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Disagreement between estimated and indirect calorimetry-derived energy requirements in patients undergoing treatment for cancer; a prospective observational cohort study

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Abstract

Purpose: Energy requirements for patients with cancer are often estimated using predictive equations that do not typically account for differences in body composition, compared with measured energy requirements by indirect calorimetry (IC). The aim was to assess agreement between measured and estimated energy requirements in patients undergoing cancer treatment and whether specific patient characteristics were associated with resting energy expenditure.

Methods: In this prospective observational cohort study, patients referred to a clinical dietitian from an oncology outpatient clinic underwent an extended nutritional assessment including IC, bioelectrical impedance analysis, hand grip strength, and 30-second chair-stand test. Estimated energy requirements were assessed by clinical dietitians and retrospectively using the Harris-Benedict equation, with agreement assessed using Bland-Altman plots, and multiple linear regression analyses.

Results: In total 67 patients (27% women) were assessed, diagnosed with head and neck cancer (n=46), pancreatic cancer (n=13), and other cancers (n=8). Agreement between IC and estimated energy requirements by clinical dietitians was found for 58% of patients (24% were underestimated, 18% were overestimated). With the Harris-Benedict equation agreement was found for 52% of patients (46% were underestimated, 1.5% were overestimated). Higher muscle mass percentage ($p=0.001$), comorbidities ($p=0.039$), cancer stage ($p=0.003$), lower body fat percentage ($p<0.001$), and lower whole-body phase angle ($p=0.003$) were associated with higher resting energy expenditure.

Conclusion: A sizeable proportion of patients had incorrectly estimated energy requirements, with both methods tending to underestimate. Body composition, comorbidities, and cancer stage were associated with affected resting energy expenditure, indicating patient groups who could benefit from IC measurement.

Introduction

Patients undergoing cancer treatment are at increased risk of unintended weight loss and loss of muscle mass, ultimately leading to malnutrition and cachexia [1, 2]. These conditions are well-established contributors to low treatment tolerance and adverse outcomes in patients with cancer [3]. Cancer cachexia is a multifactorial syndrome characterized by loss of skeletal muscle mass, often accompanied by loss of adipose tissue and systemic inflammation and may be difficult to reverse by conventional nutritional support [4]. Estimated prevalences across cancer types ranges from 25% to 70% with pancreatic and head and neck cancers demonstrating high burden of malnutrition and cachexia [5, 6].

Nutritional screening and guidance are recommended to counteract weight loss, loss of muscle mass and malnutrition for patients with cancer at nutritional risk [7]. Although nutritional guidance has been associated with improved dietary intake and physical function, weight loss can persist despite nutritional intervention [8, 9], highlighting the need for systematic screening and accurate assessment of energy requirements [2].

Clinical dietitians rely on various equations to estimate energy requirements. One approach is the use of weight-based equations with predetermined kilocalories per kilogram, as recommended by the European Society for Clinical Nutrition and Metabolism (ESPEN) [10]. Another commonly used method is the Harris-Benedict predictive equation (H-B) which estimates energy requirements from height, weight, age and sex [11]. However, neither accounts for the changes in the metabolic state associated with cancer, including systemic inflammation, treatment related physiological stress, or variations in body composition [12]. Indirect calorimetry (IC), the gold standard for measuring energy requirements in clinical settings, uses oxygen consumption and carbon dioxide production to measure resting energy expenditure (REE) with precision [13]. However, IC is not routinely implemented in clinical practice due to limited time- and economical resources [14].

Body composition, particularly muscle mass, is a key determinant of energy requirements [14], as muscle mass is more metabolically active than fat mass (14.5 kcal/kg/day versus 4.5 kcal/kg/day) [12, 15]. Body composition is, however, rarely assessed in clinical practice. Bioelectrical impedance analysis (BIA) is a validated, accessible, and non-invasive method for assessing body composition, that can supplement nutritional guidance [16].

To optimize nutritional therapy in patients with cancer, a more precise approach to assess energy requirements might be relevant. Therefore, this study aimed to assess the agreement between measured and estimated energy requirements in patients undergoing cancer treatment and to investigate if specific patient characteristics are associated with resting energy expenditure.

Methods

Study design

The design was a prospective observational cohort study using data from a baseline measurement and follow-up assessment approximately four weeks after baseline. Follow-up data were analyzed as exploratory. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies [17].

Study settings

Data were collected consecutively from November 2025 to May 2026 from the oncology outpatient clinic at Copenhagen University Hospital - Herlev and Gentofte, Denmark.

Patients

Patients (≥ 18 years) undergoing cancer treatment and referred to a clinical dietitian by the Department of Oncology were offered an extended nutritional assessment. Exclusion criteria from the extended nutritional assessment included patients receiving dialysis or patients unable to comply with procedures, including fasting requirements or severe claustrophobia. Patients with a pacemaker were not excluded but could not undergo BIA measurement due to potential interference with the pacemaker. Only patients with a valid IC measurement at baseline were included in the data analyses.

The extended nutritional assessment

All eligible patients were offered a baseline extended nutritional assessment prior to their appointment with the clinical dietitian. The assessment included measured energy requirements by IC, body composition measurements by BIA and physical function evaluated with hand grip strength test (HGS-test) and 30-second chair-stand test (30s-CST). The clinical dietitian subsequently assessed estimated energy requirements, usually using weight-based predictive equations. After primary estimation, IC measurements were presented for the clinical dietitian and used in the nutritional guidance of patients.

Measured energy requirements with IC

Measured REE was obtained using the Q-NRG+ (COSMED, Rome, Italy) indirect calorimeter with canopy, according to the COSMED guidelines[18]. Measurements were conducted in the morning to ensure a minimum six-hour fast from food, caloric or caffeinated beverages. Water and regular medication were permitted. Patients were instructed to abstain from all nicotine products and strenuous exercise for four hours and rested at least 15 minutes before measurements. Measurements were performed in a supine position, with the canopy over the head and a plastic veil around the patient, to prevent outside air from disturbing measurements. The room temperature was kept between 21-22 °C. Measurements had an average duration of 15 minutes, with the first five minutes discarded, to obtain steady state. The optimal five-minute interval was selected by the device from the remaining ten minutes. A respiratory quotient between 0.67 – 1 and coefficient of variation of oxygen consumption (CV VO_2) and carbon dioxide production (CV VCO_2) were accepted at $\leq 10\%$ [13], [19]. A variation of $\pm 10\%$ relative to estimated energy expenditure was regarded clinically acceptable [14]. Measurements of REE, respiratory quotient, CV VO_2 , and CV CO_2 were collected. Total energy expenditure (TEE) was calculated by multiplying REE with an individual activity factor (AF), assessed by the clinical dietitian.

