Use of Accelerometry to Measure Physical Activity in Older Adults at Risk for Mobility Disability

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The authors explored using the ActiGraph accelerometer to differentiate activity levels between participants in a physical activity (PA, n = 54) or “successful aging” (SA) program (n = 52). The relationship between a PA questionnaire for older adults (CHAMPS) and accelerometry variables was also determined. Individualized accelerometry-count thresholds (Thresh\textsubscript{IND}) measured during a 400-m walk were used to identify “meaningful activity.” Participants then wore the ActiGraph for 7 days. Results indicated more activity bouts/day ≥10 min above Thresh\textsubscript{IND} in the PA group than in the SA group (1.1 ± 2.0 vs 0.5 ± 0.8, \(p = .05\)) and more activity counts/day above Thresh\textsubscript{IND} for the PA group (28,101 ± 27,521) than for the SA group (17,234 ± 15,620, \(p = .02\)). Correlations between activity counts/hr and CHAMPS ranged from .27 to .42, \(p < .01\). The ActiGraph and Thresh\textsubscript{IND} might be useful for differentiating PA levels in older adults at risk for mobility disability.

Keywords: assessment, motion sensor, exercise, locomotor activity

An estimated 11 million older adults in the United States, or approximately one third of noninstitutionalized adults ≥65 years, report having mobility disability (defined as having difficulty going outside the home; Waldrop & Stern, 2003). Mobility disability poses a threat to the maintenance of independence for older adults and has been associated with higher incidence of certain chronic diseases and depressive symptoms and an increased rate of institutionalization (Fried & Guralnik, 1997; Van Den Brink et al., 2006). Because evidence suggests that physical inactivity is strongly associated with mobility disability in older adults (Avlund, Vass, & Hendriksen, 2003; Buchner, Beresford, Larson, LaCroix, & Wagner, 1992; Depp & Jeste, 2006; Hirvensalo, Rantanen, & Heikkinen, 2000; Wannamethee, Ebrahim, Papacosta, & Shaper, 2005), effective physical activity...
interventions might play a major role in reducing the risk of mobility disability and associated sequelae. Accordingly, valid and accurate measurement of physical activity in those at risk for physical disability is key to documenting current physical activity levels and measuring outcomes from interventions aimed at reducing the rate of decline in mobility.

Self-report measures (e.g., questionnaires, activity logs, surveys) have been commonly used across a wide range of ages to assess physical activity and offer an economical means of reaching a large number of people. The recall of physical activity required for such measures, however, is a challenging cognitive task (Baranowski, 1988) and might expose recall and memory limitations, particularly among older individuals. Furthermore, older adults are more likely to engage in light- to moderate-intensity physical activity, the most difficult type of activity to recall (Baranowski; Washburn, Jette, & Janney, 1990).

Motion sensors offer an objective, unobtrusive means of capturing movement of the body and are emerging as a viable alternative or supplement to traditional self-report measures. Accelerometers, a type of motion sensor, measure the acceleration of the trunk or limb to which they are attached and have the capacity to document volume and intensity of activity. The theoretical basis for the use of accelerometers in physical activity assessment is that acceleration is directly proportional to muscle forces and thus is related to energy expenditure (Melanson & Freedson, 1996). The relationship between accelerometry “activity counts” and energy expenditure during locomotor activities has prompted the development of activity-count “cut points” or thresholds that have been used to characterize activity intensity level (e.g., moderate, hard, vigorous). In light of recent physical activity guidelines that specify intensity levels (Haskell et al., 2007) and the importance of relative intensity levels in recommendations for older adults (Nelson et al., 2007), activity-count cut points could prove useful in delineating “meaningful” activity with regard to health benefits. Very few studies have included older adults, however, in the development of such cut points.

In the few studies that have been conducted, results have been encouraging regarding the validity of the ActiGraph (formerly CSA) accelerometer (Actigraph, LLC, Fort Walton Beach, FL) in older adults. Focht, Sanders, Brubaker, and Rejeski (2003) monitored adults (age range 45–86 years) during a supervised exercise session and reported acceptable convergent and concurrent validity for the ActiGraph. Boon et al. (2003) measured total energy expenditure in 20 older adults ($M \pm SD$ age $73 \pm 8$ years) via indirect calorimetry and found correlations ranging from $.5$ to $.6$ ($p \leq .03$) with ActiGraph daily activity counts. Given the potentially beneficial impact that physical activity might have on the health and functioning of older adults at risk for physical disability in addition to the heightened challenges with self-reporting in some older adult populations, additional research exploring the usefulness of accelerometry as a physical activity assessment tool in frail older adults is warranted.

