect calorimetry a gold standard for predicting energy requirements for institutionalized patients. J Am Diet Assoc 2007;107:390–2.
[5] McClave SA, Martindale RG, Vanek VW, McCarthy M, Roberts P, Taylor B, et al. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). JPEN J Parenter Enteral Nutr 2009;33:277–316.
[6] Valentini L, Schuetz T, Allison S, Howard P, Pichard C, Lochs H. ESPEN Guidelines on Enteral Nutrition. Clin Nutr 2006;25:177–360.
[7] Kreymann G, Adolph M, Muller MJ. Leitlinie Parenterale Ernährung der DGEM. Energieumsatz und Energiezufuhr. Akutel Ernaehr Med 2007;32(Suppl 1):S8–12.
[8] Fontaine E, Muller MJ. Adaptive alterations in metabolism: practical consequences on energy requirements in the severely ill patient. Curr Opin Clin Nutr Metab Care 2011;14:171–5.
[9] Schofield WN. Predicting basal metabolic rate, new standards and review of previous work. Hum Nutr Clin Nutr 1985;39(Suppl 1):5–41.
[10] Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A new predictive equation for resting energy expenditure in healthy individuals. Am J Clin Nutr 1990;51:241–7.
[11] Melzer K, Laurie KV, Genton L, Kossovsky MP, Kayser B, Pichard C. Comparison of equations for estimating resting metabolic rate in healthy subjects over 70 years of age. Clin Nutr 2007;26:498–505.
[12] Harris JA, Benedict FG. A biometric study of the basal metabolism in man. Publication No. 279 ed. Washington DC: Carnegie Institute of Washington; 1919.
[13] Benedict FG, Root HF. The physiology of extreme old age. N Engl J Med 1932;211:521–36.
[14] Benedict FG. Old age and basal metabolism. N Engl J Med 1935;212:1111–22.
[15] Benedict FG. Basal metabolism data on normal men and women (series II) with some consideration on the use of prediction standards. Am J Physiol 1928;85:607–20.
[16] Barak N, Wall-Alonso E, Sitrin MD. Evaluation of stress factors and body weight adjustments currently used to estimate energy expenditure in hospitalized patients. JPEN J Parenter Enteral Nutr 2002;26:231–8.
[17] Ahmad A, Duerksen DR, Munroe S, Bistrian BR. An evaluation of resting energy expenditure in hospitalized, severely underweight patients. Nutrition 1999;15:384–8.
[18] Druml W, Jadrna K. Recommendations for enteral and parenteral nutrition in adults. 2, English pocket version ed. Vienna: Austrian Society of Clinical Nutrition (AKE); 2008.
[19] Westerterp KR, Schols AMW. Energy metabolism. In: Sobotka L, Allison S, Fürst P, Meier R, Pertkiewicz M, Soeters P, editors. Basic in Clinical Nutrition. Third ed. Prague: Galen; 2004. p. 61–6.
[20] Lawrence M. Predicting energy requirements: is energy expenditure proportional to the BMR or to body weight? An analysis of data collected in rural Gambian women. Eur J Clin Nutr 1988;42:919–27.
[21] Benedetti FJ, Mocelin HT, Bosa VL, de Mello ED, Fischer GB. Energy expenditure and estimated caloric intake in asthmatic adolescents with excess body weight. Nutrition 2010;26:952–7.
[22] Muller MJ, Bosy-Westphal A, Kutzner D, Heller M. Metabolically active components of fat-free mass and resting energy expenditure in humans: recent lessons from imaging technologies. Obes Rev 2002;3:113–22.
[23] Piers LS, Soares MJ, McCormack LM, O'Dea K. Is there evidence for an age-related reduction in metabolic rate? J Appl Physiol 1998;85:2196–204.
[24] Lakshminarasimhan M, Steegborn C. Emerging mitochondrial signaling mechanisms in physiology, aging processes, and as drug targets. Exp Gerontol 2011;46:174–7.
[25] Zauner A, Schneeweiss B, Kneidinger N, Lindner G, Zauner C. Weight-adjusted resting energy expenditure is not constant in critically ill patients. Intensive Care Med 2006;32:428–34.
[26] Schindler K, Pernicka E, Laviano A, Howard P, Schutz T, Bauer P, et al. How nutritional risk is assessed and managed in European hospitals: a survey of 21,007 patients findings from the 2007-2008 cross-sectional nutrition day survey. Clin Nutr 2010;29:552–9.
[27] Singer P, Berger MM, Van den BG, Biolo G, Calder P, Forbes A, et al. ESPEN Guidelines on Parenteral Nutrition: intensive care. Clin Nutr 2009;28:387–400.
[28] Van GA, Cabre E, Hebuterne X, Jeppesen P, Krznaric Z, Messing B, et al. ESPEN Guidelines on Parenteral Nutrition: gastroenterology. Clin Nutr 2009;28:415–27.
[29] Braga M, Ljungqvist O, Soeters P, Fearon K, Weimann A, Bozzetti F. ESPEN Guidelines on Parenteral Nutrition: surgery. Clin Nutr 2009;28:378–86.
[30] Frankenfield DC, Ashcraft CM. Estimating Energy Needs in Nutrition Support Patients. JPEN J Parenter Enteral Nutr 2011;35:563–70.
[31] Hengstermann S, Hanemann A, Steinhagen-Thiessen E, Schulz R. Predicted equations overestimated resting energy expenditure (REE) in multimorbid elderly patients. Clin Nutr 2007;26(Suppl 2):25.
[32] Cereda E, Bertoli S, Battezzati A. Height prediction formula for middle-aged (30-55 y) Caucasians. Nutrition 2010;26:1075–81.
[33] Taylor SJ. Predicting resting energy expenditure (REE): Misapplying equations can lead to clinically significant errors. e-ESPEN 2010;5:e254–60.
[34] Taylor SJ. Energy and nitrose requirements in disease states. 1st ed. London: Smith-Gordon and Company Ltd; 2007.
[35] Weijs PJ, Vansant GA. Validity of predictive equations for resting energy expenditure in Belgian normal weight to morbid obese women. Clin Nutr 2010;29:347–51.
[36] Frankenfield DC. On heat, respiration, and calorimetry. Nutrition 2010;26:939–50.