Estimated energy requirements by clinical dietitian

Clinical dietitians estimated energy requirements using a weight-based formula (27, 30, or 35 kcal/kg/day) or, in rare occasions, the H-B equation. The choice of equations was at the clinical dietitian's discretion. In patients with a Body Mass Index (BMI) > 30 , an adjusted body weight was applied, calculated by the following equation:

$$(\text{height in cm} - 100) + (\text{actual weight} - (\text{height in cm} - 100)) / 3 \text{ [20]}$$

Comparison by the Harris-Benedict equation

To allow comparison across all patients, energy requirements were retrospectively calculated using the H-B equation:

For men:

$$66.5 + (13.752 \times \text{weight in kg}) + (5.003 \times \text{height in cm}) - (6.755 \times \text{age})$$

For women:

$$655.1 + (9.563 \times \text{weight in kg}) + (1.850 \times \text{height in cm}) - (4.676 \times \text{age})[11]$$

To estimate TEE using H-B, the individual AF assessed by the clinical dietitian was multiplied. When considered appropriate by the clinical dietitian, a stress factor was applied [14] [21]. A stress factor was not applied when using weight-based formula, for these outpatients with no suspected fever [21]. The different methods of assessing energy requirements are illustrated in *Figure 1*.

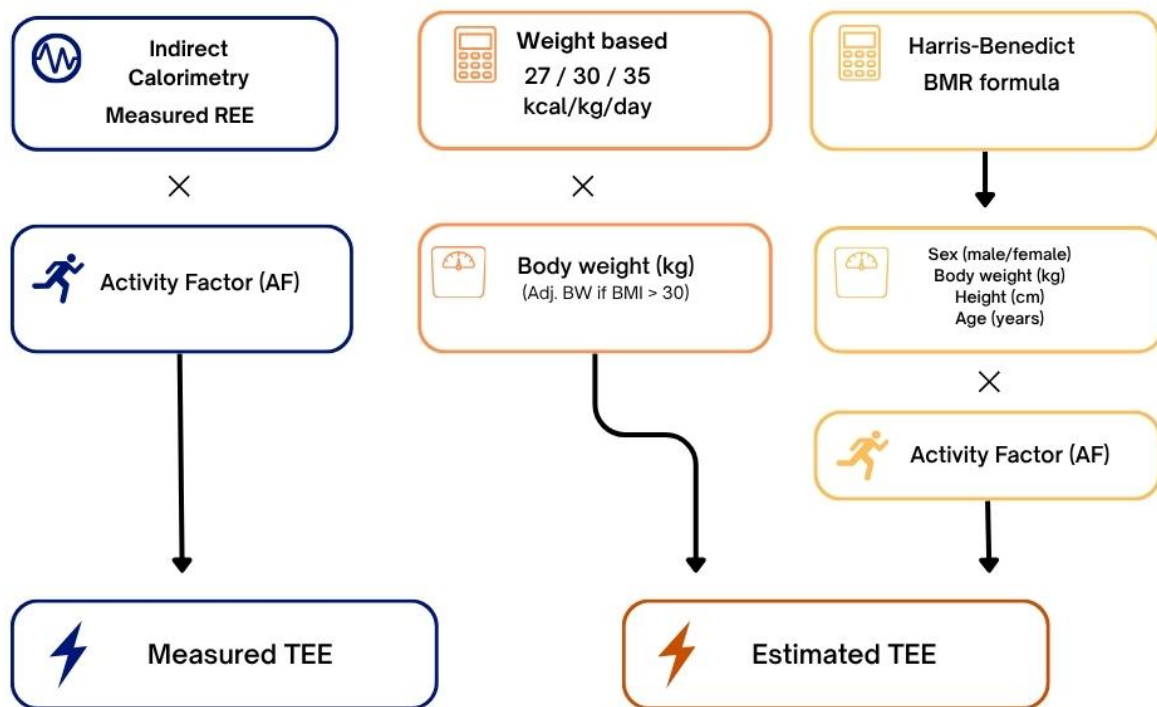


Fig. 1 Different methods used to assess energy requirements. Illustration of three different methods used to assess patients' energy requirements: measured indirect calorimetry (IC), weight-based estimation primarily used by the clinical dietitians, and the Harris-Benedict equation. Abbreviations: Adj. BW (Adjusted body weight), BMR (Basal metabolic rate), TEE (Total Energy Expenditure)

Body composition

Body composition was measured using BIA with the Inbody S10 (InBody, Seoul, South Korea) body water and composition analyzer. The analysis was performed after 15 minutes of rest, with patients instructed to empty their bladder be-

forehand and electrodes placed according to manufacturer's guidelines, in a supine position with arms and legs not touching the body [22]. The following variables were collected: skeletal muscle mass (SMM), percentage body fat, and whole-body phase angle (PhA). Percentage muscle mass was obtained by dividing SMM by body weight in kilograms. PhA was collected as a variable because it reflects cellular integrity (muscle quality) and has previously been associated with clinical outcomes in patients with cancer [23]. A low PhA was defined as a value below a 5th percentile of the age- and sex-stratified reference population [24].

Physical strength and function

HGS-test was assessed using a Jamar Smart Digital Hand Dynamometer® (Jamar Technology Inc., USA) [25] on the patient's self-reported strongest hand, seated with the forearm resting on the armrest of the chair with the elbow in a 90° angle. The maximum value of three attempts was recorded [26]. The 30s-CST test was performed using a chair with armrests and seat height at 45 centimeters, following established guidelines [27]. HGS-test-score and 30s-CST-score were categorized as normal or reduced using age- and sex-specific Danish reference values [28], with normal defined as ± 1 standard deviation of the population means and reduced as below 1 standard deviation. Body weight was obtained using a calibrated weight scale.

