# Conducting Accelerometer-Based Activity Assessments in Field-Based Research

STEWART G. TROST[1], KERRY L. MCIVER[2], and RUSSELL R. PATE[2]

*[1]Community Health Institute, Kansas State University, Manhattan, KS; and [2]Department of Exercise Science, Norman Arnold School of Public Health, University of South Carolina, Columbia, SC*

**ABSTRACT**

TROST, S. G., K. L. MCIVER, and R. R. PATE. Conducting Accelerometer-Based Activity Assessments in Field-Based Research. *Med. Sci. Sports Exerc.*, Vol. 37, No. 11(Suppl), pp. S531–S543, 2005. **Purpose:** The purpose of this review is to address important methodological issues related to conducting accelerometer-based assessments of physical activity in free-living individuals. **Methods:** We review the extant scientific literature for empirical information related to the following issues: product selection, number of accelerometers needed, placement of accelerometers, epoch length, and days of monitoring required to estimate habitual physical activity. We also discuss the various options related to distributing and collecting monitors and strategies to enhance compliance with the monitoring protocol. **Results:** No definitive evidence exists currently to indicate that one make and model of accelerometer is more valid and reliable than another. Selection of accelerometer therefore remains primarily an issue of practicality, technical support, and comparability with other studies. Studies employing multiple accelerometers to estimate energy expenditure report only marginal improvements in explanatory power. Accelerometers are best placed on hip or the lower back. Although the issue of epoch length has not been studied in adults, the use of count cut points based on 1-min time intervals maybe inappropriate in children and may result in underestimation of physical activity. Among adults, 3–5 d of monitoring is required to reliably estimate habitual physical activity. Among children and adolescents, the number of monitoring days required ranges from 4 to 9 d, making it difficult to draw a definitive conclusion for this population. Face-to-face distribution and collection of accelerometers is probably the best option in field-based research, but delivery and return by express carrier or registered mail is a viable option. **Conclusion:** Accelerometer-based activity assessments requires careful planning and the use of appropriate strategies to increase compliance. **Key Words:** PHYSICAL ACTIVITY, OBJECTIVE MONITORING, ASSESSMENT, EXERCISE, VALIDITY, RELIABILITY

Over the past decade, many significant advances have occurred in the area of physical activity assessment (34,42). Perhaps the most notable of these developments has been the proliferation of accelerometer-based activity monitors that provide real-time estimates of the frequency, intensity, and duration of free-living physical activity (10). However, using these devices in field-based research is not a "plug and play" proposition. Before using these devices in the field, the investigative team must make a number of important decisions about a) the type of accelerometer that will be used; b) whether participants will wear one accelerometer or multiple accelerometers; c) the positioning of the accelerometer(s) on the body; d) the epoch length, or time interval, over which activity counts will be summed and written to memory; and e) the number of days the accelerometer will be worn.

In addition to making these technical decisions, the investigative team also must devise a sound plan for collecting and processing the data. The investigative team must decide how the accelerometers will be distributed to participants; create clear written and/or verbal instructions telling participants how and when to wear the accelerometer; and determine how the accelerometers will be returned to the laboratory for data downloading and storage. Furthermore, the investigative team must devise a plan to promote compliance with the monitoring protocol and minimize the possibility of acquiring incomplete accelerometer data.

This paper addresses each of these important issues with a view toward establishing evidence-based guidelines or recommendations on how to successfully implement an accelerometer-based measurement protocol. In situations where empirical evidence is lacking or incomplete, appropriate recommendations for future research are presented.

## SELECTING AN ACCELEROMETER

With numerous makes and models commercially available, one of the first tasks facing the investigative team is to choose which accelerometer to use. In making this decision, a number of important factors come into play. One obvious consideration is the cost per unit, including maintenance and repair fees, and the outlay of funds needed to purchase the peripherals necessary for collecting data in the field (e.g., computer interface, software, belts, and pouches). Other important considerations include monitor size and sturdiness, potential for reactivity and subject tampering (e.g., visual displays that provide feedback or readily accessible reset buttons), the availability and quality of technical support, the user-friendliness and flexibility of software for

Address for correspondence: Stewart Trost, Ph.D., Community Health Institute, Natatorium 8B, Kansas State University, Manhattan, KS 66506; E-mail: strost@ksu.edu.

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downloading and manipulating raw activity counts, and comparability of findings with other studies.

After considering all these factors, the investigative team should then conduct an informal cost-benefit analysis and decide which make or model of accelerometer will suit its particular needs. Here, the research question will be a strong determining factor. For example, if only relative changes in the total volume of physical activity are of prime interest, then a pedometer or low-end accelerometer may suffice. On the other hand, if the aim is to quantify the number of 10-min bouts of moderate to vigorous intensity physical activity over a 14-d period, then a more expensive accelerometer is required.

Although cost is important, it should not be the primary consideration when selecting an accelerometer. All accelerometer consumers, regardless of their budget, should select a make and model that has adequate evidence of validity and reliability in their study population. Table 1 lists the technical specifications and associated validity and reliability citations for eight commercially accelerometers. As one might expect, all eight models have evidence of validity and reliability in one form or another. Consequently, the decision about which accelerometer to use becomes more complex, as the investigative team must carefully scrutinize the quality and objectivity of the supporting evidence. Essentially the key question changes from, "Is this brand of accelerometer valid and reliable?" to "Which make and model of accelerometer has the best evidence of validity and reliability?" For pedometers, the latter question is relatively straightforward to answer, as at least two published studies have simultaneously evaluated the validity and reliability of a large number of commercially available pedometers (6,31). For accelerometers, the question is more difficult to answer because, to date, no single study has simultaneously evaluated the validity and interinstrument reliability of all the accelerometer products currently available.

## Accelerometer Comparison Studies

Although studies evaluating all makes and models of accelerometers are absent, a number of studies have simultaneously evaluated the validity of two or three different makes and models of accelerometers. Notably, the majority of these studies have addressed the question of whether multiaxis accelerometers (triaxial, bidirectional, omnidirectional) provide more valid assessments of physical activity and/or energy expenditure (EE) than do single axis (vertical) accelerometers. Given the salience of this research question to the process of selecting an accelerometer, the results of these studies are briefly summarized. Findings from adult and youth studies are examined separately.

**Adult studies.** Table 2 summarizes the findings of five studies examining the relative validity of two or more types of accelerometers in adults. Double entries for the studies by Hendelman et al. (12) and Welk et al. (38) reflect the assessment of validity using two different protocols, one based solely on walking and running and another using a variety of "lifestyle activities" such as gardening and household chores.