The current investigation was funded as an ancillary study to the LIFE-P trial (Pahor et al., 2006) and served as an initial evaluation of the ActiGraph in an older adult sample with an elevated risk of major mobility disability. The overarching goal was to provide data to inform power calculations for a larger trial and conduct preliminary analyses with regard to convergent validity among physical activity measures. Specifically, the current study evaluated older adults at risk for mobility disability to address the following research objectives:
• Determine the practicality of and compliance with using the ActiGraph in nonsupervised, naturalistic settings in men and women age 70–89 years.
• Determine the capability of the ActiGraph to distinguish a difference in activity level between a subset of participants assigned to a physical activity (PA) program versus a health-education (nonexercise, “successful aging” [SA]) program.
• Develop an individualized accelerometry-based activity-count threshold associated with “meaningful” activity and evaluate its use in differentiating activity levels between the PA and SA programs.
• Determine the relationship of the ActiGraph variables with a validated physical activity questionnaire for older adults.

Method

Study Design

Participants of the current study were a subgroup from both intervention arms of a larger study called the Lifestyle Interventions and Independence for Elders pilot (LIFE-P) study. Details of LIFE-P have been described previously (Pahor et al., 2006; Rejeski et al., 2005). Briefly, LIFE-P was a multicenter randomized controlled trial designed to compare a PA intervention with an SA intervention with regard to the effect on the Short Physical Performance Battery (SPPB) score, a measure of lower extremity physical function (Guralnik et al., 1994). The study was conducted at four field centers: Cooper Institute, University of Pittsburgh, Stanford University, and Wake Forest University. The administrative coordinating center and data management and quality control center were also located at Wake Forest University. The current substudy was conducted at the University of Pittsburgh and Stanford University field centers. The appropriate institutional review board approvals were obtained. All participants provided written informed consent.

Participants

The following eligibility criteria for LIFE-P were designed, in part, to identify older, community-dwelling sedentary individuals at high risk for mobility disability:

• Age 70–89 years
• Self-reported low physical activity levels (<20 min/week spent in regular physical activity within the last month)
• At risk for mobility disability as indicated by a summary score of ≤9 on the SPPB
• Ability to complete a 400-m walk in ≤15 min without sitting or the use of an assistive device
• Willingness to provide informed consent and participate fully in either intervention and all assessment procedures
• Planned residence in the area for the study duration
In addition to English speakers, participants who had a preference for communicating in Spanish were enrolled at the Stanford field center. Individuals were excluded if they had any medical condition that would limit participation in a moderate-intensity physical activity program or if they had cognitive impairment as indicated by a Mini-Mental State Exam score of <21 (Folstein, Folstein, & McHugh, 1975).

**Intervention**

Participants were randomized, stratified by gender and field center, to the PA arm and participated in aerobic, strengthening, balance, and flexibility exercises. Walking was the primary mode of aerobic activity. Participants were required to attend an hour-long supervised exercise session three times per week for the first 2 months, two times per week for the next 4 months, and one time per week until the end of the 12-month intervention. As the class-based activity requirement was reduced, a shift to home-based physical activity was encouraged, with a goal of three times per week of home-based activity. Participants were taught how to exercise safely on their own, and tools and strategies were provided to help maintain compliance and to address possible barriers to the home-based activity requirements. The SA arm consisted of interactive classes, and field trips focused on a range of nonexercise topics relevant for older adults. Light, upper body stretching activities were conducted during the SA classes. Field-trip activities included minimal walking (e.g., walking in a museum with frequent breaks); no other activity-related actions were undertaken.

**Accelerometry**

Physical activity data were collected at the 6- or 12-month time point of LIFE-P using the ActiGraph model 7164 accelerometer (ActiGraph, LLC, Fort Walton Beach, FL). The ActiGraph is a one-dimensional accelerometer housed in a plastic enclosure measuring 5.1 × 4.1 × 1.5 cm with a weight of 42.4 g. The ActiGraph records the magnitude and intensity of movement by measuring acceleration and deceleration between the magnitudes of 0.05 and 2 g (where g is equal to 9.825 m/s, the acceleration of gravity), within a frequency range of 0.25–2.5 Hz. Output from the ActiGraph is in the form of activity “counts,” where one count is equivalent to 16 mg/s. Motion can be measured over a user-defined epoch or period of time, with a data-storage capacity of 22 consecutive days using a 1-min epoch.