Baseline characteristics

Baseline characteristics included sex, age, height, BMI classified by World Health Organization (WHO) [29], cancer diagnosis, cancer stage, oncological treatment, performance status by the Eastern Cooperative Oncology Group (ECOG) scale assessed by the referring oncologist [30], plasma C-reactive protein (CRP), number of medications per day, smoking, and alcohol use were collected from the medical chart review. Charlson Comorbidity Index [31] was calculated from medical chart review. Plasma CRP was accepted if measured ± 1 month from baseline measurements. Alcohol use was categorized per Danish Health Authority recommended limits as ≤ 10 units/week. Frailty was assessed using the Geriatric 8 screening tool (score of ≤ 14 indicating frailty) [32].

Follow-up assessment

A follow-up assessment was conducted approximately 4 weeks after baseline and included IC, BIA, HGS-test, 30s-CST, and weight measurements.

Statistical methods

Descriptive statistics were used to characterize the study population, with categorical variables presented as n (%) and continuous variables presented as medians and interquartile range. Normality was assessed by the Shapiro-Wilk test and visual assessment using histograms and QQ-plots. Agreement between estimated and measured energy requirements was defined as a variation of $\pm 10\%$, with values outside this range classified as overestimation or underestimation and visualized using Bland-Altman plots. Continuous variables were compared among the three groups using the Kruskal-Wallis test. Univariable and multivariable linear regression analyses were performed to examine associations between IC-measured REE (kcal/kg/day) and selected variables, with multivariable models adjusted for sex and age. Analyses were performed on complete cases only. Statistical significance was set at $p < 0.05$. Analyses were performed using R (version 4.5.2) and Microsoft Excel (version 2502). All data were managed using REDCap [33].

Results

Of 122 patients screened, 79 patients met the eligibility criteria and accepted participation. A total of 12 were later excluded as illustrated in a flowchart in *Figure 2*. The study included 67 patients, 27% were female, and the median age was 71 years [interquartile range (IQR) 62,76]. The majority had head and neck cancer (69%), followed by pancreatic cancer (19%). Based on BMI, 1 patient was underweight (1.5%), 34 were normal weight (51%), 21 were overweight (31%), and 11 were obese (16%). Baseline characteristics are presented in *Table 1*.

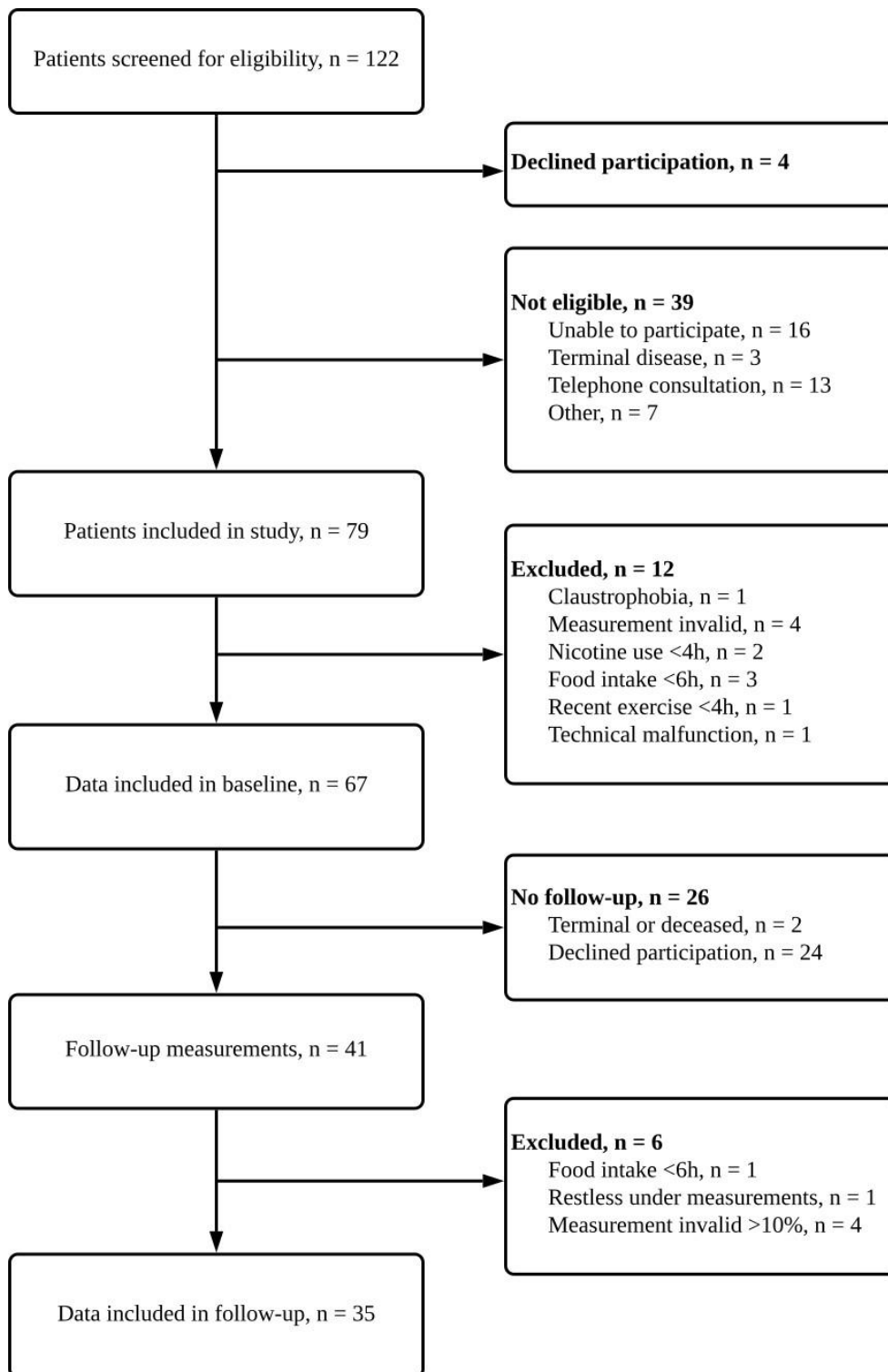


Fig. 2 Patient recruitment

Energy requirements and body composition

Median TEE measured by IC was 2240 kcal/day [IQR 1970, 2430], compared with 2140 kcal/day [IQR 1970, 2460] estimated by clinical dietitians and 2010 kcal/day [IQR 1810, 2300] calculated by the H-B equation. Only the H-B method exceeded mean difference of $\pm 10\%$ compared with IC (4.5% for clinical dietitian and 10% for H-B equation). Body

composition was assessed in 64 patients, with a median muscle mass percentage of 40% [IQR 34, 43] and a body fat percentage of 26% [IQR 22, 36]. A PhA below the reference value was observed in 72% of women and 52% of men. The results are presented in *Online Resource Table S1*. Between baseline and follow-up, TEE calculated by the H-B equation decreased significantly ($p=0.004$), whereas TEE measured by IC and the patients' body composition did not change significantly. The results are presented in *Online Resource Table S2*.