Leenders et al. (16) evaluated the relative validity of the uniaxial ActiGraph, formerly known as Computer Science and Applications (CSA) and Manufacturing Technology Inc. (MTI) (ActiGraph, LLC, Fort Walton Beach, FL), and the triaxial Tritrac-R3D, currently known as RT3 Triaxial Research Tracker (StayHealthy, Inc., Monrovia, CA), in 12 college-age women using physical activity EE (PAEE) measured by 7-d physical activity recall as a criterion measure. The correlations between daily PAEE and activity counts for the ActiGraph and the Tritrac-R3D (vector sum) were identical at r = 0.90. Notably, activity counts from the ActiGraph and the TriTrac-R3D were strongly correlated (r = 0.91). When activity counts were converted to kilocalories per kilogram per day, both the ActiGraph and Tritrac-R3D underestimated daily PAEE, with the magnitude of underestimation being greater for the ActiGraph ($-4.3$ $kcal \cdot kg^{-1} \cdot d^{-1}$) than the Tritrac-R3D ($-2.3$ $kcal \cdot kg^{-1} \cdot d^{-1}$). A different pattern of findings emerged when the same authors correlated output from the ActiGraph and TriTrac-R3D with PAEE measured using double-labeled water (17). On this occasion, the Tritrac-R3D vector sum exhibited a stronger correlation with PAEE (r = 0.54) than with CSA counts (r = 0.45). Consistent with the results obtained with self-reported PAEE, both the TriTrac-R3D and ActiGraph underestimated daily PAEE, with the TriTrac-R3D providing closer group-level approximations ($-320$ $kcal \cdot d^{-1}$) than the ActiGraph ($-495$ $kcal \cdot d^{-1}$) (17).

Hendelman et al. (12) evaluated the relative validity of the ActiGraph and TriTrac-R3D accelerometers during overland walking and a range of household and recreational activities (e.g., lawn mowing, window washing, vacuuming, and golf). During the walking trials, the correlation between ActiGraph counts and EE (METs) measured using a portable indirect calorimetry system was 0.77. For the same activities, the correlation between the TriTrac-R3D vector sum and EE was 0.89. When the walking activities were combined with golf and other various indoor and outdoor household activities, the validity coefficients for the ActiGraph and the Tritrac-R3D vector sum declined to 0.59 and 0.62, respectively.

Welk et al. (38) evaluated the relative validity of three different accelerometers (ActiGraph, TriTrac-R3D, and BioTrainer (IM Systems, Baltimore, MD)) in 52 adults performing laboratory-based treadmill exercise and nonlaboratory lifestyle activities such as sweeping, vacuuming, and shoveling. During treadmill walking and running, the Tritrac-R3D vector sum exhibited a stronger correlation with oxygen uptake ($\dot{V}O_2$) (r = 0.93) than did counts recorded by the ActiGraph (r = 0.85) and BioTrainer (r = 0.87). During the lifestyle activities, all three accelerometer models exhibited substantially lower correlations with $\dot{V}O_2$, with higher correlations observed for the TriTrac-R3D (r = 0.59) and BioTrainer (r = 0.59) than the ActiGraph (r = 0.48). In a more recent study, Welk et al. (37) examined the relative validity of the BioTrainer and the ActiTrac (IM Systems, Baltimore, MD) accelerometers during treadmill

TABLE 1. Overview of commercially available accelerometers.

| Model | Manufacturer | Type | Technical Specifications | Data Storage | Computer Interface | Data Reduction and Manipulation Software | Validity and Reliability Refs. (Ref. Nos.) |
|---|---|---|---|---|---|---|---|
| ActiGraph | The ActiGraph www.theactigraph.com | Uniaxial | Size: 2 × 1.5 × 0.6 in. Detects accelerations in the range of 0.05–2.0 *g* Frequency response: 0.25–2.0 Hz | 22 d while collecting activity data only | Reader interface unit required; connected to computer through serial port | Activity counts, with Windows software: energy expenditure, pedometer, light functions available | Children: 14,21,26,36,29 Adults: 7,9,12,38,41 |
| Actical | Mini-Mitter www.minimitter.com | Uniaxial; omnidirectional | Size: 1.1 × 1.06 × 0.39 in. Frequency response: 0.5–3 Hz | 45 d | Reader interface; connected to computer through serial port | Activity counts, energy expenditure, total activity, activity spent within intensity ranges | Children: 29,30 Adults: 41 |
| Actiwatch | Mini-Mitter www.minimitter.com | Biaxial | Size: 1.06 × 1.02 × 0.35 in. Frequency Response: 0.5–7 Hz | AW-16: 11 d AW-64: 44 d | Reader interface; connected to computer through serial port | Actiwatch rhythm, sleep, periodic limb movements | Children: 14,30 |
| ActiTrac | IM systems www.imsystems.net | Biaxial | Can detect movement at 0.012 *g* Movements sampled at 40 per second | Up to 62 d (not specific for 1-min epoch) | No interface, direct download | Milli-*g* units, data counts (0–250) | Adults: 37 |
| BioTrainer Pro | IM systems www.imsystems.net | Uniaxial, considered to be bidirectional | Movements sampled at 40 per second | 22 d | No interface, direct download | Absolute "*g*" units or kcal of activity per sampling unit | Adults: 37,38,41 |
| Tritrac-R3D | Hemokinetics, Inc. www.reining.com; no longer manufactured under this company; see RT3 | Triaxial, measures in the vertical, anteroposterior, and mediolateral directions, and generates a summary variable-vector magnitude | Size: 4.72 × 2.58 × 0.87 in. Frequency response: 0.1–3.0 Hz Detects acceleration in the range of 0.05–6.3 *g* | 7 d | Reader interface unit required; connected to computer through serial port | Activity counts per sampling unit | Children: 5,26, Adults: 12,24,39,41 |
| RT3 | StayHealthy www.stayhealthy.com | Triaxial, measures in the vertical, anteroposterior, and mediolateral directions, and generates a summary variable-vector magnitude | Size: 2.8 × 2.2 × 1.1 in. | Vector magn.: 21 d XYZ: 7 d | Activity recorder docking station required; connected to computer through serial port | Activity counts per sampling unit; total kcal and activity kcal per sampling unit | Adults: 28 |
| IDEEA | Minisun www.minisun.com | Five sensors attached to the body | A combination of the signals from each sensor are coded into different activities | | Microprocessor data downloaded to computer | Activity type, gait analysis, calculation of duration, frequency and intensity of activity; has the ability to recognize >40 activities | Adults: 44 |

TABLE 2. Summary of studies comparing different accelerometers in adults.

| | ActiGraph | TriTrac-R3D | BioTrainer | ActiTrac |
|---|---|---|---|---|
| Leenders et al. (16) | 0.90 | 0.90 | — | — |
| Leenders et al. (17) | 0.45 | 0.54 | — | — |
| Hendelman et al. (12) | 0.77 | 0.89 | — | — |
| Hendelman et al. (12) | 0.59 | 0.62 | — | — |
| Welk et al. (38) | 0.85 | 0.93 | 0.87 | — |
| Welk et al. (38) | 0.48 | 0.59 | 0.59 | — |
| Welk et al. (37) | — | — | 0.85–0.88 | 0.90–0.91 |

walking and running in 181 adults. Across all treadmill speeds, the ActiTrac exhibited a stronger correlation with $\dot{V}O_2$ (r = 0.90–0.91) than the BioTrainer (r = 0.85–0.88). In agreement with other studies, activity counts recorded by both accelerometers were strongly correlated (r = 0.92–0.95).

