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# Use of Predictive Energy Expenditure Equations in Individuals with Lower Limb Loss at Seated Rest

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**ABSTRACT**

**Background** As a result of the global war on terrorism, there has been a significant increase in young service members with traumatic amputations. Few published data are available on metabolic requirements for young, active individuals after traumatic limb loss, especially lower limb loss.

**Objective** The purpose of this study was to determine which predictive energy equation best predicted resting energy expenditure (REE) in this population.

**Methods** One hundred service members, 50 with at least one traumatic lower limb loss and 50 without limb loss, completed this study. Mean (standard deviation [SD]) age, height, and weight were 27.3 years (±5.3), 178.5 cm (±7.7), 86.5 kg (±15.8) for those with limb loss; and 29.4 years (±5.8), 179.1 cm (±6.7), 85.9 kg (±12.6) for those without. REE was measured using the Oxycon Mobile metabolic system (CareFusion). Measured REE was compared with the following REE equations: Mifflin-St Joer, Harris Benedict, Owen, 25 kcal/kg, and 30 kcal/kg.

**Results** All equations tended to underestimate or overestimate REE for both groups ($P<0.001$); however, the 25 kcal/kg had a more even distribution of disagreement for individuals with limb loss and without ($P=0.100$ and $P=0.308$, respectively), with 52% within ±10%.

**Conclusions** The 25 kcal/kg best predicts REE for young, active individuals with or without limb loss. Future studies may determine that more appropriate equations are most useful for different subgroups of this population.
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AMPUTATIONS ARE ONE OF THE "MOST DEBILItating wounds sustained by those who survive a combat injury."[1] As of September 2010, 1,033 US service members supporting the efforts of the global war on terrorism have been treated for some level of upper or lower limb loss.[2] Unfortunately, few published data are available on metabolic requirements in young, active individuals with traumatic limb loss,[3] and even fewer on which predictive resting energy expenditure (REE) equations or factors are most accurate for this population. Current REE equations or factors used to provide nutrition therapy for this population may not be accurate.

Much of the available data on metabolic requirements for individuals with limb loss are based on vascular (chronic disease–related) limb loss. However, recent reports have indicated a difference in energy expenditure (EE) in individuals with vascular limb loss and individuals with avascular (trauma-related) limb loss. Individuals with avascular limb loss are more energy efficient during periods of ambulation,[4-6] which may be related to the individual's current physical fitness level, as well as their fitness before the limb loss.[7,8] Individuals with vascular limb loss are often more sedentary and have more health-related issues from before their limb loss compared to individuals with avascular limb loss.[6] No known research studies have examined the REE of individuals with avascular limb loss.

The purpose of this cross-sectional study was to assess which predictive equation or factor best predicts REE in young, active service members with and without limb loss. This was part of a larger cohort study evaluating metabolism at rest and during ambulation in service members with limb loss. Utilization of the best predictive equation or factor will enable health care providers to develop and tailor caloric requirements for service members with or without limb loss that provide adequate nutrition, maintain muscle mass, and reduce decreased functionality related to weight loss or gain. A secondary purpose of the study was to compare predictive equations between groups.

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## METHODS

A convenience sample of service members, with and without traumatic lower limb loss, was recruited to participate in this study. Subjects were between the ages of 18 years and 50 years, in general good health, and the subjects with limb loss had at least one lower limb loss, identified as being functionally stable in their physical rehabilitation at the time of testing, and were able to ambulate without the use of an assistive device. Subjects were excluded if they were an inpatient, if the cause of the amputation was vascular, if they had an upper extremity amputation only, or if they were pregnant. The Walter Reed Army Medical Center Institutional Review Board approved the study protocol, and all participants provided written informed consent.