Agreement between measurements and estimates

Agreement was found in 58% of patients for clinical dietitian estimates compared with 52% for H-B equation. Notably, H-B equation underestimated TEE in 46% of patients compared with IC, versus 24% for clinical dietitians. The H-B equation overestimated one patient, whereas the estimates from the clinical dietitians overestimated 18% of patients compared with IC measurements. Bland-Altman analysis revealed a mean difference of -68 kcal (± 252) with 95% limits of agreement of -562 to 427 kcal for clinical dietitian estimates compared with IC. For H-B compared with IC, the mean difference was -183 kcal (± 212) with limits of agreement of -597 to 232 kcal. The regression line showed a negative slope in both Bland-Altman plots, with a steeper slope for clinical dietitians estimates compared with H-B ($R^2=0.14$ for clinical dietitian and $R^2=0.005$ for H-B). Results are presented in *Figure 3*.

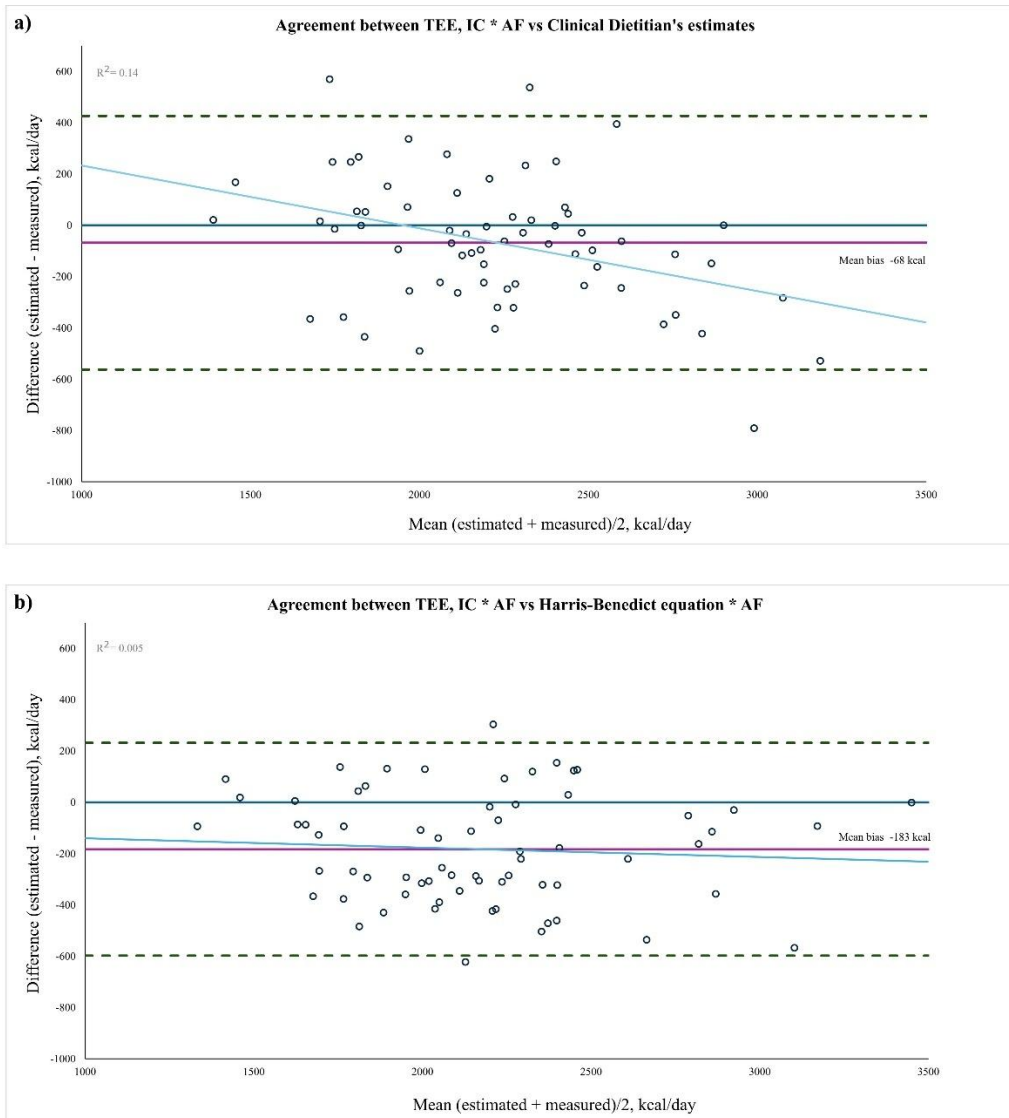


Fig. 3 Bland-Altman Plots showing agreement between measured energy requirements by IC and estimated energy requirements by a) Clinical dietitians and b) the Harris-Benedict equation. The blue line represents zero-bias. The solid lilac line represents the mean bias. The green dashed lines describe the Limits of Agreement. The light blue regression line indicates proportional bias.

Relations between measurements and patient characteristics

No significant associations were found between baseline characteristics and agreement, underestimation or overestimation for either method (*Table 2*). However, patients underestimated by clinical dietitians had a median muscle mass of 41%, a median of 25% body fat, and a median BMI of 22.3 kg/m² and overestimated patients had a median muscle mass of 36%, a median of 32% body fat, and a median BMI of 24.5 kg/m². Univariable linear regression analyses identified significant association between measured energy expenditure and body composition, PhA, hand grip strength, and cancer stage (*Table 3*). When adjusted for sex and age, these associations remained significant except for hand grip strength ($p=0.053$). Further Charlson Comorbidity Index additionally reached statistical significance (muscle mass: $R^2=0.168$,

$p=0.001$; body fat: $R^2=0.250$, $p<0.001$; PhA: $R^2=0.142$, $p=0.003$; Charlson Comorbidity Index: $R^2=0.073$, $p=0.039$; cancer stage: $R^2=0.141$, $p=0.003$). A trend toward association was observed for frailty (Geriatric-8 score: $p=0.051$). No significant associations were found between plasma CRP and 30s-CST and REE.