**Youth studies.** The findings of studies evaluating the validity of two or more makes and models of accelerometers in children and adolescents are summarized in Table 3. Welk and Corbin (39) compared the validity of the triaxial TriTrac-R3D and the uniaxial Caltrac Personal Activity Computer (Muscle Dynamics, CA) accelerometers in children using heart rate monitoring as an indicator of convergent validity. The correlation between heart rate and the TriTrac-R3D vector sum (r = 0.58) was marginally higher than that observed for the uniaxial Caltrac accelerometer and heart rate (r = 0.52). Importantly, the correlation between the TriTrac-R3D and Caltrac was 0.88, suggesting that both approaches were providing similar information.

Eston et al. (7) examined the relationships between oxygen consumption (relative to body mass raised to the power of 0.75) and output from the ActiGraph and TriTrac-R3D accelerometers in children during treadmill running/walking and unregulated play activities. Across all activities, the TriTrac-R3D vector sum exhibited stronger correlations with scaled oxygen consumption (r = 0.91) than did the ActiGraph (r = 0.78). Interestingly, during activities requiring ambulation (e.g., walking, running, and playing hopscotch), the largest accelerations were recorded in the vertical plane of the TriTrac-R3D (z-axis), but during crayoning and playing catch, the largest accelerations were recorded in the anteroposterior plane (y-axis). These findings were consistent with the view that three-dimensional accelerometers such as the TriTrac-R3D may provide better evaluations of children's free-play activities than uniaxial accelerometers.

Ott et al. (26) investigated the relative validity of the ActiGraph and TriTrac-R3D accelerometers with respect to their ability to measure children's free-play activities of different intensity. Twenty-eight children between the ages of 9 and 11 completed a circuit of eight free-play activities consisting of playing a video game, throwing and catching, walking, bench stepping, hopscotch, basketball, aerobic dance, and running. During the activities each participant wore a heart rate monitor, an ActiGraph accelerometer, and a TriTrac-R3D accelerometer. Across all eight activities, both accelerometer types were significantly correlated with heart rate and an observation-based intensity score. However, correlations observed for the TriTrac-R3D vector sum (r = 0.66–0.73) were greater than those observed for the ActiGraph (r = 0.53–0.64). Output from both accelerometer types were strongly correlated (r = 0.86), suggesting that, over a range of free-living activities, both uniaxial and triaxial accelerometers provide similar information about children's physical activity.

Puyau et al. (29) evaluated the relationships between activity counts from the ActiGraph and Actiwatch (Mini Mitter Co., Inc., Bend, OR) and EE in 26 children between the ages of 6 and 16. The participants performed a variety of physical activities in a whole room calorimeter, ranging from videogame playing to jumping rope. Stronger correlations with EE were observed for Actiwatch counts (r = 0.78–0.80) than counts recorded by the ActiGraph (r = 0.66–0.73). More recently, Puyau et al. (30) evaluated the relative validity of the Actiwatch and the Actical (Mini Mitter Co., Inc.) accelerometers using the same experimental protocol. Both the Actiwatch and the Actical were strongly correlated with EE, with the correlation for the Actical (r = 0.85) being marginally stronger than the Actiwatch (r = 0.82). Output from both accelerometers were highly correlated (r = 0.93).

Kelly et al. (14) used direct observation to evaluate the relative validity of the ActiGraph and Actiwatch accelerometers in 78 free-living children 3–4 yr old. The correlations between mean ActiGraph counts and the mean activity score from the observational system was r = 0.72. In contrast, the correlation between Actiwatch counts and the observational activity scores was low and nonsignificant (r = 0.16). The correlation between output from the two units was modest at r = 0.36.

**Other comparison studies.** Other studies have informed the issue of accelerometer selection by comparing

TABLE 3. Summary of studies comparing different accelerometers in children and adolescents.

| | MTI ActiGraph | TriTrac-R3D | Caltrac | Actiwatch | Actical |
|---|---|---|---|---|---|
| Welk et al. (39) | — | 0.58 | 0.52 | — | — |
| Eston et al. (7) | 0.78 | 0.92 | — | — | — |
| Ott et al. (26) | 0.53–0.64 | 0.66–0.73 | — | — | — |
| Puyau et al. (29) | 0.66–0.73 | — | — | 0.78–0.80 | — |
| Puyau et al. (30) | — | — | — | 0.82 | 0.85 |
| Kelly et al. (14) | 0.72 | — | — | 0.16 | — |

the validity coefficients obtained for the individual axes and the vector sum of the TriTrac-R3D triaxial accelerometer. Another study compared accelerometer types by examining the agreement between a uniaxial (ActiGraph) and triaxial (TriTrac-R3D) accelerometer with respect to the detection of sustained bouts of physical activity in free-living subjects.

Bouten et al. (2) examined the relative contributions of the individual vertical, mediolateral, and anteroposterior vectors and their summation to the prediction of EE during treadmill walking and sedentary activities in 11 adult males. For the sedentary activities, the vector sum was the best predictor of EE ($r = 0.81$), though for treadmill walking, the anteroposterior vector was the best predictor of EE ($r = 0.96$). For all activities combined, both the vector sum ($r = 0.95$) and anteroposterior vector ($r = 0.97$) were strongly associated with EE. Of interest, the principal acceleration component varied considerably by activity type. During the sitting and standing tasks, the largest accelerations were recorded in the anteroposterior plane. During the writing and arm work trials, the largest accelerations were recorded in the mediolateral plane. During treadmill walking, the vertical vector was the largest acceleration component. These observations support the view that triaxial accelerometers may provide better assessments of nonambulatory and sedentary activities than single-axis vertical accelerometers. However, for all the activities examined, significant accelerations were recorded in the vertical vector.

Coleman et al. (5) assessed the validity of the TriTrac-R3D accelerometer in obese children between the ages of 8 and 12, using heart rate as a criterion measure. After controlling for resting HR, the vector magnitude activity counts accounted for 34% of the variance in activity HR. When the contribution of each vector was examined separately using stepwise regression, resting HR and anteroposterior counts accounted for 36% of the variance in activity HR. The addition of activity counts from the mediolateral and vertical directional vectors did not account for additional variance in activity HR. Based on these findings, the authors concluded that the TriTrac-R3D vector magnitude provided a more comprehensive estimate of sedentary and physical activity in obese children than did the vertical directional vector alone.