To our knowledge, there are no widely accepted accelerometer thresholds or “cut points” with which to evaluate various activity levels in an older adult population. As a result, we calculated an individualized activity-count threshold (Thresh\textsubscript{IND}) for each participant using data collected during a 400-m walk. The average counts per minute generated by a participant during the 400-m walk served as his or her Thresh\textsubscript{IND}. For subsequent analyses, activity counts above this level were operationally defined as meaningful activity.

Activities related to the 400-m-walk data collection are as follows. The ActiGraph was initialized approximately 30 min before the participant’s clinic visit and programmed to record data in 1-min epochs. Before the walk, the monitor
was attached at the participant’s waistline using a clip and placed along the right midaxillary line. The beginning and end of the 400-m walk were identified on the ActiGraph by using the event-marker mode of the monitor. Specifically, research staff used a company-provided field-test magnet that was momentarily placed along the left side of the activity monitor case at the start and end of the 400-m walk. Marking an event in this manner resulted in a negative sign for the activity-count value corresponding to the beginning and end of the walk. As a result, the activity counts associated with the 400-m walk could be easily identified during subsequent analyses. In addition, staff recorded the start time and end time for the walk. Participants were instructed to walk 10 laps of a 20-m distance at their usual pace and without overexertion. At the end of the fourth lap, they were asked to rate their level of exertion using a 4-point scale on which 1 = light, 2 = somewhat hard, 3 = hard, and 4 = very hard. Participants with a rating of hard or very hard were required to adjust their walking pace to a light or somewhat hard intensity level. In addition, at the conclusion of the walk a subset of participants was asked to evaluate their perceived exertion level using the 15-point Borg scale for perceived exertion (Borg, 1982). Activity counts during the first and last minute of the 400-m walk were deleted, with the remaining counts averaged and used to represent the ThrshIND in counts per minute. Failure to complete the 400-m-walk test within 15 min was defined as major mobility disability and resulted in the exclusion of 1 participant from this substudy.

At the conclusion of the walk, participants kept the monitor on and wore it for the 7 days immediately after their clinic visit. During the 7-day monitoring period, participants were asked to put the monitor on each morning (after dressing) and remove it just before going to bed at night. The monitor was also removed for bathing, showering, or any other activity that might result in exposure to water. In addition, participants were asked to keep a concurrent log to record the times of day that the monitor was put on and removed. Participants were instructed to contact research staff by telephone with any questions about monitor use. After the seventh complete day of activity monitoring, participants returned their logs and activity monitors to research staff via mail.

**Physical Activity Self-Report**

The Community Healthy Activities Model Program for Seniors (CHAMPS) questionnaire (Stewart, Mills, et al., 2001) was used to assess physical activity level. It has been shown to have acceptable validity, reliability, and sensitivity to change in older adults (Harada, Chiu, King, & Stewart, 2001; King, Baumann, O’Sullivan, Wilcox, & Castro, 2002; King et al., 2000; Stewart, Verboncoeur, et al., 2001). The CHAMPS questionnaire was interviewer administered and is designed to assess weekly frequency and duration of activities typically undertaken by older adults. The recall time frame is “a typical or normal week during the past 4 weeks.” Activities listed in the CHAMPS questionnaire were assigned metabolic equivalent (MET) values specific for older adults, as described by Stewart, Mills, et al. (2001), that provide for coding and classification of activities by rate of energy expenditure. Research staff used probing techniques during the interview to determine the actual time spent in the activities categorized as
being at least moderate intensity (mod+), or ≥3 METs, where 1 MET is equivalent to the metabolic cost during quiet sitting. Outcome measures from the CHAMPS questionnaire include caloric expenditure per week and frequency per week for mod+ activities and all physical activities including those of light intensity. Activities classified as light intensity were those with an energy expenditure of <3 METs. CHAMPS data collected at 6 or 12 months were used in the present investigation.