Discussion

In this cohort study of patients undergoing treatment for cancer, substantial discrepancies were observed between energy requirements estimated by clinical dietitians and those measured with IC. The H-B equation performed even less accurately, with nearly half of all patients underestimated. Bland-Altman analyses confirmed a small mean underestimation for both estimation methods but with wide limits of agreement, indicating considerable individual variation. Body composition, including higher muscle mass, lower body fat percentage and low PhA, alongside comorbidities, and cancer stage IV, were all significantly associated with higher REE.

Agreement between measured and estimated energy requirements

Previous studies have compared measured energy requirements with predictive equations in different patient groups. In a cohort study of acutely admitted older medical patients [34], approximately half of patients were overestimated by weight-based formulas and 17% underestimated. A slightly better agreement was found in our study population. However, this difference should be interpreted considering important methodological and population differences. In the previous study, the same weight-based formulas were applied systematically across all patients, whereas clinical dietitians in the present study individualized estimates according to patient characteristics. In addition, the previous study included substantially older hospitalized patients, in whom age-related changes in body composition and metabolism generally lower energy requirements. Both studies consistently found underestimation using the H-B equation and another cross-sectional study comparing H-B with IC in patients with cancer [35] reported underestimation in 75% of their cohort. This is further supported by previous studies suggesting that patients with cancer have elevated energy requirements and are particularly vulnerable to inaccurate estimation using predictive equations [36, 37].

Both Bland-Altman plots in the current study demonstrated wide limits of agreement and a negative regression slope, indicating a tendency to underestimate patients with higher energy requirements. This tendency was more pronounced for clinical dietitian estimates than for the H-B equation, suggesting underestimation became more pronounced with higher energy requirements. One possible contributing factor is the use of adjusted body weight for patients with BMI > 30 in the clinical dietitians' estimates as opposed to the use of actual weight in the H-B equation. However, this interpretation should be regarded as exploratory, given the relatively low R^2 -values of the regression lines.

Patient characteristics and increased energy requirements

In the adjusted linear regression model, higher muscle mass percentage was associated with increased REE, while a higher body fat percentage was associated with decreased REE. This is consistent with the well-established understanding of increased metabolic activity of skeletal muscle mass relative to adipose tissue. The findings are also supported by a cohort study similarly reporting higher energy requirements in patients with greater muscle mass [38]. Patients underestimated by clinical dietitians tended to have higher muscle mass, lower body fat, and lower BMI than those overestimated. Although these differences did not reach statistical significance, they suggest that reliance on weight-based formulas without

consideration of body composition may contribute to underestimation in patients with relatively high muscle mass and low BMI.

An association between increased REE (kcal/kg/day) and low PhA was also identified. PhA reflects cellular integrity and has been linked to malnutrition, low muscle mass, and poor survival in patients with cancer [23, 39]. To our knowledge, few studies have investigated the association between REE and PhA, but one study [39] found that low PhA was associated with lower energy requirements, contrary to the findings of the current study. This contradiction may be explained primarily by REE being expressed in kcal/day in the older malnourished cohort rather than kcal/kg/day as in the current study. As patients with low PhA in the referred to study [39] also had low BMI, their findings may reflect differences in body weight adjustment and population rather than a true contradiction. Further studies are needed to determine whether PhA is a reliable marker of increased energy requirements in patients with cancer. Higher Charlson Comorbidity Index and stage IV cancer were also associated with increased energy requirements. A study in older patients [40] found a significant association between higher number of chronic diseases and increased energy requirements, while a study in patients with colorectal cancer [41] found that stage IV cancer was associated with increased energy requirements over time. To our knowledge, the association between comorbidity and energy requirements has not been examined in patients with cancer, and further studies are needed to explore this in these patients.

Discrepancies between estimated and measured energy requirements

Discrepancies between measured and estimated energy requirements likely reflect the combined influence of multiple factors. In the adjusted linear regressions model, body fat percentage explained the largest proportion of the variation in REE, followed by muscle mass percentage, PhA, advanced cancer stage, and comorbidity. Notably, even the strongest individual predictor explained only 25% of the variation of increase in REE, suggesting energy requirements in patients with cancer are not driven by a single factor but represent a complex interplay of factors. The remaining unexplained variation could indicate additional factors, not captured in this study, which may contribute to energy requirements. Further studies could consider additional variables to further clarify the determinants of energy requirements in this patient population.

The AF applied to REE to estimate TEE represents an additional source of variability. In the current study, this factor was determined by clinical dietitians based on subjective patient-reported physical activity, which may introduce inaccuracies in both estimated and measured TEE [42]. The H-B equation underestimated energy requirements in nearly half of the patients in the current study. Notably, the H-B equation was originally derived to estimate basal metabolic rate rather than REE, and some literature suggests that REE exceeds basal metabolic rate by approximately 10% [43]. However, this interpretation is not universally accepted, as other literature argues that H-B equation was developed under conditions resembling REE more than basal metabolic rate [44].

Strength and limitations

This study has several strengths. Measurements were conducted by the same two investigators throughout the study period, ensuring methodological consistency, and patient compliance was supported by scheduling assessment on existing hospital visit days and reminding patients beforehand. IC, which is the clinical gold standard for measuring REE, allowed for precise and reliable measurements. Body composition was assessed using BIA, a simple and widely accessible method in clinical practice[45].

Some limitations should be acknowledged. The outpatient setting meant that full adherence to IC criteria (fasting, abstinence from nicotine products, and physical rest) could not be guaranteed despite systematic screening upon arrival. Transportation to the hospital prior to measurement may have introduced variability, due to physical activity during transit. Furthermore, the small sample size, especially for follow up, and the single-center design limit the generalization and the replicability of the findings. Patients unable to attend follow-up due to weakness or illness may have experienced worse patient outcomes, suggesting that the results may be subject to selection bias, with the most severely ill patients likely underrepresented in the follow up data.

Conclusion

In this cohort of patients undergoing cancer treatment, estimated energy requirements frequently differed from IC-derived energy requirements, with a tendency towards underestimation, particularly using the H-B equation. An increase in muscle mass, comorbidities, and cancer stage IV as well as lower body fat and PhA were found to be significantly associated with increased energy requirements. Patients with these characteristics could therefore be considered to benefit from IC measurements. The multifactorial nature of energy requirements in patients with cancer highlights the needs for larger studies to identify patient groups who could benefit from measured rather than estimated energy requirements.

