Translating accelerometer counts into energy expenditure: advancing the quest

Research that uses accelerometers to measure physical activity has expanded exponentially over the past decade. There were approximately 90 papers per year published in 2003 and 2004 compared with fewer than 10 per year in 1993 and 1994 (6). Since the beginning of the development and application of accelerometers for physical activity assessment, there has been a desire to translate the output data from the devices into information on caloric estimates of energy expenditure (5). This interest in using accelerometers to measure energy expenditure is apparent even in the naming of some accelerometer devices, such as the Caltrac and Actical.

Accelerometer data, commonly expressed as the dimensionless unit, “counts,” are inherently neither meaningful nor interpretable. Translating counts into a quantitative estimate of caloric expenditure or the related categorical measure of time spent in moderate- or vigorous-intensity activity makes the data more useful for multiple applications. Translation of counts to caloric expenditure benefits epidemiological studies of disease and physical activity because energy expenditure is theorized to be physiologically related to mechanisms of diabetes, cancer, and other chronic conditions. Current public health guidelines for physical activity are expressed in terms of time spent above intensity criteria (7), so accelerometry is most useful for surveillance of adherence to these recommendations only if raw counts can be translated into time spent in moderate and vigorous activity. An indication of calories expended or minutes per day of moderate or vigorous activity has the potential to motivate behavioral change. These goals are linked because they all require conversion of counts into units of energy expended.

In general, the approach to translate accelerometer counts into energy expenditure has been to compare activity counts and oxygen consumption measured during performance of a series of activities that reflect activities of daily living. Some studies concentrated on ambulatory activities of walking and running, which represent the type of movement best captured by waist-worn accelerometers (4). Other studies included more activities with varying degrees of static or variable movement energy expenditure (e.g., lifting, vacuuming, racquet sports) that more completely encompass activities of daily life (4). After the simultaneous counts and oxygen consumption are obtained, regression methods are applied to determine the relationship between the two measures, and an equation to predict energy expenditure from accelerometer counts and/or a count threshold for a particular intensity of activity is determined. In most studies, a single linear regression is the analytic approach.

The equations and cutoffs determined from these calibrations are sensitive to the type of activities included in the particular study (8). This is a function of estimating activity energy expenditure from movement of the body’s center of mass. Although studies have been done with multiple accelerometers being worn on the trunk and extremities, the use of one device worn on the waist is most common and is the application considered here. It is well recognized that waist-mounted accelerometers cannot accurately detect upper body movements or the effort related to lifting or carrying loads. In general, equations primarily based on walking and running will underestimate the energy cost of activities that involve substantial upper body activity such as raking or sweeping. Equations developed with these “lifestyle” activities will overestimate the energy cost of activities that are primarily locomotor. The various mix of these two types of activities across calibration studies or in an observational study with the application of a given estimation equation will affect the overall correlation between counts and energy expenditure as well as the individual-level variability of the estimates (8).

In this issue of the Journal of Applied Physiology, Crouter et al. (2) present an advance in estimating energy expenditure from accelerometer data. The novel aspect presented by Crouter et al. is their use of a two-regression approach to estimate energy expenditure with the choice of regression based on the observed coefficient of variation (CV) among 10-s accelerometer counts. This approach helps to address the disparities in the relationship between counts and energy expenditure related to activity type. Regular rhythmic accelerations as observed in walking and running result in a low CV that leads to the choice of one regression equation, whereas more variable activities with a resulting larger CV lead to use of the other equation. The combination of the estimates from the two regressions results in more accurate and more precise energy expenditure estimates for the activities examined.

The utilization of the CV to determine regression selection is an appropriate and unique response to the problem of discriminating locomotor from more mixed movement activities. Heil (3) has applied a two-regression approach to accelerometer data from multiple body placements, but the choice of regression was based on count level for particular activities, not variability. Work is also underway to specifically identify particular activities from accelerometer count data, which would allow more precise translation of counts to energy expenditure (Pober D. and Freedson P., personal communication). However, this activity-specific approach currently requires individual-level pattern training and multiple accelerometers for pattern recognition (1). Crouter et al. (2) show improved accuracy of energy expenditure prediction over single regression approaches when applying the two-regression approach in a cross-validation group. The use of information already available from the single accelerometer counts and the cross-sample generalizability of the regression equations make the Crouter et al. approach potentially practical for physical activity surveillance or studies with large numbers of participants where individual calibration is not feasible.

The analysis approach described by Crouter et al. (2) represents a significant advance in the quest to estimate physical activity energy expenditure from accelerometry as demonstrated by the close agreement observed between measured and estimated energy expenditure. They also provide a means to distinguish walking based activity from other types of activity for investigators specifically interested in physical activity achieved through locomotor activities. As is true for any novel approach, their work needs to be confirmed in larger samples and with free-living individuals. Furthermore, it will be important to assess how well the two-regression approach extends from energy expenditure estimates for specific activities to the estimate of total energy expenditure from a free-living mix of activities.
REFERENCES


Richard P. Troiano
Applied Research Program
Risk Factor Monitoring and Methods Branch
National Cancer Institute
National Institutes of Health
Bethesda, Maryland
e-mail: troianor@mail.nih.gov