Validation of a Novel Protocol for Calculating Estimated Energy Requirements and Average Daily Physical Activity Ratio for the US Population: 2005-2006

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Abstract

Objective: To validate the PAR protocol, a novel method for calculating population-level estimated energy requirements (EERs) and average physical activity ratio (APAR), in a nationally representative sample of US adults.

Methods: Estimates of EER and APAR values were calculated via a factorial equation from a nationally representative sample of 2597 adults aged 20 and 74 years (US National Health and Nutrition Examination Survey; data collected between January 1, 2005, and December 31, 2006). Validation of the PAR protocol—derived EER (EER_{PAR}) values was performed via comparison with values from the Institute of Medicine EER equations (EER_{IOM}).

Results: The correlation between EER_{PAR} and EER_{IOM} was high (0.98; $P<.001$). The difference between EER_{PAR} and EER_{IOM} values ranged from 40 kcal/d (1.2% higher than EER_{IOM}) in obese (body mass index [BMI] ≥30) men to 148 kcal/d (5.7% higher) in obese women. The 2005-2006 EERs for the US population were 2940 kcal/d for men and 2275 kcal/d for women and ranged from 3230 kcal/d in obese (BMI ≥30) men to 2026 kcal/d in normal weight (BMI <25) women. There were significant inverse relationships between APAR and both obesity and age. For men and women, the APAR values were 1.53 and 1.52, respectively. Obese men and women had lower APAR values than normal weight individuals (P=.23 and P=.15, respectively), and younger individuals had higher APAR values than older individuals ($P<.001$).

Conclusion: The PAR protocol is an accurate method for deriving nationally representative estimates of EER and APAR values. These descriptive data provide novel quantitative baseline values for future investigations into associations of physical activity and health.

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For editorial comment, see page 1353

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Epidemiologic research suggests that the recent increased prevalence of obesity and chronic noncommunicable diseases[1] is the result of physical inactivity and long-term positive energy balance (ie, energy expenditure [EE] < energy intake).[1-3] Nevertheless, comprehensive examinations of the associations among physical activity (PA), diet, and health are constrained by a lack of measurement protocols that provide accurate estimates of energy and activity-related risk factors. Although energy-related measurement protocols have informative value, they are limited in scope or validity. For example, predictive equations for estimated energy requirements (EERs) are ubiquitous but have restricted utility because of an absolute reliance on self-reported PA data. These subjective reports have poor validity and are predisposed to significant systematic biases.[4]

Although there are objective methods that capture total daily EE (eg, doubly labeled water [DLW]), none directly or accurately measure actual PA or activity EE. For example, the DLW-derived PA level index (total daily EE/resting EE) is a measure of neither PA nor activity EE but rather is an inherently confounded assessment of all variations in total daily EE independent of resting EE, for example, adaptive thermogenesis, pharmacodynamics (eg, caffeine and nicotine use), and

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emotional state. Studies that do not measure PA directly are limited because activities that differ in type or intensity (eg, walking vs resistance training) have unique beneficial physiologic effects that are related only tangentially to EE.[5-7] For example, eccentric-contraction overloading of skeletal muscle induces increments in protein synthesis that are not proportional to EE.[8] Therefore, studies examining only activity EE will by design misclassify the actual exposure, thereby ignoring the metabolic and physiologic health outcomes specific to activity per se. Furthermore, because resting EE is proportional to body mass to the 0.75 power ($kg^{[0.75]}$) but activity EE depends on body mass to the 1.0 power ($kg^{[1.0]}$) and the ratio of weight-dependent and non—weight-dependent activities,[9,10] comparisons across populations with differing mean body mass or patterns of PA[11,14] will be spurious. For example, in a cross-national comparison, African American women had similar DLW-derived activity EE as African women in Nigeria, yet, on average, the US women weighed 20 kg more.[12,13] Despite similar activity EE, the American women were much less active and, as a result, achieved fewer activity-related benefits (eg, decreased adiposity). This outcome illustrates that for any given "dose" of activity EE, activity per se will be lower for heavier individuals. Therefore, heavier individuals benefit less per unit of activity EE. This finding suggests that current measurement protocols are insufficient to examine the metabolic and physiologic health benefits of PA.

In contrast to inherently confounded or subjective measures for assessing PA, such as DLW-derived PA level indices and self-report questionnaires, accelerometry-based PA monitors (ACCs) have become an accepted research technology for objectively capturing the patterns of movement associated with PA.[15] The ACC can assess patterns of PA directly (ie, volume, intensity, frequency, and duration),[16-21] and 3 to 5 days of monitoring can estimate habitual PA reliably.[22]

Given the limitations of existing protocols, the objective of this study was to validate the PAR protocol, a novel method for calculating population-level estimates of EERs and total daily PA (ie, average PA ratio [APAR]) via ACC-derived, objective measurements of PA, in a nationally representative sample of the US population. These metrics allow examinations of the associations of PA per se and health outcomes that may be used to develop empirically supported public health policy.

METHODS

Study Population

Data were obtained from the National Health and Nutrition Examination Survey (NHANES) 2005-2006,[23] a complex sample of the US population conducted by the Centers for Disease Control and Prevention. The data collection period was between January 1, 2005, and December 31, 2006. The NHANES 2005-2006 was the first nationally representative data set to include all the variables used to calculate the APAR (see the APAR example later herein). The National Center for Health Statistics ethics review board approved the protocols, and written informed consent was obtained from all the participants. The study sample was limited to adults aged 20 to 74 years in 2005-2006 with complete age, height, weight, sleep, dietary, and accelerometry (ACC) data.

Factorial Calculation of Total Daily EE and EERs

Total daily EE is the total amount of energy an individual expends over 24 hours and is conceptualized in factorial equations as the sum of 3 major components: resting EE, activity EE, and the thermic effect of food.[24] The EERs represent the daily dietary energy intake necessary to maintain energy balance (ie, stable body mass and composition) in an adult of defined weight, height, sex, age, and level of PA. Because EE equals energy requirements (ie, total daily EE = EERs) for individuals in energy balance, factorial equations that estimate total daily EE are used extensively in research and clinical settings to evaluate EERs.[25-27] The factorial approach provides reliable estimates across a diverse spectrum.[28,29] For the present analysis, total daily EE was calculated as the product of estimated resting EE (in kilocalories per day), APAR (PAR per hour value), and the thermic effect of food as 7.5% of total daily EE: total daily EE = resting EE × APAR × 1.075.[25,26]

Laboratory-based measurements of resting EE are technically demanding, time-consuming, and impractical for large population-level studies. As such, regression-based equations validated via