Statements and declarations

Author contributions

Study conception and design were developed by Anne Wilkens Knudsen and Cecilia Margareta Lund in collaboration. All authors contributed to the refinement of the study protocol. Data collections were performed by Molly Emilia Stevelt Davies and Nicolaj Sindahl Jensen. Analyses were performed by Molly Emilia Stevelt Davies. The manuscript was written by Molly Emilia Stevelt Davies and all authors commented on and revised previous versions of the manuscript. All authors read and approved of the final manuscript.

Ethics approval

This study was approved by the Hospital Executive Board as a quality development project (Workzone number: 25054948), for which formal informed consent for registration of additional data was not required. The study was further presented to and approved by the Patient Advocacy Board of the Department of Oncology at Herlev and Gentofte Hospital.

Consent to participate

All patients were informed of the extended nutritional assessment and agreed to participate. As this study was approved as a quality development project, formal written consent was not required.

Data availability

The data supporting the findings of this paper are not available upon request due to the nature of the quality development work under which data were collected.

Declarations of Generative AI and AI assisted technologies in the review process

During the review of this work, the authors used ChatGPT4 and Claude Sonnet 4.6 to improve readability and flow. Afterwards the authors edited and reviewed content as needed, taking full responsibility for the content of the publication.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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References

1. Martin L, Senesse P, Gioulbasanis I, et al (2015) Diagnostic criteria for the classification of cancer-associated weight loss. *J Clin Oncol* 33:90–9. <https://doi.org/10.1200/JCO.2014.56.1894>
2. Arends J, Baracos V, Bertz H, et al (2017) ESPEN expert group recommendations for action against cancer-related malnutrition. *Clin Nutr* 36:1187–1196. <https://doi.org/10.1016/j.clnu.2017.06.017>
3. Arends J (2024) Malnutrition in cancer patients: causes, consequences and treatment options. *Eur J Surg Oncol* 50:107074. <https://doi.org/10.1016/j.ejso.2023.107074>
4. Fearon K, Strasser F, Anker SD, et al (2011) Definition and classification of cancer cachexia: an international consensus. *Lancet Oncol* 12:489–495. [https://doi.org/10.1016/S1470-2045\(10\)70218-7](https://doi.org/10.1016/S1470-2045(10)70218-7)
5. Argilés JM, López-Soriano FJ, Stemmler B, Busquets S (2023) Cancer-associated cachexia — understanding the tumour macroenvironment and microenvironment to improve management. *Nat Rev Clin Oncol* 20:250–264. <https://doi.org/10.1038/s41571-023-00734-5>
6. Bossi P, Delrio P, Mascheroni A, Zanetti M (2021) The spectrum of malnutrition/cachexia/sarcopenia in oncology according to different cancer types and settings: a narrative review. *Nutrients* 13:1980. <https://doi.org/10.3390/nu13061980>
7. Muscaritoli M, Arends J, Bachmann P, et al (2021) ESPEN practical guideline: clinical nutrition in cancer. *Clin Nutr* 40:2898–2913. <https://doi.org/10.1016/j.clnu.2021.02.005>
8. Bargetzi L, Brack C, Herrmann J, et al (2021) Nutritional support during the hospital stay reduces mortality in patients with different types of cancers: secondary analysis of a prospective randomized trial. *Ann Oncol* 32:1025–1033. <https://doi.org/10.1016/j.annonc.2021.05.793>
9. Engelstrup E, Beck AM, Munk T, et al (2023) The association between nutrition impact symptoms, nutritional risk, and risk of reduced overall survival in patients with head and neck cancer. A retrospective study. *Clin Nutr ESPEN* 57:239–245. <https://doi.org/10.1016/j.clnesp.2023.06.034>
10. Arends J, Bachmann P, Baracos V, et al (2017) ESPEN guidelines on nutrition in cancer patients. *Clin Nutr* 36:11–48. <https://doi.org/10.1016/j.clnu.2016.07.015>
11. Harris JA, Benedict FG (1918) A biometric study of human basal metabolism. *Proc Natl Acad Sci U S A* 4:370–3. <https://doi.org/10.1073/pnas.4.12.370>

12. Purcell SA, Elliott SA, Baracos VE, et al (2016) Key determinants of energy expenditure in cancer and implications for clinical practice. *Eur J Clin Nutr* 70:1230–1238. <https://doi.org/10.1038/ejcn.2016.96>
13. Achamrah N, Delsoglio M, De Waele E, et al (2021) Indirect calorimetry: the 6 main issues. *Clin Nutr* 40:4–14. <https://doi.org/10.1016/j.clnu.2020.06.024>
14. Bendavid I, Lobo DN, Barazzoni R, et al (2021) The centenary of the Harris-Benedict equations: how to assess energy requirements best? Recommendations from the ESPEN expert group. *Clin Nutr* 40:690–701. <https://doi.org/10.1016/j.clnu.2020.11.012>
15. Javed F, He Q, Davidson LE, et al (2010) Brain and high metabolic rate organ mass: contributions to resting energy expenditure beyond fat-free mass. *Am J Clin Nutr* 91:907–12. <https://doi.org/10.3945/ajcn.2009.28512>
16. Dupertuis YM, Jimaja W, Beardsley Levoy C, Genton L (2025) Bioelectrical impedance analysis instruments: how do they differ, what do we need for clinical assessment? *Curr Opin Clin Nutr Metab Care* 28:379–387. <https://doi.org/10.1097/MCO.0000000000001142>
17. von Elm E, Altman DG, Egger M, et al (2008) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 61:344–9. <https://doi.org/10.1016/j.jclinepi.2007.11.008>
18. Delsoglio M, Dupertuis YM, Oshima T, et al (2020) Evaluation of the accuracy and precision of a new generation indirect calorimeter in canopy dilution mode. *Clin Nutr* 39:1927–1934. <https://doi.org/10.1016/j.clnu.2019.08.017>
19. Compher C, Frankenfield D, Keim N, et al (2006) Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *J Am Diet Assoc* 106:881–903. <https://doi.org/10.1016/j.jada.2006.02.009>
20. Shah B, Sucher K, Hollenbeck CB (2006) Comparison of ideal body weight equations and published height-weight tables with body mass index tables for healthy adults in the united states. *Nutr Clin Pract* 21:312–319. <https://doi.org/10.1177/0115426506021003312>
21. Kondrup J, Bak L, Hansen BS, et al (1998) Outcome from nutritional support using hospital food. *Nutrition* 14:319–21. [https://doi.org/10.1016/s0899-9007\(97\)00481-4](https://doi.org/10.1016/s0899-9007(97)00481-4)
22. InBody Co., Ltd (2020) InBody S10 user's manual. Seoul
23. Amano K, Bruera E, Hui D (2023) Diagnostic and prognostic utility of phase angle in patients with cancer. *Rev Endocr Metab Disord* 24:479–489. <https://doi.org/10.1007/s11154-022-09776-z>
24. Mattiello R, Amaral MA, Mundstock E, Ziegelmann PK (2020) Reference values for the phase angle of the electrical bioimpedance: systematic review and meta-analysis involving more than 250,000 subjects. *Clin Nutr* 39:1411–1417. <https://doi.org/10.1016/j.clnu.2019.07.004>
25. Santos GMX dos, Mauad LD de S, Nardim HCB, et al (2025) Test-retest reliability and concurrent validity of three different handgrip dynamometers (Jamar, Jamar Plus+ and Biodex) in healthy young adults. *Hand Ther.* <https://doi.org/10.1177/17589983251352104>
26. Roberts HC, Denison HJ, Martin HJ, et al (2011) A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach. *Age Ageing* 40:423–429
27. Jones CJ, Rikli RE, Beam WC (1999) A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Res Q Exerc Sport* 70:113–119. <https://doi.org/10.1080/02701367.1999.10608028>