**Accelerometer-Data Processing**

A program was created for use with SAS v. 9.1.3 (SAS Institute, Inc., Cary, NC) to download, process, and calculate accelerometer variables. Daily plots were constructed for each participant that provided a visual display of average activity counts per hour and an indication of which hours the monitor was being worn, according to the participant’s log. Our SAS program also generated printouts for each day of monitoring that listed the activity counts for each minute of the day and whether the activity monitor was being worn, according to the log data. Visual inspection of these outputs was used to help identify monitor malfunctions and data-entry errors or omissions. For example, negative numbers sporadically occurring throughout a file indicated a monitor malfunction. Similarly, zeroes occurring during times where it was confirmed that the monitor was being worn continuously during activity (e.g., during the 400-m walk) also indicated monitor malfunction. All spurious data were considered to be missing.

In addition to recording monitor “on” and “off” times, participants used the logs to document reasons for not wearing the monitor (e.g., forgetfulness, broken attachment clip, illness). Furthermore, if a participant failed to document monitor on and off times, the associated day was treated as one with missing data.

Days on which the participant did not wear the monitor for at least 10 hr were eliminated from analysis (wearing time did not have to be continuous). A minimum of 5 days of recording was required to estimate per-day averages of the accelerometry variables. Previous work in this area suggests that 3–4 days of monitoring in adults is sufficient to achieve 80% reliability for moderate- or higher intensity physical activity (Matthews, Ainsworth, Thompson, & Bassett, 2002).

**Statistical Analysis**

Data are presented as $M \pm SD$, except where noted. Group differences in selected baseline characteristics were evaluated using $t$ tests. Descriptive statistics were used to summarize the practicality and compliance with the accelerometry protocol. We also employed $t$ tests to determine the capability of the accelerometry-derived variables to distinguish a difference in activity level between the PA and SA arms. Because this was exploratory research, adjustments for multiple comparisons were not made. Spearman’s correlation coefficients were computed to evaluate convergent validity of accelerometry with the CHAMPS physical activity questionnaire.
Results

Participant Characteristics
Baseline characteristics of the 106 study participants are presented in Table 1. The group ranged in age from 70 to 86 years, with 67% being women and 23% representing racial or ethnic minorities. Almost two thirds of the group (62%) had achieved some level of college education. Self-reported health conditions included hypertension (70%), diabetes (26%), cancer (25%), myocardial infarction (9%), congestive heart failure (7%), and stroke (6%). The average SPPB score was 7.4 (0 = unable to complete all three components of the battery; 12 = highest level of performance), with 45% having scores ≤7. A low SPPB score has been shown to be predictive of increased risk of mobility disability in initially nondisabled older adults (Guralnik et al., 2000; Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995). Over half the group (57%) reported difficulty in walking a quarter of a mile without stopping to rest. There were no between-group differences in baseline characteristics.

Practicality of and Compliance With Using the ActiGraph
Factors related to the practicality of the accelerometer and compliance with the protocol were categorized as either monitor-related or participant-related factors. Monitor-related factors included unit malfunction and unit-attachment problems. Of the 106 study participants, 3 experienced monitor malfunction resulting in a loss of 21 days of data. Four participants had problems with monitor attachment (e.g., monitor kept falling off, broken clip), resulting in a loss of 10 days of data. Participant-related factors included incomplete logs and not wearing the monitor. Eighteen participants (17%) submitted incomplete logs equivalent to a loss of 37 days of monitoring. Three participants did not wear the monitor daily per protocol for a variety of reasons (e.g., illness, vacationing), resulting in a loss of 6 days of data. Overall, 742 days of monitoring were possible (106 participants × 7 days), with monitor- and participant-related factors accounting for an overall loss of 74 days, or approximately 10% of possible data. In general, the monitors were well tolerated, with only 1 participant reporting the unit to be “uncomfortable.”

Capability of Accelerometry Variables and an Individualized Activity Count Threshold to Differentiate Activity Levels Between the PA and SA Arms
Of the 106 participants enrolled in the substudy, 3 experienced a monitor malfunction, 1 did not meet the criterion for number of days worn, 4 did not meet minimum requirements for hours worn per day, and 5 did not provide 400-m-walk data sufficient to calculate individualized count thresholds. As a result, 93 participants (88%) were evaluated. Data were collected at the 6-month time point for 80 participants and at the 12-month time point for 13 participants (n = 5 PA arm, n = 8 SA arm).

