

## Original Article

# Comparison of measured energy requirements and the Danish Health Authority's recommendation estimates

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## ABSTRACT

**INTRODUCTION.** The Danish Health Authority (DHA) recommends a model for estimating total daily energy expenditure (TDEE) among inpatients at nutritional risk. This study aimed to investigate whether TDEE measured (M) by indirect calorimetry (IC) is equivalent to estimated TDEE (E) among medical patients and whether the agreement or lack thereof between E and M TDEE is associated with specific patient characteristics.

**METHODS.** This cross-sectional study included anthropometrics, IC and data from medical records. The DHA E TDEE is based on body weight and stresses metabolism. Descriptive statistics, t-tests, logistic and linear regression analyses were performed. The study was registered with the North Jutland Protection Agency (2024-154). No grant was received for this study.

**RESULTS.** Overall, 148 patients were included in the analysis. Among these, the mean age was  $63.1 \pm 15.0$  years, and the mean BMI was  $22.7 \pm 5.0$  kg/m<sup>2</sup>. Mean differences between E and M TDEE were seen in the total population ( $p < 0.001$ ). Patients with a BMI  $< 25.0$  kg/m<sup>2</sup> were underestimated ( $p < 0.001$ ), whereas patients with a BMI  $25.0$ - $29.9$  kg/m<sup>2</sup> were overestimated ( $p = 0.018$ ), and those with a BMI  $> 30$  kg/m<sup>2</sup> were underestimated. Muscle mass was strongly associated with the difference between E and M ( $p < 0.001$ ).

**CONCLUSIONS.** Estimated TDEE underestimates TDEE in patients with a BMI  $< 25$  kg/m<sup>2</sup> and overestimates BMI above the recommended value. The difference is related to muscle mass. We suggest introducing a greater emphasis on muscle mass measurement. TDEE may be measured in patients at nutritional risk who lose weight, although dietary requirements are met.

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The importance of providing the right amount of nutrition to hospitalised patients has become increasingly evident. Earlier practice focused on energy- and protein-dense food for patients at nutritional risk, using oral nutrition supplements, enteral nutrition and parenteral nutrition when obviously required [1]. Evidence now shows that in very catabolic states, including high levels of inflammation, overfeeding may even be worse than underfeeding [2, 3]. In medical patients, this evidence underscores that nutritional support may need to be individualised based on patients' actual markers of inflammation, and that caution due to high inflammation no longer applies only to intensive care units [4].

Validated screening for initial detection of nutritional risk is recommended, so that nutritional care can be prioritised for those at nutritional risk [1, 5]. The screening tool NRS-2002 is recommended for use in Danish hospitalised patients. The tool grades the severity of disease into four degrees, with “0” indicating no inflammation and “1” indicating a low/mild degree of inflammation, such as in chronic diseases. A score of “2” is given for patients with severe infections, and a score of “3” is given for a high degree of inflammation, head injuries and patients in the intensive care unit [6]. Furthermore, the Danish Health Authority (DHA) provides guidance on which severity level to choose [7]. The NRS-2002 is an independent risk factor for malnutrition-associated mortality and adverse outcomes [8, 9]. Strong evidence indicates that the unfavorable consequences of nutritional risk are primarily reduced by adequate dietary support and thus sufficient nutrient intake [9, 10]. The fulfilment of dietary needs, however, requires an individual approach to the patients' current nutritional requirements.

Daily total energy expenditure (TDEE) is formed by resting energy expenditure (REE) and activity-related energy expenditure. REE may again be subdivided into basal metabolism and diet-induced thermogenesis [11]. The basic metabolic rate is energy expended when at complete rest, resulting from cellular metabolism such as ion pumping across membranes, protein and nucleic acid turnover, breathing, heart rate and muscle tone [11]. Thus, the metabolic rate is increased during disease activity, as shown by, e.g., a lower heart rate and a higher respiratory rate [12]. In hospital wards, estimates that are typically based on different equation models and/or the DHA assessment of nutritional requirements. This has been shown not always to be sufficient compared with measuring REE by calorimetry [12-14].

The guideline from the DHA uses energy expenditure multipliers of 1.1 for bedridden, 1.2 for sedentary and 1.3 for light activity in hospitalised patients, although the literature does not provide a direct reference that explicitly categorises them accordingly [7]. However, studies underscore the necessity of individualised assessments of energy requirements, particularly in clinical settings [15]. One study focused on energy requirements in elderly patients with pressure ulcers, showing that even in a diseased state, the energy expenditure does not necessarily increase significantly [16].