28. Kristensen MT, Dall CH, Aadahl M, Suetta C (2022) Systematic assessment of physical function in adult patients across diagnosis. *Ugeskr Laeger* 184:V02220134
29. World Health Organization (2000) Obesity: preventing and managing the global epidemic. Report of a WHO consultation. *World Health Organ Tech Rep Ser* 894:i–xii, 1–253
30. Oken MM, Creech RH, Tormey DC, et al (1982) Toxicity and response criteria of the Eastern Cooperative Oncology Group. *Am J Clin Oncol*: 5:649–655
31. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 40:373–83. [https://doi.org/10.1016/0021-9681\(87\)90171-8](https://doi.org/10.1016/0021-9681(87)90171-8)
32. Bellera CA, Rainfray M, Mathoulin-Pélissier S, et al (2012) Screening older cancer patients: first evaluation of the G-8 geriatric screening tool. *Ann Oncol* 23:2166–2172. <https://doi.org/10.1093/annonc/mdr587>
33. Harris PA, Taylor R, Minor BL, et al (2019) The REDCap consortium: building an international community of software platform partners. *J Biomed Inform* 95:103208. <https://doi.org/10.1016/j.jbi.2019.103208>
34. Knudsen AW, Engelsted SN, Lund CM, et al (2025) Assessing energy expenditure: accuracy of predictive equations versus indirect calorimetry in older hospitalized patients at the medical ward. *Clin Nutr ESPEN* 69:458–467. <https://doi.org/10.1016/j.clnesp.2025.07.1118>
35. Barcellos PS, Borges N, Torres DPM (2021) Resting energy expenditure in cancer patients: agreement between predictive equations and indirect calorimetry. *Clin Nutr ESPEN* 42:286–291. <https://doi.org/10.1016/j.clnesp.2021.01.019>
36. Cao D xing, Wu G hao, Zhang B, et al (2010) Resting energy expenditure and body composition in patients with newly detected cancer. *Clin Nutr* 29:72–77. <https://doi.org/10.1016/j.clnu.2009.07.001>
37. Souza MTP, Singer P, Ozorio GA, et al (2018) Resting energy expenditure and body composition in patients with head and neck cancer: an observational study leading to a new predictive equation. *Nutrition* 51–52:60–65. <https://doi.org/10.1016/j.nut.2017.12.006>
38. Houmøller CP, Hellerup SH, Nøhr NK, et al (2024) Measured versus estimated energy requirement in hospitalized patients. *Clin Nutr ESPEN* 59:312–319. <https://doi.org/10.1016/j.clnesp.2023.12.011>
39. Kawase F, Masaki Y, Ozawa H, et al (2024) Association of resting energy expenditure with phase angle in hospitalized older patients: a cross-sectional analysis. *Eur J Clin Nutr* 78:187–192. <https://doi.org/10.1038/s41430-023-01370-z>
40. Fabbri E, An Y, Schrack JA, et al (2015) Energy metabolism and the burden of multimorbidity in older adults: results from the Baltimore longitudinal study of aging. *J Gerontol A Biol Sci Med Sci* 70:1297–1303. <https://doi.org/10.1093/gerona/glu209>
41. Purcell SA, Wallengren O, Baracos VE, et al (2020) Determinants of change in resting energy expenditure in patients with stage III/IV colorectal cancer. *Clin Nutr* 39:134–140. <https://doi.org/10.1016/j.clnu.2018.12.038>
42. Hills AP, Mokhtar N, Byrne NM (2014) Assessment of physical activity and energy expenditure: an overview of objective measures. *Front Nutr* 1:5. <https://doi.org/10.3389/fnut.2014.00005>

43. Gonzalez-Campoy JM, Castorino K, Ebrahim A, et al (2013) Clinical practice guidelines for healthy eating for the prevention and treatment of metabolic and endocrine diseases in adults: cosponsored by the American Association of Clinical Endocrinologists/the American College of Endocrinology and the Obesity Society. *Endocr Pract* 19:1–82. <https://doi.org/10.4158/EP13155.GL>
44. Frankenfield D, Roth-Yousey L, Compher C (2005) Comparison of predictive equations for resting metabolic rate in healthy nonobese and obese adults: a systematic review. *J Am Diet Assoc* 105:775–789. <https://doi.org/10.1016/j.jada.2005.02.005>
45. Ward LC (2019) Bioelectrical impedance analysis for body composition assessment: reflections on accuracy, clinical utility, and standardisation. *Eur J Clin Nutr* 73:194–199. <https://doi.org/10.1038/s41430-018-0335-3>

Tables

Table 1. Baseline characteristics of the study population (N = 67)