Mâsse et al. (19) evaluated the agreement between the uniaxial ActiGraph and triaxial TriTrac-R3D with respect to detecting bouts of physical activity in 34 women between the ages of 30 and 65. Interaccelerometer agreement for physical activity aggregated in 10-min and daily intervals was high (intraclass correlation coefficient (ICC) $> 0.88$). Agreement with respect to the number and length of bouts detected by the two accelerometers was also moderate to strong, with 71.3% of bouts detected agreeing in length. The authors concluded that the TriTrac-R3D and the ActiGraph were equally effective for detecting bouts of moderate-intensity physical activity in field settings.

**Summary of comparison studies.** Studies comparing the relative validity of different makes and models of accelerometers provide useful information for investigators deciding which brand of accelerometer to use in their investigations. The majority of studies conducted in this area have compared the validity of uniaxial and multiple axis accelerometers. In both adult and youth studies, the validity coefficients reported for multiple axis units have been marginally higher than those reported for uniaxial models. Most studies, however, report a strong positive correlation between the output from both accelerometer types, suggesting that uniaxial and multiple axis accelerometers provide comparable physical activity information.

### Interinstrument Reliability

Perhaps due to the strong interest in predicting physical activity intensity and/or EE, most of the studies in the activity monitoring literature have focused on validity and calibration rather than interinstrument reliability. Studies published to date have either evaluated interinstrument reliability by comparing outputs from accelerometers worn on opposite hips or used high-precision shaker or turntable devices to examine technical reliability over multiple trials.

**Contralateral hip studies.** Nichols et al. (24) evaluated the interinstrument reliability of the TriTrac-R3D accelerometer in 20 young adults. Participants wore a single TriTrac-R3D unit on the left and right hip while walking and running on a treadmill at speeds ranging from 3.2 $km \cdot h^{-1}$ to 9.7 $km \cdot h^{-1}$. The participants also completed a walking bout at 6.4 $km \cdot h^{-1}$ at a 5% grade. The protocol was completed on two separate occasions, allowing for the computation of test-retest reliability. Intraclass reliability coefficients for the TriTrac-R3D vector sum recorded on the left and right hip ranged from 0.73 to 0.87. Test-retest reliability coefficients ranged from 0.87 to 0.92. Trost et al. (36) calculated the interinstrument reliability for two ActiGraph accelerometers worn on the left and right hip. Thirty children between the ages of 10 and 14 completed three 5-min treadmill bouts at 3, 4, and 6 mph, respectively. Across all speeds, the intraclass reliability coefficient was 0.87. Welk et al. (37) evaluated the interinstrument reliability of the BioTrainer and ActiTrac accelerometers in a sample of 181 adults. Participants completed three 6-min activity trials consisting of treadmill walking/running at 3, 4, and 6 mph. For the BioTrainer, intraclass reliability coefficients for the output recorded on the left and right hip ranged from 0.60 to 0.71. For the ActiTrac, the corresponding reliability coefficients ranged from 0.40 to 0.87.

Powell and Rowlands (28) employed a contralateral hip study design to evaluate the interinstrument reliability of the RT3 Triaxial Research Tracker (StayHealthy, Inc., Monrovia, CA). A single subject performed two separate activity trials (2 d apart) consisting of six activities: resting, walking at 4 and 6 $km \cdot h^{-1}$, running at 8 and 10 $km \cdot h^{-1}$, and a sit-to-stand task. During both trials, the subject wore eight RT3 units, four on the left hip and four on the right hip. Interinstrument coefficient of variation (CV) for the vector sum during the locomotor activities was less than 6%; however, relatively high variations were evident during the sit-to-stand task (8–25%). No significant between-unit differences for activity counts were recorded during the rest and the low-intensity trials; however, significant between-unit differences were detected during the vigorous-intensity trials.

To date, only one study has compared interinstrument reliability from different makes and models of accelerometers. Welk et al. (41) examined between-unit variation in four different accelerometers (ActiGraph, BioTrainer Pro, TriTrac-R3D, and Actical) during multiple trials of treadmill walking at 3 mph. The intraclass reliability coefficients across the three trials were 0.80 for the ActiGraph, 0.73 for the TriTrac-R3D, 0.68 for the BioTrainer Pro, and 0.62 for the Actical. The CV for the ActiGraph, TriTrac-R3D, and BioTrainer Pro was comparable at 8.9, 9.4, and 10.0%, respectively. However, the CV for the Actical across the three walking trials was 20%.

**Technical reliability studies.** A number of studies have used mechanical shaker or oscillating devices to assess within- and between-unit variation in accelerometer output. Kochenberger et al. (15) used a laboratory table shaker to evaluate the interinstrument reliability of the TriTrac-R3D accelerometer. The intraclass reliability coefficient for nine TriTrac-R3D units was 0.97. Nichols et al. (24) also used a mechanical table shaker to evaluate the interinstrument reliability of the TriTrac-R3D accelerometer. No significant differences between the output from each unit were noted and the CV was less than 2%. Fairweather et al. (8) constructed a laboratory-based mechanical accelerometry system to evaluate the interinstrument reliability of the ActiGraph accelerometer. The correlation between pairs of accelerometers approached unity ($r = 0.98–0.99$) and the CV was approximately 3%.

Brage et al. (3) used a mechanical oscillating device to evaluate the intra- and interinstrument reliability of the ActiGraph. The mean intrainstrument CV for all units was 4.4%. However, large variations were noted at very low and very high accelerations. With respect to interinstrument reliability, the ICC for a single measurement was 0.96–0.99. When compared with the grand mean for activity counts over all trials, each of the six accelerometers tested exhibited small but significant differences. The magnitude of the difference ranged from 3.5 counts per 3-s interval to 23 counts per 3-s interval. On the basis of these findings, the authors recommended inclusion of "unit" as a covariate in statistical analyses and the development of unit-specific calibration equations.

Metcalf et al. (22) used a motorized turntable to evaluate the intra- and interinstrument reliability of the ActiGraph accelerometer. The ActiGraph demonstrated strong intrainstrument reliability. At medium speed, the average CV was 1.4% and the ICC was 0.84. At high speed, the average CV was less than 1% and the ICC was 0.93. To evaluate interinstrument reliability, six separate batches of four ActiGraphs were run on the turntable for 10 min at medium and high speeds. At medium speed, the CV ranged from 1.4 to 5.3% and the ICC ranged from 0.71 to 0.99. At high speed, the CV ranged from 1.8 to 5.3% and the ICC ranged from 0.87 to 0.98.

Powell et al. (27) evaluated the technical reliability of the RT3 triaxial accelerometer over a range of motion frequencies. Each RT3 unit was mounted on motorized vibration table, which delivered vibrations at 2.1, 5.1, and 10 Hz. The ICC for the vector sum and the three individual axes was 0.99. The interinstrument CV decreased as frequency increased, ranging from 21.9–26.7% at 2.1 Hz to 4.2–7.2% at 10.0 Hz. Intrainstrument variability also decreased with increasing frequency. At 2.1 Hz, the within-unit CV ranged from as little as 2.1% to as much as 56.2%. At the 10.0-Hz setting, the CV ranged from 0.2 to 2.9%.

