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Energy Balance Measurement: When Something is *Not* Better than Nothing

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Abstract

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Conflicts of Interest Dr. Schoeller reports a patent, Methods of determining energy balance using breath carbon isotope ratios, pending. All other authors declare no potential conflict of interest.

Energy intake (EI) and physical activity energy expenditure (PAEE) are key modifiable determinants of energy balance, traditionally assessed by self-report despite its repeated demonstration of considerable inaccuracies. We argue here that it is time to move from the common view that self-reports of EI and PAEE are imperfect, but nevertheless deserving of use, to a view commensurate with the evidence that self-reports of EI and PAEE are so poor that they are wholly unacceptable for scientific research on EI and PAEE. While new strategies for objectively determining energy balance are in their infancy, it is unacceptable to use decidedly inaccurate instruments, which may misguide health care policies, future research, and clinical judgment. The scientific and medical communities should discontinue reliance on self-reported EI and PAEE. Researchers and sponsors should develop objective measures of energy balance.

Introduction

Almost weekly, a new study links self-reported subjective energy expenditure (EI) or physical activity energy expenditure (PAEE) to yet another lifestyle factor or disease. For instance, a recent study discovered that 42% of patients with acute hip fracture consume insufficient energy and urged clinicians to consider steps to ensure sufficient consumption among such patients(1). Another study concluded that after-school snacks contribute 13% of children's total EI, representing a target for energy reduction(2) to control obesity. The recent declaration of obesity as a disease by the American Medical Association underscores the need for a united multi-disciplinary effort to develop obesity prevention and treatment strategies. Considerable research is conducted to understand the contribution of EI and expenditure to global increases in obesity. Such studies have enormous potential to shape clinical, public health, and policy conclusions or recommendations. Therefore, it is vitally important to examine whether self-reported EI (SREI) and expenditure data are sound. What if the evidential foundation of those conclusions and recommendations is a house of cards? Here, we alert readers to the significant limitations of self-report measures of EI and PAEE. We go beyond the commonly voiced view that self-report measures of EI and PAEE are imperfect, but nevertheless suitable for use and offer the contrary view that they are so poor as measures of actual EI and actual PAEE that they no longer have a justifiable place in scientific research aimed at understanding actual EI and actual PAEE.

A comprehensive understanding of energy balance is needed

Recent high-profile papers concluded that US adults and children have decreased EI in recent years(3, 4), prompting speculation of why corresponding decreases in obesity prevalence were not observed. These studies, however, like many before them, examined self-reported changes in only one of the components of energy balance to draw inferences about obesity prevalence. Fat accretion results from long-term positive energy balance, which is collectively determined by EI, resting energy expenditure, diet-induced thermogenesis, energy absorption, and PAEE. Hence, accurate determination of energy balance requires careful measures of all energy balance components(5), either in the confines of a metabolic ward or by frequent clinical measurements. Such resource-intensive approaches are feasible in short-term studies with few participants at highly specialized research facilities. Studies conducted at the community level, therefore, often focus on only

two (EI and PAEE) of the components of energy balance. In this case, it is imperative that the information obtained be accurate.

Are the subjective methods for determining EI or PAEE accurate?

Self-reported energy intake

Changing EI typically has a higher magnitude of impact on body weight than does changing activity(6). Therefore, the accuracy of EI data is critical. A large number of influential studies on US trends in aspects of diet (e.g.(7)) rely on EI data collected by the National Health and Nutrition Examination survey (NHANES), a highly valuable effort conducted by the Centers for Disease Control and Prevention (CDC) to collect extensive health-related information from the US population. Although NHANES collects many rigorous measurements related to body weight, it obtains EI data through self-reported dietary recall, despite the fact that self-report questionnaires have been repeatedly shown to be seriously flawed. To emphasize this point, a top team of nutritional epidemiologists and biostatisticians recently pooled data from 5 large studies that had examined the validity of Food Frequency Questionnaires and 24-h dietary recalls against recovery biomarkers. Across this diverse sample of Americans, subjective estimates of EI explained less than 10% of the variance of true EI(8). Such large random error variance will not just lead to reduced power and underestimated associations or effects as is often claimed, but if EI is a confounder, if one controls only for SREI, then substantial residual confounding and spurious findings (type 1 errors; false positives) will occur. Because of that, the lead author of that pooling project wrote “I agree that self-reported energy intakes should not be used for investigating associations between energy intake and health-related outcomes,” though he allowed that they could be used for other purposes(9). Moreover, the errors are decidedly not random. Compared with measures from the doubly labeled water (DLW) technique, self-reported measures systematically underestimate EI by hundreds of kcal/d(10). Specifically, the NHANES surveys may underreport EI as much as 800 kcal/d(11). Despite repeated demonstrations of the serious shortcomings of self-reported measures of EI, many researchers continue to assert the validity of SREI solely on the basis of its reproducibility(12). This is like using a mismarked ruler. One can reproduce the result, but it is still wrong.