All subjects presented themselves to the testing center at their scheduled session. Testing was completed in the morning on test days. All subjects were instructed to abstain from food, beverage, and caffeine for 3 to 4 hours before testing.[9] If subjects indicated that they had recently eaten or had caffeine within 3 to 4 hours before the testing session, they were rescheduled for another day. Demographic and anthropometric data, including age, height, weight, and level of limb loss, were collected for each subject. Height was recorded by using a digital stadiometer (QuickMedical). For subjects with bilateral amputations, their official height measured at their last pre-injury Army Physical Fitness Test was recorded. This is an official military measurement conducted according to precise standards.[10] Weight was recorded with a digital scale (SECA, Vogel+Halbe). Adjusted weight for subjects with limb loss was calculated by using a method by Mozumdar and Roy,[11] in which measured lower limb lengths account for the proportion of the body that was amputated. Body mass index (BMI) was calculated for subjects with limb loss, using the adjusted weight. Lower limb loss was classified into five groups: unilateral transtibial (TT), unilateral transfemoral (TF), bilateral transtibial, bilateral transfemoral, and one limb transtibial and the other limb transfemoral (TT/TF) limb loss.

Body composition measurements (fat-free mass percentage and fat mass percentage) were calculated by using dual-energy x-ray absorptiometry (Windows XP version software, version 5.1, 2008; Hologic Discovery-Wi). Subjects were scanned while they were wearing minimal clothing, with prostheses, jewelry, and metal objects removed.

Resting energy expenditure (REE) was measured by using the Oxycon Mobile metabolic analysis system (CareFusion).[12] Subjects rested comfortably for 5 to 10 minutes before the testing session to allow their heart rates to return to resting. In addition, the test procedures were explained in detail to the subjects so that they were familiar with the test requirements. All tests took place in the same quiet, moderately lighted, air-conditioned room. Subjects were fit with a mask that allowed them to breathe comfortably through both their nose and mouth. REE was collected continuously while the subjects rested in a seated position for 5 to 10 minutes.[9,13] REE was calculated from the last 2 minutes of the test period, when the subjects were determined to have reached steady-state oxygen consumption.[14] Steady state was defined as a variation of less than 10% in oxygen consumption and rate of elimination of carbon dioxide.[14] If subjects had not reached steady state within 5 to 10 minutes, the study was continued until they were able to reach steady state.

Measured REE was compared with five predictive energy equations or factors (calculations for males), all of which are suitable for healthy, normal-weight adults older than 18 years. Calculations were completed with weight in kilograms and height in centimeters.

- Mifflin-St. Joer (MSJ)[15,16]: $REE\ (kcal)=5+10(wt)+6.25(ht)-5(age)$
- Harris-Benedict (HB)[16,17]: $REE\ (kcal)=88.362+4.799(ht)+13.397(wt)-5.677(age)$
- Owen[18]: $REE\ (kcal)=10.2(wt)+879$
- 25 kcal/kg[19]
- 30 kcal/kg[20]

Age, height, and adjusted BMI were found not to be normally distributed, so differences in demographic data between service members with and without limb loss were assessed by using a Mann-Whitney test. The level of significance was set at $P<0.05$. Measured and predicted REE data were normally distributed, so within-groups differences between REE and each predictive equation or factor were analyzed by using paired $t$ tests, and intraclass correlation coefficients were calculated to examine the level of agreement between measured REE and the predictive equations or factors. The level of significance was set at $P\leq 0.01$. The frequency of agreement and disagreement for each predictive equation/factor also was assessed, with agreement defined as a percent difference in predicted EE equal to or less than 10% of the measured EE, and negative and positive disagreement as more than 10% below or above the predicted, respectively. This frequency assessment illustrated the tendency of the predictive equation to agree or negatively or positively disagree with the measured value and was not included in the statistical analysis. We also considered the Bland-Altman method as an additional analysis. This method compares new clinical measurements or interventions with a current standard in an effort to replace the old standard if the two techniques are similar.[21] The bias, or mean difference between the two techniques, is displayed on plots. Determination of clinical significance is based on a visual assessment of the plots.[22] These plots were used to determine whether similar findings existed in systematic differences between the estimated REE and measured REE. No transformations were performed for measures that demonstrated systematic bias, because the primary purpose of creating the plots was to visualize how well the measures agree or disagree.

Analyses were performed by using PASW Statistics 18 (PASW Statistics for Windows, version 18.0, 2009, SPSS Inc).

## RESULTS

One hundred service members, 50 with and 50 without traumatic lower limb loss, completed this study between 2010 and 2011. Data for one service member with traumatic lower limb loss were not collected properly, and thus they were not included in the analysis. Also, data for one female subject without an amputation were collected, but no female subjects with amputations volunteered; therefore, her data were not included in the analysis. Between-group