These stages are integrated in the IT systems used in hospitals and therefore guide the nutritional requirements of hospitalised Danish patients at nutritional risk. For the national recommendation regarding nutritional requirements, international guidelines from the European Society for Clinical Nutrition and Metabolism (ESPEN) were consulted [7] appendix IX. This led to a recommendation for nutritional requirements for patients at nutritional risk across different clinical situations, as shown in [Supplemental Table 1](#).

This study aimed to investigate whether TDEE measured by indirect calorimetry (IC) aligns with estimated TDEE based on the DHA recommendations for hospitalised medical patients [7]. Furthermore, the aim was to investigate whether agreement between estimated and measured TDEE is associated with specific patient characteristics, including body composition.

## Methods

This study is a secondary analysis of previously published data that investigates the accuracy of international predictive equations [12]. In the present study, only patients at nutritional risk were included, as the DHA guideline only addresses nutritional risk.

### Study design and participants

In this cross-sectional study, participants were recruited during admission to medical wards at a university hospital. The patients were recruited at all medical wards by medical students and by an affiliated laboratory

technician. All patients provided written informed consent.

The inclusion criteria were:  $\geq 18$  years old, at nutritional risk according to the NRS-2002, and able to provide written informed consent. The exclusion criteria were: pregnancy, need for oxygen therapy, oedema, pacemaker, ascites and failure to meet the preparation criteria. The preparation criteria were as follows: No exercise within 24 hours of measurement, a fasting period of at least eight hours, including oral, enteral and parenteral nutrition as well as fluids. Fasting aims to ensure that the REE is not influenced by diet-induced thermogenesis.

## Data collection

Data were collected during a two-day period. The following data were collected:

- Demographics: gender and age.
- Anthropometrics: height and weight, as well as body composition (skeletal muscle mass (SMM) and fat mass), measured by Inbody S10.
- IC: REE by the medical device “Q-NRG+” from COSMED.
- Data from medical records: admission time and diagnosis, the nutritional risk assessment based on the NRS-2002, hospital ward and estimated energy requirement.

The full data collection method is described in more detail elsewhere [14].

## Estimated daily total energy expenditure based on the recommendations from the Danish Health Authority

Danish hospitals are recommended to estimate TDEE using equations regarding patients at nutritional risk [7]. The DHA recommends that TDEE be estimated based on the individual's disease severity and body weight [7]. Disease-induced metabolism or “stress-metabolism” is categorised as either normal, mild, moderate or severe stress-metabolism. The recommendations are:

- 25-30 kcal/kg/day if normal stress
- 27 kcal/kg/day if mild stress
- 27 kcal/kg/day if moderate stress
- 20-30 kcal/kg/day if severe stress (none in this study)
- 20 kcal/kg/day if BMI  $\geq 30$  kg/m<sup>2</sup>.

If the patient has a BMI below 18.5 kg/m<sup>2</sup> or above 30 kg/m<sup>2</sup>, it is recommended to create a tailored nutritional plan based on ideal body weight resulting in a BMI of 25 kg/m<sup>2</sup>. This weight replaces the patient's actual weight when estimating TDEE and REE.

The activity factor (AF) is a measure of an individual's physical activity profile based on the volume and intensity of their physical activity. When the research staff measured height and weight, the patient had to get out of bed. The need for assistance getting out of bed and the conversation with patients about their general whereabouts in the ward contributed to the decision on the level of AF for the individual patient.

## Statistics

Data were stored in Research Electronic Data Capture and analysed using Stata/MP version 18. Descriptive statistics are presented as mean  $\pm$  SD for continuous variables and n (%) for categorical variables. Normality was assessed using the Shapiro-Wilk test. Paired T-tests were conducted when comparing the difference between

measured and estimated TDEE. Logistic regression analyses were performed to investigate the associations between underestimation and overestimation of estimated TDEE relative to measured TDEE. Linear regression analyses were used to compare measured TDEE and body weight, SMM, as well as SMM percentage (SMM%). The level for statistical significance was set to  $p < 0.05$ .

*Trial registration:* not relevant.

