HARRIS–BENEDICT EQUATIONS DO NOT ADEQUATELY PREDICT ENERGY REQUIREMENTS IN ELDERLY HOSPITALIZED AFRICAN AMERICANS

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Background: Malnutrition, associated with poor outcome in the elderly, may be exacerbated by weight loss during hospitalization. Accurate estimation of energy requirements is important, particularly if predictions are applied to caloric supply. Because data on energy requirements for the elderly are limited, particularly for African-American patients, predictions are commonly made with equations derived from a younger, caucasian, cohort from 80 years ago.

Method: To compare measured resting metabolic rate (RMR) in a hospitalized elderly African-American cohort in an urban community hospital during 1998 with Harris–Benedict predictions of basal energy expenditure (BEE). Energy expenditure was measured by a strict protocol with a portable metabolic cart, and height and weight were measured standardly and used to calculate BEE and body mass index (BMI).

Results: In 61 subjects, aged 79.6+/-8.9 years, measured RMR was significantly greater than predicted BEE (p=0.001, t-test). Caloric expenditure averaged 24.7+/-5 kcal/kg/day, but the range was broad (14–39 kcal/kg/day). The BEE prediction was 20.3+/-2.4 kcal/kg/day.

Conclusion: In elderly hospitalized African-American patients, the Harris–Benedict equation significantly underestimated energy requirements. Given the link between unintentional weight loss and increased mortality on the one hand and potential clinical complications of overfeeding on the other, measurement of energy expenditure is warranted. (*J Natl Med Assoc.* 2004;96:209–214.)

Key words: calorimetry ♦ African Americans ♦ weight ♦ kcal

INTRODUCTION

The ill elderly often present with elevated nutritional risk[1-9] and a history of weight loss. Elderly patients who lose weight during hospital admissions have an eight-fold greater in-hospital and nearly three-fold greater 90-day mortality, when compared to patients without significant weight loss[10].

To predict energy needs in the elderly, many clinicians use regression equations that were derived from measurement of heat production in a metabolic chamber, using a relatively young, healthy, entirely caucasian population[11]. Age has been identified as a key variable in resting energy expenditure, due to the loss of metabolically active tissue in favor of fat mass during the aging process[2]. Energy expenditure measurements in the elderly, however, are limited[12-14] and racial composition of the patient group not specified. Ill patients, with energy expenditure measured

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Table 1. Primary Reasons for Admission (Number of Patients)

Diagnosis	Men (21)	Women (40)
Cancer	4	1
Cardiovascular/Diabetes	3	8
Dementia	2	2
Gastrointestinal	2	6
Infection	7	13
Malnutrition		2
Physical Rehabilitation	1	3
Pulmonary	1	1
Skin/Joint	3	6
Surgery	2	

during hospitalization, often have energy needs that are greater than expected based on their body composition[2]. Younger, healthy but overweight African-American women have significantly lower energy expenditure[15] and disappointing response to weight reduction efforts[16] than their caucasian counterparts. Thus, predictions from a young, healthy caucasian population may not be appropriate for the oldest elderly, ill, or hospitalized African-American patients.

We hypothesized that Harris–Benedict equations would be unreliable for elderly, hospitalized African-American patients. We also hypothesized that energy requirements might be elevated in elderly African-American patients during hospitalization, a factor that could provide a periodic stimulus for loss of body weight. Thus, the current observational cohort study was undertaken to evaluate actual measured energy requirements in elderly, hospitalized African-American patients.

METHODS

All African-American patients 65 years or older, who were admitted to the Skilled Nursing Facility or general medical floors of the University of Pennsylvania Health System/Presbyterian Medical Center in Philadelphia, PA during 1998, were potential candidates for study. Of those patients referred for nutritional consultation or for management of enteral or parenteral feedings, a subset received measurement of energy expenditure by indirect calorimetry. Patients who had a length of stay <3 days, who required respiratory isolation, or were unable to cooperate with the test were excluded from measurement. Also excluded were any measurements where steady state gas exchange conditions were not achieved and where inaccuracy of the energy expenditure measurement was likely, as explained below. Each patient was measured only once. No diagnoses or nutritional states were excluded. Demographic information was collected on all patients from medical record review.