Characteristics	Total cohort (N = 67)
Sex, female	18 (27%)
Age, years	71 [62, 76]
BMI, kg/m ²	24.5 [22.4, 27.1]
Cancer type	
Pancreas cancer	13 (19%)
Head and neck cancer	46 (69%)
Other	8 (12%)
Cancer stage	
Stage I	18 (27%)
Stage II	4 (6%)
Stage III	20 (30%)
Stage IV	23 (34%)
Stage unknown	2 (3%)
Oncology treatment	
Chemotherapy	19 (28%)
Surgery	10 (15%)
Radiotherapy	23 (34%)
Immunotherapy	5 (7.5%)
No treatment at baseline	26 (39%)
Charlson Comorbidity Index	6 [5, 9]
Number of medications per day	6 [3, 9]
Performance Status (ECOG)	
0	38 (57%)
1	22 (33%)
2+	7 (10%)
Geriatric 8-score	
Frail ≤ 14	45 (67%)

Not frail >14	22 (33%)
Hand grip strength	
Reduced	24 (36%)
30-second chair-stand test*	
Reduced	20 (30%)
Smoking	
Former or current smoker	47 (70%)
Alcohol consumption	
Current or former excess alcohol use	21 (31%)

Continuous data are presented as median and IQR with [Q1, Q3]

Categorical data are presented as number and percentage (%). Percentages are calculated excluding missing data.

Hand grip strength and 30-second chair-stand test are assessed according to reference[28].

*n=66.

Alcohol consumption was categorized according to recommended limits by the Danish Health Authority (≤ 10 units of alcohol per week).

Table 2 Agreement between total energy requirements estimated by clinical dietitians, Harris-Benedict equation and measured energy requirements by IC, and association with selected variables

	Comparison between dietitian and IC					Comparison between H-B and IC			
	Overestimation*	Agreement	Underestimation**	<i>p</i>		Overestimation*	Agreement	Underestimation**	<i>p</i>
	n	n = 12	n = 39	n = 16		n = 1	n = 35	n = 31	
Muscle mass, %	64	36 [33, 42]	40 [35, 43]	41 [36, 45]	0.322	42 [42, 42]	40 [34, 43]	40 [34, 44]	0.861
Body fat, %	64	32 [24, 39]	26 [22, 36]	25 [18, 33]	0.297	24 [24, 24]	26 [23, 36]	26 [21, 37]	0.706
Whole-body phase angle, °	64	5.1 [4.4, 5.5]	5.0 [4.5, 5.8]	4.6 [4.4, 5.6]	0.870	5.1 [5.1, 5.1]	5.2 [4.4, 6.1]	4.9 [4.4, 5.4]	0.553
30-second chair-stand	66	12 [11, 15]	14 [11, 18]	15 [13, 18]	0.492	21 [21, 21]	14 [12, 19]	14 [11, 18]	0.393
Geriatric-8 score	67	14.0 [9.9, 15.1]	13.0 [10.2, 14.2]	13.8 [11.9, 15.0]	0.395	16.0 [16.0, 16.0]	13.0 [10.0, 15.0]	13.5 [11.8, 14.8]	0.236
Charlson Comorbidity Index	67	6 [5, 6]	6 [5, 8]	5 [4, 9]	0.467	5 [5, 5]	6 [4, 7]	6 [5, 9]	0.470
Plasma C-Reactive Protein, mg/L	61	6 [4, 17]	5 [4, 24]	5 [4, 9]	0.872	4 [4, 4]	4 [4, 9]	7 [4, 36]	0.116
Age, years	67	71 [63, 75]	71 [63, 76]	74 [58, 76]	0.948	74 [74, 74]	70 [59, 76]	74 [65, 77]	0.387
BMI, kg/m ²	67	24.5 [22.9, 26.0]	25.3 [22.6, 29.1]	22.3 [20.3, 27.5]	0.238	25.0 [25.0, 25.0]	25.3 [22.9, 28.1]	23.6 [21.5, 26.4]	0.370

H-B = Harris-Benedict equation, IC = Indirect calorimetry

Data are presented as median and IQR with [Q1, Q3]

*Estimation >10% above IC measurements

**Estimation > 10% below IC measurements

p-values (p) were analyzed by a Kruskal-Wallis test.

Table 3 The association between measured resting energy expenditure (REE, kcal/kg/day) and selected variables

	Unadjusted model						Adjusted model*				
	n	R ²	Estimate β	SE	95% CI	p	R ²	Estimate β	SE	95% CI	p
Muscle mass, %	64	0.142	0.187	0.058	0.07 – 0.303	0.002*	0.168	0.235	0.068	0.099 – 0.372	0.001*
Body fat, %	64	0.226	-0.138	0.033	-0.203 – -0.073	<0.001*	0.250	-0.159	0.036	-0.23 – -0.087	<0.001*
Whole-body phase angle, °	64	0.070	-0.736	0.340	-1.415 – -0.057	0.034*	0.142	-1.274	0.411	-2.095 – -0.452	0.003*
Hand grip strength (reduced vs normal)	67	0.062	1.402	0.679	0.047 – 2.757	0.043*	0.065	1.363	0.693	-0.021 – 2.747	0.053
30-second chair-stand (reduced vs normal)	66	0.004	-0.374	0.718	-1.809 – 1.061	0.604	0.022	-0.442	0.727	-1.895 – 1.011	0.545
Geriatric-8 score (frail vs not frail)	67	0.050	1.294	0.697	-0.098 – 2.686	0.068	0.066	1.417	0.712	-0.006 – 2.839	0.051
Charlson Comorbidity Index	67	0.030	0.185	0.130	-0.074 – 0.444	0.158	0.073	0.317	0.150	0.017 – 0.617	0.039*
Cancer stage (IV vs I-III)	65	0.132	2.067	0.668	0.732 – 3.402	0.003*	0.141	2.119	0.679	0.761 – 3.478	0.003*
Plasma C-Reactive Protein, mg/L	61	0.021	0.021	0.019	-0.017 – 0.058	0.269	0.029	0.023	0.019	-0.016 – 0.061	0.238

Unadjusted and adjusted linear regression analyses.

*The model was adjusted for age and sex

Results are presented as coefficient of determination (R²), unstandardized regression coefficients (β) with standard error (SE) and 95% confidence intervals (CI). P-values (p) are analyzed from a linear regression model.

Supplementary Files

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