## Results

### Patient demographics

The analysis included 148 participants at nutritional risk according to the NRS-2002 and therefore had requirements estimated using the DHA recommendations [7].

Among the included patients, 62.2% were female with a mean age of  $63.1 \pm 15.0$  years and a mean BMI of  $22.7 \pm 5.0$  kg/m<sup>2</sup>. Most patients were admitted to the gastroenterology ward (88.5%), and most had an estimated AF of 1.3 (89.7%). The mean admission day on which the patients had their IC measurement was 8.1 days (see **Table 1**).

**TABLE 1** Demographic data for patients included in this study (N = 148).

<i>Sex, n (%)</i>	
Female	92 (62.2)
<i>Age</i>	
Mean ± SD, yrs	63.1 ± 15.0
<i>Age groups, n (%):</i>	
18-29 yrs	6 (4.1)
30-59 yrs	43 (29.1)
60-74 yrs	61 (41.2)
≥ 75 yrs	38 (25.7)
<i>Hospital wards, n (%)</i>	
Endocrinology	3 (2.0)
Gastroenterology	131 (88.5)
Pulmonology	5 (3.4)
Hematology	1 (0.7)
Nephrology	5 (3.4)
Rehabilitation unit	3 (2.0)
<i>Activity factor, n (%)</i>	
1.1	5 (3.4)
1.2	10 (6.8)
1.3	133 (89.7)
<i>BMI</i>	
Mean ± SD, kg/m <sup>2</sup>	22.7 ± 5.0
<i>BMI groups, n (%):</i>	
< 18.5 kg/m <sup>2</sup>	30 (20.3)
18.5-24.9 kg/m <sup>2</sup>	85 (57.4)
25.0-29.9 kg/m <sup>2</sup>	19 (12.8)
≥ 30.0 kg/m <sup>2</sup>	14 (9.5)

**Comparison of estimated and measured daily total energy expenditure**

Using the DHA estimates for TDEE compared with the values measured by IC, 72 patients (48.6%) were underestimated, and 25 (16.9%) were overestimated by more than 10%. Thus, only 51 (34.5%) of patients were estimated within ± 10% TDEE as measured by IC. The mean difference between estimates and measured TDEE was significant, with the DHA equation underestimating TDEE compared with TDEE measured with IC ( $p < 0.001$ ). When grouping patients by BMI, all estimates differed significantly from the measured IC, except for patients with a BMI  $\geq 30$  kg/m<sup>2</sup> ( $p = 0.246$ ). The groups with a BMI  $< 18.5$  kg/m<sup>2</sup> and between 18.5 and 25.0 kg/m<sup>2</sup> were significantly underestimated when comparing the DHA equation with the TDEE measured by IC ( $p < 0.001$ ),

whereas patients with a BMI of 25.0-29.9 kg/m<sup>2</sup> were significantly overestimated when comparing the DHA equation with the TDEE measured by IC (p = 0.018) (see Table 2).

**TABLE 2** Mean differences between Danish recommendations and indirect calorimetry (IC) in patients at nutritional risk as well as patients divided into sub-groups. A negative difference indicates an underestimation of daily total energy expenditure (TDEE) when using the Danish Health Authority (DHA) equation compared with TDEE measured by IC. A positive difference indicates an overestimation of TDEE when using the DHA equation compared with TDEE measured by IC (p < 0.05).

	Difference, mean ± SD, kcal	p value	n
All patients	-153.1 ± 336.7	< 0.001	148
<i>BMI groups</i>			
< 18.5 kg/m <sup>2</sup>	-355.3 ± 201.1	< 0.001	30
18.5-24.9 kg/m <sup>2</sup>	-157.9 ± 321.3	< 0.001	85
25.0-29.9 kg/m <sup>2</sup>	171.2 ± 286.9	0.018	19
≥ 30.0 kg/m <sup>2</sup>	-130.8 ± 403.1	0.246	14

Patients with a BMI < 18.5 kg/m<sup>2</sup> had an increased odds ratio of being underestimated compared with patients with a BMI of 18.5-24.9 kg/m<sup>2</sup> (p = 0.007). In the group of patients with a BMI of 25-29.9 kg/m<sup>2</sup>, the odds ratio of being overestimated was increased (p = 0.019). Patients with a leukocyte concentration above 10 × 10<sup>9</sup>/l had an increased odds ratio of being both over- and underestimated (p = 0.032, p = 0.009). For all other variables, no significant increase or decrease in odds ratio was found (see Table 3).