Resting metabolic rate (RMR) was measured by indirect calorimetry using a portable metabolic cart (Deltatrac, Sensormedics, CA). A strict protocol was used, which has been validated with 1% replicability of measurement error[17]. Patients were at rest for at least 30 minutes in a thermoneutral environment and were silent. Ventilated patients had not experienced a change in ventilator settings during or 30 minutes prior to the measurement and had not received oral or bolus enteral feedings in the previous four hours to avoid any impact of thermic effect of feeding. Continuous 24-hour feedings of enteral or parenteral nutrition solutions were not stopped for RMR tests. Steady state measurement was defined as five consecutive one-minute measures of vO_2 and vCO_2 with a coefficient of variation of ≤5%[17]. Steady state vO_2 and vCO_2 were applied to the abbreviated Weir formula to determine energy expenditure[18]:

$$RMR=1.4* [(3.9vO_2)+(1.1vCO_2)].$$

Five of the 61 patients required mechanical ventilation during the RMR measurement, and data were analyzed first, including their results and a second time without these five patients. The respiratory quotient (RQ) was calculated as vCO_2/vO_2, and RQ>1 was used to detect inaccurate indirect calorimetry tests in patients whose caloric intake was not >150% RMR, to suggest overfeeding as a cause of the high RQ. Inaccurate tests by RQ were not accepted for the study[17].

Estimated energy requirements (BEE) were calculated by the Harris–Benedict equations[11]:

$$BEE\ (male)=66.5+13.7Wt(kg)+5.0Ht(cm)–6.8\ Age\ (years);\ R^2=0.75,\ p<0.0001;$$
$$BEE\ (female)=655.1+9.6Wt(kg)+1.8Ht(cm)–4.7\ Age\ (years);\ R^2=0.53,\ p<0.0001.$$

Body mass index (BMI) was calculated as weight(kg)/height(m^2). BMI was subset into underweight (BMI <18.5 kg/m^2), normal weight (18.5–24.9), and overweight or obese (BMI ≥25 kg/m^2) according to NHLBI standards[19].

Statistical Method

Descriptive statistics included mean, standard deviation, and percentages. Pearson's correlation was used to compare RMR to BEE, height, weight and age for the entire cohort, and controlled for gender. Differences in RMR and BEE for individual subjects were compared statistically by paired t-test. Differences in RMR and BEE by gender were compared by ANOVA with post-hoc Scheffe test. For all statistical evaluations, $p<0.05$ was considered significantly different.

RESULTS

Demographics

A total of 61 patients, of which 66% were female, were included in the study. The primary reason for admission covered a full range of medical conditions (Table 1). Only 3/21 men and 2/40 women were receiving mechanical ventilation during their RMR measurement.

The mean age was 79.6+/-8.9 (range 65–102 years). Age was not significantly different by gender (men=78.2+/-7.1 versus women=80.3+/-9.7 years). Also in women, but not men, age was significantly correlated with RMR (-0.408, p=0.009).

Body Mass Index

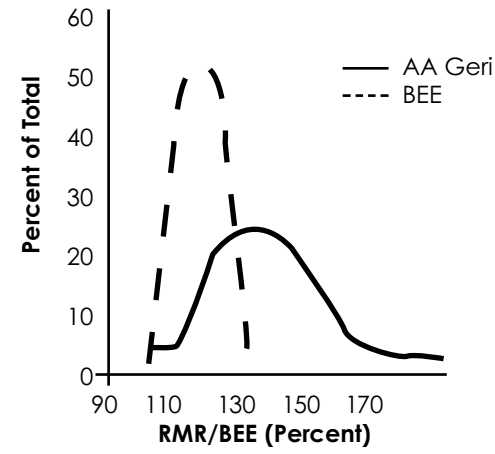
The mean BMI was 21.5+/-4.9 kg/m^2—21.8+/-4.7 for men and 21.3+/-5.1 for women. Seven of 21 men and 12/40 women had BMI <18.5 kg/m^2, while 10 men and 18 women had BMI in the normal range, and four men and 10 women were either overweight or obese by BMI.