**Summary of interinstrument reliability studies.** Investigations evaluating the interinstrument reliability of accelerometers range from studies comparing output from units mounted on opposite hips to sophisticated technical reliability studies using high-precision oscillating devices. Nearly all studies reviewed report high levels of interinstrument reliability. Nevertheless, there is some evidence to suggest that interunit variability increases significantly at very low and very high movement frequencies. Consequently, investigators are encouraged to routinely calibrate their accelerometers and include accelerometer serial number in their data sets.

### Selecting an Accelerometer: Summary

The decision to purchase a particular make and model of accelerometer is influenced by a multitude of factors. However, for most researchers, the relative validity and interinstrument reliability of a given accelerometry product is of primary importance. Although some evidence indicates that some accelerometers may perform better than others under certain conditions, the reported differences are not consistent or sufficiently compelling to single out one brand or type of accelerometer as being superior to the others. Therefore, when it comes to selecting an accelerometer, issues of affordability, product reliability, monitor size, technical support, and comparability with other studies may be equally as important as the relative validity and reliability of an instrument.

## HOW MANY ACCELEROMETERS?

One of the key limitations of accelerometers is that they are insensitive to certain types of movements, in particular, nonambulatory physical activities with arm and or limb movements. To address this limitation, a small number of studies have examined whether additional accelerometers worn on the wrist or ankle can improve the accuracy of prediction equations compared with a single accelerometer on the hip or lower back.

Swartz et al. (32) compared the explanatory power of three site-specific prediction equations to convert ActiGraph counts to METs, an equation based on counts recorded on the wrist, an equation based on counts recorded on the hip, and an equation using a combination of counts recorded on the wrist and hip. Seventy participants between the ages of 19 and 74 completed a variety of free-living activities categorized as yard work, homework, family care, occupational, and recreation. While completing these activities, EE was measured using the Cosmed K4b$^2$ portable metabolic system. The MET prediction equation developed from the accelerometer worn on the wrist demonstrated poor predictive validity, accounting for less than 5% of the variance in observed METs. The equation based on the accelerometers worn on the hip explained only 32% of the variance. The combination of output from the hip and wrist resulted in an increase in explanatory power; however, the improvement was only marginal, accounting for an additional 2.6% of the variance in METs compared with the hip alone.

Melanson and Freedson (21) compared the explanatory power of EE prediction models derived from accelerometers worn on the ankle, hip, and wrist. The authors derived and cross-validated prediction equations based on output from one, two, and three accelerometer placements. Prediction equations using two placements (ankle and wrist or hip and wrist) and three placements (ankle, wrist, and hip) exhibited higher $R^2$ (0.94–0.95) and lower SEE (0.75–0.93) than the equation using a single placement on the wrist (r-square = 0.86, SEE 1.05). In the cross-validation sample, differences between observed and predicted EE values were smallest for the two and three placement prediction equations; although the increase in precision over the best single placement equation was relatively small ($<$0.20 kcal·min$^{-1}$). The results demonstrated that multiple accelerometer placements result in a more accurate prediction of measurement of EE during treadmill walking and running. The improvements over the single monitor placement were not physiologically significant, however.

Notably, the use of multiple accelerometers has not been rigorously evaluated in children. This appears to be an oversight because the ability to measure arm or limb movements in conjunction with movements of the torso may be helpful when using accelerometers to assess physical activity in preschool-age children. Notably, children of this age frequently engage in nonambulatory activities such as climbing, digging in a sandbox, and riding tricycles.

### Number of Accelerometers: Summary

Studies employing multiple accelerometers to estimate physical activity energy expenditure report marginal improvements in explanatory power. These small improvements do not warrant the increased subject burden associated with wearing multiple accelerometers. The use of multiple monitors in population groups with unique movement patterns (e.g., preschool children) deserves further study.

## MONITOR PLACEMENT

The relative position of the accelerometer on the body is another important consideration for the investigator. Ideally, the accelerometer should be attached as close as possible to body's center of mass. However, feasibility and subject burden should be carefully considered when planning a study. To date, a small number of studies have specifically addressed the issue of monitor placement.

Bouten et al. (1) investigated the influence of monitor placement on accelerometer output and the prediction of EE during walking (3–7 km·h$^{-1}$). Using both measured and simulated acceleration data, a total of six different body segments were evaluated: lower back, lower leg/foot, upper leg, head and trunk, lower arm/hand, and upper arm. Acceleration output recorded at the lower back was the best predictor of EE (r = 0.92–0.97), although acceleration data from all sites demonstrated moderate to strong associations with observed EE. Furthermore, when the authors partitioned the acceleration output into the kinematic (the acceleration due to body movement) and the gravitational component (the acceleration due the gravitational pull of the earth), the influence of the gravitational component was strongest for the limb placements, supporting the utility of the trunk placement; either on the lower back or hip.

Nilsson et al. (25) examined whether placement of a uniaxial accelerometer on the hip or back would affect the assessment of physical activity in 16 free-living 7-yr-old children. Over the 4-d monitoring period, no significant differences emerged between the two monitor placements for total counts per minute (751 $\pm$ 100 hip and 729 $\pm$ 112 back). The correlation between counts recorded on the hip and lower back was r = 0.81. When counts were classified as either moderate or vigorous intensity, the hip placement resulted in higher estimates of moderate physical activity, although the difference was significant only when counts were accumulated in 5-s epochs. There were no significant differences between the hip and back placements for estimated time spent in vigorous and very vigorous physical activity.

Yngve et al. (43) examined whether monitor placement on the hip or lower back could influence the assessment of treadmill and overland walking and running in healthy adults. Compared to activity counts from the monitor placed on the hip, the counts recorded on the back were significantly lower during normal and fast walking, but significantly higher during jogging. The magnitude of these differences, however, were quite small and of questionable practical significance. In a separately conducted field-based study, 34 adults wore an accelerometer on the hip and lower back for seven consecutive days. Presumably, the participants were responsible for putting the monitor on the correct place each day. There were no significant differences for mean activity counts per minute from the lower back 392 $\pm$ 139 and hip 402 $\pm$ 143. Moreover, placement of the monitor had no effect on estimated time spent at moderate and vigorous physical activity.

Welk et al. (38) examined the issue of monitor placement using three different models of accelerometers (ActiGraph, BioTrainer and TriTrac-R3D) Forty-two adults completed three 6-min bouts of walking with the monitor positioned in three different locations on the right hip: 1) anterior axillary line (iliac crest), 2) mid-axillary line, and 3) the posterior axillary line. No significant placement effects were observed for either the BioTrainer or TriTrac-R3D. However, small but statistically significant differences were observed for the ActiGraph, with significantly higher counts recorded for the mid-axillary line than either anterior or posterior axillary line. The practical significance of these findings is uncertain, given that it is unlikely that the average study participant would wear their accelerometer on exactly the same site on each monitoring day.