Accelerometry variables are provided in Table 2. The arms were similar in terms of average hours per day the monitor was worn and average activity counts
per hour, but the SA arm wore the monitor for more days (6.8 days) than the PA arm (6.5 days, \( p = .02 \)). The analytic sample displayed considerable variability in Thresh\textsubscript{IND} despite the fact that the 400-m-walk pace was restricted in terms of permitted perceived intensity level (i.e., light to somewhat hard). Physical exertion scores reported during the 400-m walk were \((M \pm SD) 1.56 \pm 0.65\), with an average 400-m-walk speed of \(0.81 \pm 0.19\) m/s. This was associated with a 400-m-walk time of \(9.1 \pm 2.2\) min, with a range of 5.5–15.0 min. No significant differences between arms in perceived exertion (4-point scale) or walk speed were

### Table 1 Participant Characteristics at Baseline

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Physical Activity ((N = 54))</th>
<th>Successful Aging ((N = 52))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(M \pm SD) or (\mathbf{n}, %)</td>
<td>Range</td>
</tr>
<tr>
<td>Age (years)</td>
<td>(77.6 \pm 4.0)</td>
<td>71–86</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>(85.7 \pm 19.4)</td>
<td>55–148</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>(163.3 \pm 10.6)</td>
<td>142–188</td>
</tr>
<tr>
<td>Body-mass index (kg/m(^2))</td>
<td>(32.0 \pm 5.7)</td>
<td>21–44</td>
</tr>
<tr>
<td>Female</td>
<td>(36 (67%))</td>
<td></td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>(44 (83%))</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>(2 (4%))</td>
<td></td>
</tr>
<tr>
<td>Latino, Hispanic, or Spanish</td>
<td>(7 (13%))</td>
<td></td>
</tr>
<tr>
<td>other</td>
<td>(1 (2%))</td>
<td></td>
</tr>
<tr>
<td>Physical function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPPB score</td>
<td>(7.3 \pm 1.8)</td>
<td>2–9</td>
</tr>
<tr>
<td>SPPB score (\leq 7)</td>
<td>(25 (46%))</td>
<td></td>
</tr>
<tr>
<td>400-m-walk speed (m/s)</td>
<td>(0.77 \pm 0.20)</td>
<td>0.45–1.22</td>
</tr>
<tr>
<td>frequency of all activities per wk(^a)</td>
<td>(11.8 \pm 7.4)</td>
<td>0–30</td>
</tr>
<tr>
<td>frequency of moderate PA per wk(^a)</td>
<td>(2.3 \pm 3.5)</td>
<td>0–15</td>
</tr>
<tr>
<td>calories spent in all activities per wk(^a)</td>
<td>(1,860.7 \pm 1,490.8)</td>
<td>0–5,897</td>
</tr>
<tr>
<td>calories spent in moderate PA per wk(^a)</td>
<td>(561.3 \pm 893.9)</td>
<td>0–4,494</td>
</tr>
<tr>
<td>MET hr per wk (all activities)(^a)</td>
<td>(21.2 \pm 16.3)</td>
<td>0–75</td>
</tr>
<tr>
<td>MET hr per wk (moderate PA)(^a)</td>
<td>(6.1 \pm 9.3)</td>
<td>0–43</td>
</tr>
</tbody>
</table>

*Note. SPPB = Short Physical Performance Battery; PA = physical activity.*

\(^a\)From CHAMPS questionnaire.
### Table 2: Accelerometry and CHAMPS Variables by Group