Energy Requirements

Mean RMR for the entire cohort was 1391.9+/-271.4 (range 914–2,361 kcal/day). RMR for the 56 patients who did not require mechanical ventilation during the RMR measurement was 1369.8+/-267.4 kcal/day. Normalized to measured body weight, the RMR was 24.8+/-5 (range 14.2–39.1) kcal/kg/day. Mean Harris–Benedict BEE for the entire cohort was 1149.7+/-183.1 kcal (range 841–1856), and 1146.6+/-187.6 in nonventilated patients. Normalized to measured body weight, the BEE was 20.3+/-2.4 (range 13.9–27.5 kcal/kg/day).

RMR was significantly greater than BEE ($p<0.001$, paired t-test). Only 16/61 patients (1/21 men and 15/40 women) had RMR within 10% of BEE. Only 2/61 patients had RMR <90% of Harris–Benedict BEE prediction. RMR was 123.5+/-14.7% of Harris–Benedict BEE (range=84–145%) for men, and 120.2+/-19.1% (range 89–173%) for women. Absolute RMR was significantly greater for men than for women (men=1558.4+/-207.5 versus women=1304.6+/-261.7 kcal/day, p=0.0001, ANOVA) but not when normalized to body weight (men=25.3+/-4.8 versus women=24.5+/-5.2).

Figure 1. Frequency Histogram of Measured RMR (Kcal) as Percentage of Harris-Benedict Prediction for Individual Patients



African-American (AA) Geri = Current Data Set
BEE = Harris-Benedict Data, reference 11

Figure 1 is a frequency histogram, presenting the measured RMR (solid line) as a percentage of the Harris–Benedict prediction (dashed line). The curve from current data is shifted considerably to the right, since 74% of all measurements are >110% BEE.

DISCUSSION

In this group of elderly African-American hospitalized patients, resting energy expenditure was significantly greater than Harris–Benedict equation predictions. If the Harris–Benedict predictions were applied to caloric delivery, weight loss as a result of underfeeding might be expected. The reasons for this difference may be myriad, but consideration should be given to issues of age, metabolic stress, and race.

Age

The use of Harris–Benedict equations for predicting energy requirements in the elderly has been criticized because of the limited representation of elderly subjects in the original study populations[20,21].

In the 1919 series of 239 healthy subjects[11], the age for men was 27+/-9 (range=16–63) and for women was 31+/-14 (range=15–74) years. In 1935[22], Benedict reported on data from older, healthy subjects (eight men age=84.1+/-6.8 and 35 women age=75.9+/-6.1) with a range of 66–91 years, but the original equations were not revised, even though 5/8 men and 9/36 women had measured RMR that was >10% different from the earlier predictions[22]. In fact, the ages of men in this current cohort all exceeded the range of ages included in the Harris–Benedict equation, and the mean age for men and women was greater than the upper boundary of age range. Clearly, on the basis of age difference alone, the Harris–Benedict predictions may not be appropriate for such an elderly group of patients.

Metabolic Stress

The Harris–Benedict equations have also been criticized for use in hospitalized patients[21]. Benedict[23] made a clear statement against using "hospital normals" to determine physiological standards. He stated in 1928 that ill subjects would likely have reduced basal energy needs due to malnutrition[23], whereas the opposite is likely true[20,21,24-26].

Hypermetabolism has been defined as a measured RMR >110% of Harris–Benedict BEE[20,25]. In the current cohort, the mean RMR was 120% of the Harris–Benedict prediction and consistent with hypermetabolism. Our patients had energy expenditure measured during an unstable, stressed period requiring hospitalization. Hypermetabolism has frequently been described in patients with critical illnesses, including sepsis, postoperative states, and medical disorders with an inflammatory component. For example, Long et al.[25] documented an increase in RMR of 120% beyond resting energy predictions due to surgery, 135% for trauma, 160% for severe sepsis, and 210% for severe burns. Clearly, Table 1 verifies by clinical conditions the likelihood of hypermetabolism. Our undernourished patients, those with BMI <18.5 kg/m^2, were similar to a previously reported group of 14 elderly, hospitalized, severely underweight (BMI 15.8+/-1.8 kg/m^2) patients[26]. That group's mean RMR was 126% of the Harris–Benedict prediction, and mean caloric expenditure was 31.4 kcal/kg. It was therefore not surprising that our cohort of elderly patients with a wide variety of medical illnesses would have elevated energy needs; however, the range in kcal/kg is broad.