### Monitor Placement: Summary

Studies comparing different placement options indicate that accelerometers are best placed on hip or the lower back. Small but significant differences have been reported for hip and back placements, as well as different locations on the hip area. The practical significance of these findings are questionable.

## EFFECT OF EPOCH LENGTH

Accelerometers function by integrating a filtered digitized acceleration signal over a user-specified time interval, commonly referred to as an epoch. At the end of each epoch, the summed value or activity count is written to memory. If the volume of activity (activity counts over a specified time frame) is the outcome of interest, epoch length is not an issue. However, if one applies cut points to determine the amount of time spent in different levels of intensity, then the choice of epoch length may affect the study results and should be carefully considered before collecting data in the field.

Perhaps due to the ease of converting activity counts into minutes of activity, the majority of studies using accelerometers to estimate physical activity intensity or energy expenditure have used cut points based on 1-min epochs. Although this practice may have minimal impact on activity assessments in adults, several authors have noted that use of 1-min cut points may be problematic in children and may obscure the short bursts of moderate to vigorous physical activity (MVPA) typically exhibited by children (34,40). That is, if a child alternates between vigorous physical activity and rest within a given minute, the accumulation of counts for that minute will only reflect the average activity level during that period, and the short burst of vigorous physical activity remains undetected.

Nilsson et al. (25) empirically examined in the influence of epoch length on the prediction of exercise intensity and detection of 10-min bouts of activity. A total of 16 7-yr-old children wore a single accelerometer for four consecutive days. The accelerometers were initialized to sum and store activity counts in 5-s intervals (5-s epoch). Activity counts were subsequently reintegrated into 10-, 20-, 40-, and 60-s epochs and classified counts as either moderate, vigorous, and very vigorous activity using the adult MET prediction equation developed by Freedson et al. (9). For the classification of epochs less than 60 s, the Freedson equation was divided by the appropriate scaling factor to obtain a cut points for 5, 10, 20, and 40 s. No significant epoch effects were noted for moderate-intensity physical activity. However, significant epoch effects were observed for estimated time spent in vigorous- and very vigorous–intensity physical activity. Estimated time in vigorous physical activity was inversely associated with epoch length, declining from approximately 40 min with 5-s epochs to as little as 10 min with 60-s epochs. Similarly, for very vigorous activity, estimated time declined from approximately 11 min with 5-s epochs to just over 1 min based on 60-s epochs. These findings vividly show that, among children, the commonly used 1-min epoch is too long, resulting in a smoothing effect and subsequent underestimation of physical activity behavior.

### Epoch Length: Summary

To determine the amount of time spent in different levels of physical activity intensity, investigators have developed cut points corresponding to MVPA. These cut points are typically based on 1-min epochs. Because children typically perform activity intermittently in short bursts lasting several seconds, 1-min time intervals maybe inappropriate and may result in underestimation of participation in MVPA. The results of one empirical study provides strong support for this assertion. The issue of epoch length has not been systematically studied in adults.

## HOW MANY DAYS OF MONITORING ARE NEEDED?

The minimum number of days participants need to wear an accelerometer has important implications for compliance and overall study costs. For investigators, the goal is to monitor activity for a sufficient number of days so that the resulting daily average reflects an individual's usual or habitual level of physical activity. However, care is needed to select a monitoring protocol that is not overly burdensome on the participants or project resources. Investigators must also operationally define a complete monitoring day.

To determine the number of monitoring days required, most studies have employed variance partitioning techniques to estimate and calculate the ICC for a single day of monitoring, where $\sigma_b^2$ is the between-subject variance component and $\sigma_w^2$ is the within-subject variance component.

$$\mathrm{ICC_s} = \sigma_b^2/(\sigma_b^2 + \sigma_w^2) \qquad [1]$$

The Spearman–Brown prophecy formula is then used to calculate the number of days or repeated observations needed to obtain a specified level of reliability (typically 0.80). Where $N$ is the number of measures or days needed, $\mathrm{ICC_t}$ is the desired level of reliability, and $\mathrm{ICC_s}$ is the single-day reliability. The general formula for determining the number of measures needed to achieve the desired level of reliability is:

$$N = [\mathrm{ICC_t}/(1 - \mathrm{ICC_t})][(1 - \mathrm{ICC_s})/\mathrm{ICC_s}] \qquad [2]$$

Studies using the above techniques to examine day-to-day variability in accelerometer-based physical activity level are summarized below. Because of the inherent differences in the amount and tempo of physical activity, findings from adult and youth objective monitoring literature are examined separately.

### Adult Studies

Gretebeck and Montoye (11) estimated the number of monitoring days needed to obtain a reliable measurement of physical activity. Assuming an error-free measurement in the variable to be correlated with physical activity, it was estimated that between 5 and 6 d of monitoring was required to estimate the true relationship with less than 5% error. Coleman and Epstein (4) used generalizability theory to estimate the number of monitoring days necessary to reliably estimate activity measured by the TriTrac-R3D accelerometer. Thirty-four college-age males wore the TriTrac-R3D for seven consecutive days. It was estimated that between 3 and 4 d of monitoring was required to obtain a reliable estimate of physical activity based on the TriTrac-R3D vector sum. To obtain a reliable estimate of average MET level, it was estimated that between 4 and 5 d of monitoring was required. Levin et al. (18) used Caltrac-based estimates of daily MET-minutes from 14 noncontiguous days to estimate inter- and intraindividual variation in objectively measured physical activity. The single-day ICC was 0.41. Applying the Spearman–Brown prophecy formula and reliability cut point of 0.80, it was estimated that approximately 6 d of monitoring was required to estimate habitual physical activity

Matthews et al. (20) used variance partitioning techniques to examine the number of days needed to reliably estimate various accelerometry parameters including total daily activity counts, time spent in moderate intensity activity (both ambulatory and nonambulatory), time spent in vigorous physical activity, and time spend in sedentary behavior. In contrast to earlier studies examining between-day variability in objectively measured physical activity, the study included a relatively large sample of men and women of diverse ages. Additionally, in contrast to the many studies using a 7-d monitoring protocol, subjects in this study completed 21 consecutive days of monitoring. For both men and women, it was concluded that 3–4 d of monitoring was required to achieve an ICC of 0.80, whereas at least 7 d was required to reliably assess patterns of inactivity. Notably, the 7-d protocol achieved a reliability of 0.90 for all the activity indices.