**TABLE 3** Logistic regression analysing associations between patient characteristics and the odds ratio of under-/overestimation of estimated daily total energy expenditure.

	Underestimation of estimated TDEE				Overestimation of estimated TDEE			
	underestimation, n (%)	total, N	OR (95%CI)	p value	underestimation, n (%)	total, N	OR (95%CI)	p value
<b>Age groups</b>								
18-29 yrs	4 (80.0)	5	1 (ref.)		1 (50.0)	2	1 (ref.)	
30-59 yrs	26 (65.0)	40	0.46 (0.05-4.56)	0.511	3 (17.6)	17	0.21 (0.01-4.48)	0.321
60-74 yrs	34 (65.4)	52	0.47 (0.05-4.55)	0.516	9 (33.3)	27	0.50 (0.03-8.95)	0.638
≥ 75 yrs	8 (30.8)	26	0.11 (0.01-1.16)	0.066	12 (40.0)	30	0.67 (0.04-11.72)	0.782
<b>BMI groups</b>								
< 18.5 kg/m <sup>2</sup>	25 (83.3)	30	4.36 (1.50-12.64)	0.007	0	5	-	-
18.5-24.9 kg/m <sup>2</sup>	39 (53.4)	73	1 (ref.)		12 (26.1)	46	1 (ref.)	
25.0-29.9 kg/m <sup>2</sup>	2 (22.2)	9	0.25 (0.05-1.28)	0.096	10 (58.8)	17	4.05 (1.26-13.03)	0.019
≥ 30.0 kg/m <sup>2</sup>	6 (54.5)	11	1.05 (0.29-3.74)	0.945	3 (37.5)	8	1.70 (0.35-8.22)	0.509
<b>Plasma CRP level groups</b>								
≤ 10 mg/l	37 (56.1)	66	1 (ref.)		10 (25.6)	39	1 (ref.)	
> 10-100 mg/l	23 (57.5)	40	1.06 (0.48-2.34)	0.885	9 (34.6)	26	1.54 (0.52-4.53)	0.437
> 100 mg/l	4 (80.0)	5	3.14 (0.33-29.58)	0.318	2 (66.7)	3	5.80 0.47-71.07	0.169
<b>Plasma albumin level groups<sup>a</sup></b>								
Below ref. interval	39 (60.9)	64	1.34 (0.58-3.00)	0.479	12 (32.4)	37	0.864 (0.31-2.43)	0.782
Within ref. interval	21 (53.8)	39	1 (ref.)		10 (35.7)	28	1 (ref.)	
Above ref. interval	1 (50.0)	2	0.86 (0.05-14.71)	0.915	0	1	-	-
<b>Blood leukocytes groups</b>								
< 3.5 × 10 <sup>9</sup> /l	2 (40.0)	5	0.63 (0.10-4.00)	0.629	0	3	-	-
3.5-10 × 10 <sup>9</sup> /l	42 (51.2)	82	1 (ref.)		15 (27.3)	55	1 (ref.)	
> 10 × 10 <sup>9</sup> /l	28 (77.8)	36	3.33 (1.36-8.18)	0.009	10 (55.6)	18	3.33 (1.11-10.04)	0.032

ref. = reference; TDEE = daily total energy expenditure.

a) Ref. values 36-48 g/l for ages of 18-40 yrs, 36-45 g/l for ages of 40-70 yrs, and 34-45 g/l for ages of > 70 yrs.

**Association between measured daily total energy expenditure and anthropometric measurements**

Significant results were found when investigating the association between measured TDEE and body weight, as well as measured TDEE and SMM. These results were significant both with and without adjustment for sex and age ( $p < 0.001$ ,  $p < 0.001$ ). After adjusting for sex and age, a correlation was observed between SMM% and measured TDEE ( $p = 0.036$ ) (see Table 4).

**TABLE 4** Association between measured daily total energy expenditure and body weight, skeletal muscle mass and skeletal muscle mass percentage.

