Clinical Nutrition ESPEN xxx (2016) e1–e8

Contents lists available at ScienceDirect

Clinical Nutrition ESPEN

journal homepage: http://www.clinicalnutritionespen.com

Original article

Estimating energy expenditure in vascular surgery patients: Are predictive equations accurate enough?

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ARTICLE INFO

Article history:
Received 31 August 2016
Accepted 7 September 2016

Keywords:
Resting energy expenditure
Peripheral arterial disease
Schofield equation
Harris Benedict equation
Miller equation

SUMMARY

Background & aims: Malnutrition is prevalent in vascular surgical patients who commonly seek tertiary care at advanced stages of disease. Adjunct nutrition support is therefore pertinent to optimise patient outcomes. To negate consequences related to excessive or suboptimal dietary energy intake, it is essential to accurately determine energy expenditure and subsequent requirements. This study aims to compare resting energy expenditure (REE) measured by indirect calorimetry, a commonly used comparator, to REE estimated by predictive equations (Schofield, Harris–Benedict equations and Miller equation) to determine the most suitable equation for vascular surgery patients.
Methods: Data were collected from four studies that measured REE in 77 vascular surgery patients. Bland–Altman analyses were conducted to explore agreement. Presence of fixed or proportional bias was assessed by linear regression analyses.
Results: In comparison to measured REE, on average REE was overestimated when Schofield (+857 kJ/day), Harris–Benedict (+801 kJ/day) and Miller (+71 kJ/day) equations were used. Wide limits of agreement led to an over or underestimation from 1552 to 1755 kJ. Proportional bias was absent in Schofield ($R^2 = 0.005$, $p = 0.54$) and Harris–Benedict equations ($R^2 = 0.045$, $p = 0.06$) but was present in the Miller equation ($R^2 = 0.210$, $p < 0.01$) even after logarithmic transformation ($R^2 = 0.213$, $p < 0.01$).
Conclusions: Whilst the Miller equation tended to overestimate resting energy expenditure and was affected by proportional bias, the limits of agreement and mean bias were smaller compared to Schofield and Harris–Benedict equations. This suggested that it is the preferred predictive equation for vascular surgery patients. Future research to refine the Miller equation to improve its overall accuracy will better inform the provision of nutritional support for vascular surgery patients and subsequently improve outcomes. Alternatively, an equation might be developed specifically for use with vascular surgery patients.

1. Introduction

Vascular surgery encompasses a broad range of pathologies including arterial occlusive or aneurysmal disease as well as venous disease. The prevalence of vascular disease is increasing in the older population [1], many of whom present to the tertiary setting with advanced stages of disease, often associated with ulceration. The nutritional status of these patients is heterogeneous. It is well established in the literature that overweight and obesity are either independently risk factors or strongly associated with other risk factors for cardiovascular diseases, including peripheral vascular disease [2], aneurysmal disease [3] and venous disease [4]. In

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Abbreviations: AAA, abdominal aortic aneurysm; EER, estimated energy expenditure; eREE, estimated resting energy expenditure; HB, Harris–Benedict equation; Ht, height; kg, kilograms; kg/m^2, kilograms per metre squared; kJ, kiloJoule; kJ/day, kiloJoules per day; LLVU, lower limb venous ulcer; mREE, measured resting energy expenditure; n, number; Q1, first quartile; Q3, third quartile; REE, resting energy expenditure; SD, standard deviation; Wt, weight.

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http://dx.doi.org/10.1016/j.clnesp.2016.09.001

contrast, these same patients may be frail due to underlying comorbidities [5], which compounded by poor nutritional status makes recovery from major surgery or wound healing an ongoing challenge.

To illustrate the heterogeneity and complexity of vascular surgery patients, previous work by our team has reported higher BMI amongst patients with peripheral vascular disease (mean 28.5 kg/m^2) [6], yet in a sample of vascular surgery inpatients suffering wounds we found that 68% were identified as being overweight yet almost one third were identified as being at risk of nutritional deterioration by means of unintentional weight loss [7]. This highlights the possibility of obesity masking muscle loss or deteriorating nutritional status, such as is the case in those that might be suffering from sarcopenic obesity. In fact our own work has observed an association between larger aortic abdominal aneurysms and a reduction in muscle mass [8]. Recent work from De Waele has also demonstrated that 61% of elective vascular surgery patients are at risk of malnutrition [9] and chronic critical limb ischaemia [10] and lower limb venous ulcer [11] patients have also been identified as malnourished.

Given the heterogeneity in nutritional status amongst vascular surgery patients and the high prevalence of malnutrition (over and under), the nutritional management of these patients is complex. In current practice, the provision of nutrition intervention is guided by the use of predictive equations to estimate REE. Predictive equations are derived from comparisons with indirect calorimetry, a readily available and cost effective technique. In Australia, Schofield and Harris–Benedict equations are the most common predictive equations used [12]. These equations were developed from indirect calorimetry data from predominantly healthy young population groups [13,14] and hence may not be accurate estimates of REE for older adults with complex medical histories, including vascular disease. To theoretically calculate total energy expenditure, stress factors (multipliers of REE) are commonly used to account for the perceived increase in REE due to illness [15]. While activity factors (multipliers of REE) may also be used to theoretically account for energy expenditure associated with varying levels of physical activity [16].