### Youth Studies

Janz et al. (13) examined the between-day reliability of accelerometer-based physical activity assessment in children between the ages of 7 and 15. The ICC for 4 d of monitoring ranged from 0.75 to 0.78, whereas 6-d reliability coefficients ranged from 0.81 to 0.84. Treuth et al. (33) determined the number of days needed to reliability estimate daily ActiGraph activity counts activity in 68 African-American girls aged 8–9. The ICC for average activity counts over the 4-d monitoring period was 0.37. Applying the Spearman-Brown prophecy formula, it was concluded that a minimum of 7 d of measurement would be required to achieve a reliability of 0.80. In similar fashion, Murray et al. (23) estimated the between- and within-subject variance components for objectively measured daily MVPA in 436 eighth-grade girls. The single-day reliability coefficient for MET-weighted MVPA was 0.42. Applying the Spearman–Brown prophecy formula, it was estimated that 5 or 6 d was necessary to obtain a reliability of 0.80.

Trost et al. (35) examined age-related trends in the reliability of objectively measured physical activity in a population-based sample of children and adolescents. Among children in grades first through sixth, the single-day reliability of MVPA, assessed by the ActiGraph accelerometer, ranged from 0.46 to 0.49. In comparison, the single-day reliability among adolescents in grades 7–12 was notably lower, ranging from 0.31 to 0.32. At these levels of variability, it was estimated that between 4 and 5 d of monitoring would be necessary to achieve a reliability of 0.80 in children; and between 8 and 9 d of monitoring would be necessary to achieve a reliability of 0.80 in adolescents. Importantly, for both children and adolescents, 7 d of monitoring produced acceptable estimates of daily MVPA (ICC = 0.76−0.86) and accounted for significant differences is weekday and weekend physical activity.

### Number of Days of Monitoring: Summary

The findings from adult and youth studies are summarized in Figure 1A and B, respectively. For adults, it would appear that between 3 and 5 d of monitoring is required to reliably estimate the outcome variables typically reported in accelerometry studies. Among children and adolescents, however, the number of monitoring days needed to achieve a reliability of 0.80 ranges from 4 to 9 d. In light of this inconsistency, and the observation of weekend and weekday differences in physical activity behavior, a 7-d monitoring protocol would appear to be a sensible choice for youths.

## DISTRIBUTION AND COLLECTION OF ACCELEROMETERS

The most common approach to distributing and collecting accelerometers in small-scale field-based research has been a face-to-face appointment taking place at the investigator's laboratory/clinic or the participant's home, school, or worksite. For larger epidemiological and intervention studies, however, face-to-face distribution and collection methods may not be feasible, particularly if the project is limited in staff and/or accelerometers and there is a need to complete activity assessments over a relatively short time interval. In such situations, a common approach has been to distribute and/or collect the accelerometers by registered or express mail. Indeed, many studies distribute accelerometers to participants on a face-to-face basis and provide a prepaid envelope so that participants can return the monitors by registered or express mail. This approach makes certain that participants are adequately briefed about the care and use of the accelerometer and avoids the need for a return visit to the home or laboratory for data retrieval. This approach

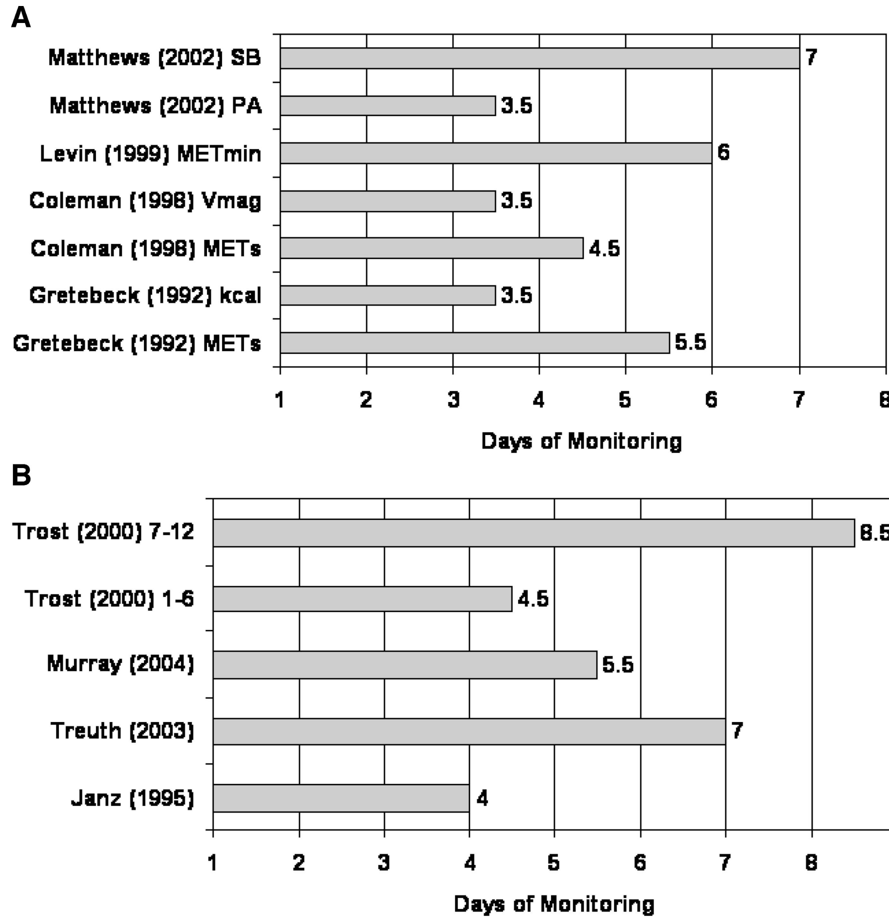


**FIGURE 1—A. Number of days needed to reliably estimate physical activity: summary of adult studies. B. Number of days needed to reliably estimate physical activity: summary of youth studies.**

works particularly if participants are initially recruited into the study at one central location (e.g., medical setting or research laboratory). Importantly, personal experience with the ActiGraph accelerometer indicates that the security procedures associated with air travel or express mail (i.e., x-ray screening) does not adversely affect the data stored on the accelerometer. Other brands of accelerometers also should be impervious to x-ray scanning. However, all investigators are encouraged to complete several "practice mailings" before committing to a mail-based distribution-collection protocol. For all makes and models of accelerometers, investigators should ensure that participants are provided with correctly addressed prepaid envelopes with sufficient strength and padding to prevent damage to the monitor.

## STRATEGIES TO PROMOTE COMPLIANCE

Clearly, compliance with the monitoring protocol is of critical importance in any study using accelerometers to quantify physical activity behavior. Even the most sophisticated accelerometers cannot force participants to wear them every hour of the day! However, despite its importance, the topic of compliance has received relatively little attention in the research literature. Although a number of investigators have addressed the issue of compliance by quantitatively defining what constitutes a complete monitoring day and devising useful and nonbiased strategies to impute missing accelerometer data, to these authors' knowledge, no experimental studies investigating the efficacy of different strategies to promote compliance have been conducted.