Race

Energy expenditure has been evaluated to a very limited degree in elderly community-dwelling African-American subjects. To our knowledge, these data are the first reported in hospitalized African-American patients of this age. In two trials of elderly African-American subjects (28 males, 37 females in each trial),the mean age was 15 years younger, BMI 6–10 units higher, and weight 20 kg greater than the current cohort[27,28]. Although the absolute resting energy expenditure is essentially the same as our current measures (1,631 kcal in men[27], 1,576 kcal in men[28] and 1,390 kcal in women[27], 1,431 kcal in women[28], it is greatly increased in our cohort when considered relative to body weight in kg (approximately 17 kcal/kg in reference 23 versus the current cohort's 25 kcal/kg/day. The weight is not available in reference 27).

Perhaps the most pertinent reason for the difference between the current data and predictive equations is that Harris and Benedict did not study African-American subjects in the original data used to develop their predictive equations[11]. Benedict later measured basal energy needs of Jamaican blacks in 1928 using a "field respiration apparatus" to measure 23 young (18–21 years) men and 19 young (16–24 years) women[29]. While the mean deviations from Harris–Benedict predictions were –3.4+/-1.3% in men and –5.4+/-0.8% in women, 26/45 measurements varied by >10%. Whether these differences predominantly reflected a population difference or change in measurement methodology is not clear. Recent studies, however, have suggested that a difference in RMR between African-American and caucasian subjects may be based on the expression of uncoupling protein genes[15].

Limitations

The study reported herein has several limitations. First, *total* energy expenditure was not measured due to the unavailability of doubly labeled water methodology[28], and activity expenditure was not accounted for. For the community-dwelling population, total energy expenditure is estimated at 150% RMR[31]. By contrast, in ill, ventilated patients, average total energy expenditure is only 110% RMR, though the RMR may be considerably elevated from basal needs[24]. Perhaps actual total energy needs for this group of patients lie between these two measures, as activity energy expenditure during hospitalization is typically very limited due to the

added impact of illness on old age and frailty.

Secondly, the energy intake side of the energy balance equation and serial body weights were not measured, so we have no information on the adequacy of caloric intake or actual weight loss. Significant weight loss during hospitalization may have a profound impact on mortality in elderly patients[10]. The elderly have excess mortality with reduced BMI and with loss of >10% of maximum lifetime weight within 10 years[32]. In this cohort, 31% were malnourished by BMI at admission. By contrast to the general population, overweight in the elderly does not confer excess risk of mortality until the BMI is >27 or 28 kg/m^2 [33]. In this cohort, 23% were overweight or obese.

Implications

The clinical question that remains is how best to determine a given elderly individual's caloric needs in the setting of acute illness. This is particularly critical if supplemental enteral or parenteral feedings are required for a prolonged period of time, as underfeeding may lead to malnutrition and poor outcomes,[1-9] and the significant risks of overfeeding include refeeding syndrome,[34] hepatic steatosis,[35] and excess CO_2 production.[36]

Using our group's mean estimate of 25 kcal/kg would be a place to begin, though this figure conceals the actual broad range of caloric need (14–39 kcal/kg/day). To estimate caloric needs for weight maintenance, an additional factor for caloric expenditure of physical activity is needed. A variable multiplier of the resting energy estimate between 1.1 (very inactive) to 1.5 (fully and frequently ambulatory) should be considered. It is advisable to add 500 kcal/day to promote a safe rate of weight gain, if that outcome is desired, such as in patients whose BMI is <18.5 kg/m^2. Clearly, patients at greater nutritional risk should have individual RMR measurements using indirect calorimetry. Future trials of measured RMR in a large cohort of elderly, hospitalized African-American patients are needed to develop improved predictive equations, though it may be that the variability among hospitalized patients in general makes predictive equations inherently limited.

Summary

This study underscores the limitations of predictive equations in current use to estimate energy requirements in very elderly, ill, African-American patients. Since no adequate estimate has been clinically validated in this population, and the actual range in energy needs is quite variable, the safest plan for longer-term nutrient prescription and for all patients with nutritional risk remains the measurement of energy expenditure.

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