Despite most clinicians likely predicting an increase in energy expenditure for vascular patients [17], Gardner et al. recently observed a lower REE in peripheral arterial disease patients with intermittent claudication (IC) compared to healthy controls when measured by indirect calorimetry [18]. This suggests that Schofield and Harris–Benedict equations alone could be overestimating REE. Use of stress and/or activity factors may further exacerbate any overestimations.

Various other factors affecting REE commonly exist amongst vascular surgery patients, specifically older age, illness, overweight and obesity [19]. Accurately estimated nutritional requirements are pertinent for clinical practice where nutrition has the role in aiding timely recovery. The inaccurate provision of nutrition can contribute to poor immune response, exacerbating the susceptibility to infection and poor recovery from surgical procedures. An underestimation may lead to loss of lean muscle mass, function and poor wound healing [20]. An overestimation could lead to weight gain and increase the risk of cardiovascular disease progression [2].

Additionally, the application of Schofield and Harris–Benedict equations in older adults has been controversial. Neither equation was created from a representative sample of older adults [13,14] and may not adequately reflect the reduced REE associated with aging [20]. The use of an equation developed from older adults (>60 years) such as the Miller equation (Ng Z., Yaxley A., Miller M., 2014, unpublished results) may be more suitable for older vascular surgery patients.

To the authors' knowledge, no study has investigated the accuracy of predictive equations to estimate REE in vascular surgery patients. This study aims to: (1) compare REE measured by indirect calorimetry and REE estimated by Schofield, Harris–Benedict and Miller equations to determine their agreement, and (2) provide insight for the use of predictive equations in vascular surgery patients.

2. Materials and methods

A secondary analysis of data collected from four studies during 2011–2014 was performed. Studies included conveniently sampled adults (aged ≥18 years) who presented to Southern Adelaide Local Health Service's Vascular Surgery Department. Potential participants were screened against study specific inclusion and exclusion criteria. Descriptive characteristics and measured REE (mREE) were extracted from the four studies to form the basis for data analyses. Studies were conducted according to the Declaration of Helsinki and all procedures involving human subjects, were approved by the Southern Adelaide Human Research and Ethics Committee. All participants involved provided written informed consent.

Participants with an abdominal aortic aneurysm (AAA) ($n = 20$) [8] and lower limb venous ulcers (LLVU) ($n = 33$) (Nevin L., Thomas J., Miller M., 2013, unpublished results) were recruited into two separate studies investigating the effects of respective diseases on REE. No specific inclusion and exclusion criteria were placed on AAA participants [8]. Participants with LLVU secondary to chronic venous insufficiency, determined by venous duplex ultrasound and absence of arterial disease, determined by ABPI, were recruited. This ensured the disease was venous in nature. LLVU participants were also required to be medically stable with normal thyroid function to reduce confounding. Patients who were pregnant were excluded due to radiation exposure and those unable to provide informed consent (i.e. presence of dementia) were excluded, as alert and active participation was required for the duration of the measurements.

A sub-sample of participants with occlusive disease ($n = 24$) was extracted by an investigator blinded to data analysis from a randomised controlled trial ($n = 19$) [21] and an observational study ($n = 5$), to provide a comparative sample size. The observational study invited patients scheduled for endovascular intervention (angioplasty or stenting) to evaluate the impact of endovascular intervention on REE. Participants were required to be otherwise medically stable to reduce confounding and able to mobilise independently to undergo measurements (Chan C., Delaney C., Miller M., 2011, unpublished results).

Energy expenditure was measured using GEM open-circuit indirect calorimetry (GEM; GEM Nutrition Ltd, Cheshire, UK) by the same standardised protocol across all studies. The calorimeter was calibrated using room air. Following an overnight fast, participants adopted a supine position in a thermo-neutral room where a ventilated hood was placed over the resting participant. Ten minutes were allowed for acclimatisation before oxygen and carbon dioxide was measured every 30 s for 30 min. Daily REE was derived from oxygen consumption and carbon dioxide production calculated according to the de Weir equation [22] as designated by the manufacturer.

Standard protocols were used to conduct all anthropometric measurements. Standing height was measured by a stadiometer to the nearest 0.1 cm (Design No.1013522, Surgical and Medical Products, Seven Hills, Australia). When standing height could not be obtained (e.g. wheelchair bound patient), a broad-blade calliper (Shorr Productions, Oley, MD, USA) was used to measure knee height to the nearest 0.1 cm. Weight to the nearest 0.1 kg was measured by Lunar Prodigy Pro dual-energy x-ray absorptiometry

Please cite this article in press as: Suen J, et al., Estimating energy expenditure in vascular surgery patients: Are predictive equations accurate enough?, Clinical Nutrition ESPEN (2016), http://dx.doi.org/10.1016/j.clnesp.2016.09.001