In light of this, strategies to promote compliance are summarized in Table 4. These strategies may be viewed as participant or investigator based. Participant-based strategies require the individuals wearing the accelerometer to perform specific tasks that, in theory, promote greater compliance (i.e., completing of a daily monitoring log). Investigator-based strategies, on the other hand, are the activities performed by project staff that help participants remember to wear the accelerometer on a daily basis for the length of time specified.

## RECOMMENDATIONS FOR PRACTICE

The goal of this review is to provide evidence-informed guidelines for successfully implementing an accelerometer-based measurement protocol. We specifically examined the issues of product selection, number of accelerometers needed, placement of accelerometers, epoch length, and days of monitoring required to estimate habitual physical activity. We also discussed the various options related to distributing and collecting monitors and compliance strategies. The preceding sections lead to the following conclusions and recommendations:

TABLE 4. Strategies to promote compliance with activity monitoring in field-based studies.

| Compliance Strategies | Comments |
|---|---|
| Ask participants to complete an activity monitoring log. | Participant records the time the monitor is on and off, in addition to recording activities performed without the monitor, or activities known to be insensitive to accelerometry. The log is typically very useful for data analysis and reduction. Completing the log on a daily basis can serve as a valuable self-monitoring tool. |
| Make reminder calls | At least one phone call to remind participants to wear their accelerometer and to ask about problems/barriers. In school-based studies, this could be done in the classroom. This is an effective and cost-effective strategy, and the proliferation of cell phones and text messaging makes this an attractive option. |
| Provide participants with tips or lists of frequently asked questions (FAQs) about wearing accelerometers correctly. | Can be in the form of tip sheets or flyers disseminated at initial appointment. E-mail, Web sites, and voice and text messaging also may be good dissemination options. Tips or FAQs can be easily included in an activity monitoring log booklet where participants are provided with a new tip or reminder each day. |
| Apply "relapse prevention model" to the problem of not wearing the accelerometer. | Before the monitoring period, identify situations where participants will encounter barriers to wearing the model. Device solutions or plans to overcome barriers, such as wearing under clothes. |
| Display written materials/flyers on bulletin boards or refrigerators to prompt wearing the monitor. | Place colorful attention-grabbing flyers, refrigerator magnets, stickers in locations where participants will see them on a daily basis. Include reminder statements such as "Are you wearing your activity monitor?" |
| Provide advance notice of the study to employers, teachers, coaches, referees, and other sports officials and educate them about wearing protocols. | In certain situations, participants may be asked to take accelerometers off to conform to dress code or uniform regulations. This is a common occurrence in youth sports. In many situations, such as action is unnecessary. To avoid this problem, communicate with officials before the study and educate them on the process. |
| Show participants an example of output to show that you can tell when they are not wearing them. | Although care should be taken not to intimidate or coerce participants, showing them a sample output as part of the prestudy education process can promote greater accountability. |
| Provide incentives contingent on compliance, such as money, gift certificates, coupons, extra credit. | Participant compensation is frequently employed in studies as a compliance strategy. Incentives and standards to receive the incentive need to be appropriate and conform to institutional review board regulations. Some investigators have provided incentives on a sliding scale based on the number of completed monitoring days. |

- No definitive evidence exists currently to indicate that one make and model of accelerometer is more valid and reliable than another. Selection of accelerometer therefore remains primarily an issue of product reliability, practicality, technical support, and comparability with other studies.
- Contralateral hip studies and technical reliability studies involving single axis and triaxial accelerometers report generally acceptable levels of instrument reliability. However, the observation of substantial interunit variation in one study and the existence of increased variability at very low and high movement frequencies underscore the need for ongoing quality control and unit calibration.
- Studies employing multiple accelerometers to estimate physical activity energy expenditure report marginal improvements in prediction power. These small improvements do not warrant the increased subject burden associated with wearing multiple accelerometers.
- Studies comparing different placement options indicate that accelerometers are best placed on hip or the lower back. Where possible, placements on the ankle or wrist should be avoided.
- The use of count cut points based on 1-min time intervals maybe inappropriate in children and may result in underestimation of participation in moderate to vigorous physical activity. The issue of epoch length has not been systematically studied in adults.
- Among adults, 3–5 d of monitoring is required to reliably estimate habitual physical activity. Among children and adolescents, the number of monitoring days required ranges from 4 to 9 d, making it difficult to draw a definitive conclusion for this population. The observation of weekend versus weekday differences in physical activity among youths suggests that a 7-d monitoring protocol is a sensible choice.
- For both adults and youths, the number of monitoring days will depend on the setting, population under study, study resources, and the research question at hand (e.g., the need for population-level vs individual-level estimates of physical activity behavior).
- In smaller scale field-based studies, face-to-face distribution and collection of accelerometers is probably the best option, but delivery and return by express carrier or registered mail is a viable option in larger epidemiological studies and intervention trials.
- All studies should implement multiple strategies to promote compliance with the monitoring protocol. Strategies can be either investigator or participant based.

## RESEARCH NEEDS

Although significant advances have been made over the past decade, much remains to be learned about the use of accelerometers in field-based research. Improvements in the use of accelerometers can occur by addressing the following research needs.

- A relatively small number of studies have simultaneously compared the validity and reliability of accelerometers under standardized conditions. Thus, additional studies comparing the validity and inter-instrument reliability of different makes and models of accelerometers are warranted. Such studies should include nonlaboratory "lifestyle" physical activities in the experimental protocol.

- The utility of multiple accelerometers to assess physical activity and/or energy expenditure should be systematically investigated in young children (i.e., preschoolers) as multiple accelerometers may be more apt to detect the nonambulatory activities typically exhibited by this population.
- The impact of epoch length on adult estimates of physical activity should be investigated, particularly as it relates to the detection of bouts of physical activity and meeting public health guidelines for physical activity.
- Studies are needed to determine the optimal epoch length for measurement of free-living physical activity behavior and how this parameter varies with age or any other subject characteristic.
- The statistical assumptions underlying the use of the intraclass correlation coefficient and the Spearman–Brown prophecy (e.g., compound symmetry) should be carefully examined. This issue has been examined in adults using self-reported physical activity data, but has yet to be investigated with accelerometer-based estimates of physical activity.
- Studies are needed to identify the psychological, sociocultural, and environmental factors that are associated with or predict compliance to monitoring protocols. Why do some individuals wear their accelerometers as directed and others do not?
- Experimental studies testing the efficacy of specific strategies to promote participant compliance are needed.
- The development of a more affordable accelerometer is urgently needed. Many researchers would like to use accelerometers in their research but instead must rely on less expensive pedometers to objectively measure physical activity. In the era of affordable small electronic devices with big capabilities (e.g., camera cell phones and the BlackBerry), it is difficult to understand why the cost of accelerometers has not declined.

The results of the present study do not constitute endorsement by the authors or ACSM of the products described in this paper.

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