	Unadjusted			Adjusted <sup>a</sup>		
	coefficient (B), kcal (95% CI)	p value	R <sup>2</sup>	coefficient (B), kcal (95% CI)	p value	R <sup>2</sup>
Body weight, kg	14.64 (11.45-17.84)	< 0.001	0.36	11.13 (8.00-14.25)	< 0.001	0.51
SMM, kg	49.59 (41.59-57.60)	< 0.001	0.52	43.17 (31.90-54.43)	< 0.001	0.54
SMM, %	9.63 (-2.36-21.62)	0.115	0.02	-11.86 (-22.94--0.79)	0.036	0.36

B = basal; R<sup>2</sup> = coefficient of determination; SMM = skeletal muscle mass.

a) Adjusted for sex and age.

**Discussion**

This study aimed to investigate the degree of over- or underestimation between measured and estimated TDEE based on recommendations from the DHA, which follow international guidelines for disease-related malnutrition [7]. In patients with a BMI ≤ 25 kg/m<sup>2</sup>, REE was often underestimated, whereas in those with a BMI of 25-29.9 kg/m<sup>2</sup>, REE was more frequently overestimated than in IC. This was also reflected in the associations with body weight and SMM. The discrepancy in the underestimations may be explained either by altered disease-related activity or by the effect of AF. This may also apply for patients with a BMI ≥ 30 kg/m<sup>2</sup>; however, a fair correlation was observed between estimated and measured values, maybe since in BMI ≥ 30 kg/m<sup>2</sup>, estimated requirements are set to 20 kcal/kg/day as opposed to 27 kcal/kg/day in the BMI group just below, which may also include those with a BMI of 29.9 kg/m<sup>2</sup>. It may be speculated whether a graduated method should be

used rather than cutoffs, or if one should evaluate adipose tissue placement to differentiate between metabolically active and silent fat tissue [11]. Why high leucocytes and not CRP seem to be significantly associated with increased basic metabolic rate remains unexplained. However, whereas both CRP and leukocyte counts reflect different aspects of immune and inflammatory responses, their elevations can have distinct implications for metabolism. CRP serves as a marker of systemic inflammation, whereas leukocyte counts may indicate specific immune responses [17, 18]. Further research is necessary to elucidate the precise mechanisms by which these factors interact and differentially influence metabolism. Muscle tissue plays a key role in REE due to its high metabolic activity. In our study, both body weight and absolute SMM were strongly associated with measured TDEE, confirming that energy needs are better predicted by metabolically active tissue than by BMI alone. Interestingly, SMM% showed a weaker inverse association with TDEE after adjustment, suggesting that total lean mass, rather than its relative proportion, is the more important factor. It furthermore appears that the effect on requirements is determined solely by sex, not by age. The role of skeletal muscle in energy metabolism is central to this discussion. Muscle tissue is metabolically active, even at rest, and contributes substantially to REE due to its constant demand for adenosine triphosphate to maintain ion gradients and protein turnover. Our study confirms this, showing a strong correlation between SMM and TDEE (Table 4). This remained significant even after adjusting for sex and age, emphasising the importance of considering lean body mass rather than total body weight in energy requirement estimates.

Whereas absolute SMM correlated positively with TDEE, SMM% showed a weaker and inversely directed correlation when adjusted, possibly reflecting that a patient with a high SMM% (but low absolute weight) may still have relatively lower total energy needs than larger individuals. This finding suggests that total metabolically active tissue mass (i.e., absolute SMM) is more predictive of energy expenditure than the relative proportion alone.

As the estimated requirements are based on international guidelines, it may be surprising that under- and overestimations are found but cannot easily be explained. An explanation may be that international recommendations are based on the same estimation methods studied herein [12, 14].

In our cohort of patients with many different diseases, most of whom had diseases of the gastrointestinal tract, we found only a few obese patients, compared with the general hospitalised population [9, 10]. This may be explained by a larger part of these patients suffering from intestinal failure, a patient group in which very few are obese [19].

## Conclusions

The requirements set in the recommendations on how to care for nutritional risk by the DHA seem to underestimate nutritional needs, the lower the patient's BMI is, up to BMI 25 kg/m<sup>2</sup>, whereas those with a BMI of 25-29.9 kg/m<sup>2</sup> were more frequently overestimated. Finally, patients with a BMI exceeding 30 kg/m<sup>2</sup> were underestimated. Only weight, muscle mass and leukocytes seem to significantly affect calorie needs. IC may be considered in patients not responding to nutritional therapy.

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