Several approaches have been suggested to adjust for underreporting. One such approach is to compare estimated basal metabolic rate (BMR) with SREI. If the value falls below a threshold that is deemed physiologically implausible ($<1.35 \times \text{BMR}$), then those data are ignored(13). There are, however, several issues with this approach, including the exclusion of large amounts of data that fall below the cutoff and a large residual unexplained variation in BMR determination(14). Also, the cutoff approach assumes that only a subset of the population underreports. However, dietary underreporting varies with the type of foods consumed, age, gender, smoking habits, education, social class, dietary restraint, the body mass index of respondent, and other life-stage factors(15). Thus, a correction of self-reported intakes by a fixed factor cannot satisfactorily correct EI.

Self-reported PAEE

Another key component of energy balance is PAEE, which can be broadly divided into energy expenditure due to intentional and non-intentional activity. PAEE includes exercise; sports; occupational, leisure-time, and household activities; personal care; and transportation. Such multiple activities make it difficult to recall and then categorize PAEE(16). PAEE is often over-reported and the percent of over-reporting varies with race, degree of overweight, and weight loss(17). This creates both systematic and random errors that are similar to those seen in SREI.

Technological advancements in portable sensing devices such as pedometers and accelerometers have made it possible to determine physical activity objectively in real time. However, for a given activity and duration, the expended energy may differ by body weight and efficiency of motion. Thus, approaches such as the combination of accelerometry with heart rate monitoring(18) or additional movement measures(19) have remarkably improved the accuracy of determining PAEE when compared against the DLW technique.

Bad data lead to bad conclusions

Creating negative energy balance by decreasing EI and increasing energy expenditure is a cornerstone of the management of obesity. Admittedly, recording habitual intake and activity is linked with better weight loss(20) and may be encouraged for enhancing patient compliance and weight loss. For drawing scientific conclusions, however, reliance on the accuracy of reported EI or PAEE is problematic, even in clinically oriented research.

As noted, studies consistently demonstrate that a large number of subjects underreport EI and over-report PAEE. This makes it challenging to reconcile weight change (or lack thereof) with a patient's reported effort and may influence clinical judgment. For instance, a recent study concluded that 45% of pregnant women underreported their daily EI(21). EI was reported to be as low as 1194 kcal for the underreporting subgroup compared with 2125 kcal/d for the group considered to be normal reporters(21).

Subjective methods of consumption are not only used for studies related to energy balance and body weight, but also to draw conclusions that inform clinical practice and dietary recommendations for conditions such as chronic kidney disease, cancers, heart disease, diabetes, and Alzheimer's disease. The lack of validity of some messages intended for clinical application is highly disconcerting. Inaccurate dietary data collection can result in spurious associations and effects(22, 23) that can directly impact patient care. Despite the published cautions and limitations of subjective measures of food intake for numerous health conditions(24–27), studies using SREI often yield conclusions, such as, “we identified a dietary pattern that was strongly protective against the development of Alzheimer's Disease”(28). Yet, many such studies continue to reach varying and often conflicting conclusions about the associations of various food components with specific disease risks. This makes it difficult for clinicians and health care professionals, who are often at the receiving end of questions from patients about the ability of a particular food or food product to help or harm, to respond confidently with evidence-based advice. By extension, avoiding inaccuracy is particularly vital for conclusions about national trends. An

assertion such as “energy intake has decreased in recent years,” if erroneous, could adversely impact obesity-related policies at the local and national levels.

Moving forward

For research, clinical practice, and policy determination, a great need exists for accurately determining EI and expenditure. It is time to recognize that even if methods are cheap and convenient, inaccurate scientific methods will lead to inaccurate conclusions. Interpretations based on inadequate measurement tools may cause misguided national and local health care policies, funding for and by major organizations, and health care advice to individuals. Like other antiquated methods, self-reported PAEE and EI need to be recognized as inaccurate measurements by the scientific and funding communities.

In the future, we urge that resources be redirected to developing superior methods to objectively, precisely, and accurately measure alterations in energy balance. Improvements have been made in the development of more objective tools for measuring PAEE. Such tools are not perfect but have been shown to better assess PAEE compared with self-report(29). Objective measures of EI are not as mature, and accuracy (especially at the individual level) is still only modest, but emerging alternatives include digital photography, chewing and swallowing monitors, and wrist motion detectors that count plate to mouth motion (30–33). More research is needed to develop these and other objective tools. In addition, long-term funding should be made available for the measurement of EI where consumption can be measured for long periods of time. Meanwhile, the use of decidedly inaccurate instruments to accurately measure EI or PAEE needs to be discontinued. In this case, the adage “something is better than nothing” must be changed to “something is worse than nothing.”

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