<table>
<thead>
<tr>
<th>Accelerometry variables</th>
<th>Physical Activity (N = 50)</th>
<th>Successful Aging (N = 43)</th>
<th>p</th>
<th>ES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>Range</td>
<td>M ± SD</td>
<td>Range</td>
</tr>
<tr>
<td>number of days worn</td>
<td>6.5 ± 0.8</td>
<td>5–7</td>
<td>6.8 ± 0.5</td>
<td>5–7</td>
</tr>
<tr>
<td>hours worn per day</td>
<td>14.4 ± 1.3</td>
<td>12.0–17.2</td>
<td>14.5 ± 1.1</td>
<td>12.1–18.0</td>
</tr>
<tr>
<td>activity counts per hour</td>
<td>8,363.4 ± 4250.7</td>
<td>1,236.0–21,735.6</td>
<td>7,474.0 ± 3,601.6</td>
<td>1,539.8–15,460.6</td>
</tr>
<tr>
<td>activity counts per day</td>
<td>119,927.4 ± 6,0501.7</td>
<td>18,268–272,302.3</td>
<td>107,463.8 ± 51,361.3</td>
<td>22,407–224,988</td>
</tr>
<tr>
<td>Thresh(_{IND}) (counts/min)</td>
<td>1,498.3 ± 726.2</td>
<td>149.3–3,132.8</td>
<td>1,407.0 ± 634.9</td>
<td>214.3–2,843.3</td>
</tr>
<tr>
<td>time spent above Thresh(_{IND}) (min/day)</td>
<td>18.5 ± 27.2</td>
<td>0.6–165</td>
<td>11.0 ± 11.4</td>
<td>0.4–55.6</td>
</tr>
<tr>
<td>activity counts above Thresh(_{IND}) (counts/day)</td>
<td>28,100.9 ± 27,520.5</td>
<td>767.2–120,050.1</td>
<td>17,234.2 ± 15,619.5</td>
<td>1,213.3–86,834.7</td>
</tr>
<tr>
<td>number of activity bouts ≥ 10 min above Thresh(_{IND}) (bouts/day)</td>
<td>1.1 ± 2.0</td>
<td>0–12.2</td>
<td>0.5 ± 0.8</td>
<td>0–4.0</td>
</tr>
<tr>
<td>CHAMPS variables(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>calories spent (all activities)</td>
<td>2,788.2 ± 1,880.9</td>
<td>0–8,577.2</td>
<td>2,155.1 ± 1,662.1</td>
<td>0–8,334.5</td>
</tr>
<tr>
<td>calories spent (mod+)</td>
<td>950.1 ± 1,132.9</td>
<td>0–4,374.2</td>
<td>565.4 ± 1,066.7</td>
<td>0–5,192.0</td>
</tr>
<tr>
<td>MET hr/wk (all activities)</td>
<td>31.7 ± 20.9</td>
<td>0–96</td>
<td>23.8 ± 16.9</td>
<td>0–76</td>
</tr>
<tr>
<td>MET hr/wk (mod+)</td>
<td>11.1 ± 13.7</td>
<td>0–53.6</td>
<td>6.0 ± 10.5</td>
<td>0–47.5</td>
</tr>
<tr>
<td>Frequency (all activities)</td>
<td>16.4 ± 8.5</td>
<td>0–38</td>
<td>13.3 ± 7.3</td>
<td>0–41</td>
</tr>
<tr>
<td>Frequency (mod+)</td>
<td>4.1 ± 4.3</td>
<td>0–18</td>
<td>2.3 ± 3.4</td>
<td>0–12</td>
</tr>
</tbody>
</table>

\(^a\)N = 49 PA.

Note. Includes data from 6- (n = 80) and 12-month (n = 13) time points ES = effect size; Thresh\(_{IND}\) = individualized activity count threshold; CHAMPS = Community Healthy Activities Model Program for Seniors questionnaire; mod+ = activities of a moderate intensity level or greater.
found for 6- and 12-month participants; thus, data from the two time points were combined for reporting. At the conclusion of the walk, a subset of participants \( n = 51 \) was queried using the Borg 15-point scale and reported an average rating of perceived exertion of \( 11.8 \pm 2.1 \). Despite a similarity in \( \text{Thresh}_{\text{IND}} \) between arms during the 400-m walk, there was a trend toward more time spent above the \( \text{Thresh}_{\text{IND}} \) in the PA arm \( (18.5 \pm 27.2 \text{ min/day}) \) than in the SA arm \( (11.0 \pm 11.4 \text{ min/day}, p = .08) \). In addition, the PA group significantly exceeded the SA group in terms of mean activity counts above \( \text{Thresh}_{\text{IND}} \) and in number of bouts ≥10 min above \( \text{Thresh}_{\text{IND}} \).

**Relationship Between Accelerometry Variables and the CHAMPS Questionnaire**

Mean activity counts per day were positively correlated with all CHAMPS-derived variables (Table 3). Accelerometry variables using the \( \text{Thresh}_{\text{IND}} \) showed no significant correlation to CHAMPS variables, with the exception of a positive correlation between activity counts above \( \text{Thresh}_{\text{IND}} \) and calories expended in all activities \( (r = .25, p \leq .05) \).

**Discussion**

It is important to note that one of the overarching goals of this exploratory research was to determine whether actigraphy, using the methods described, held promise for assessing physical activity (specifically walking behavior) in older adults. Toward that end, analyses were not intention to treat, and \( p \) values produced by \( t \) tests were not adjusted for multiple comparisons. Thus, our results should be viewed as those of an exploratory, pilot study.

One of the specific aims of this pilot study was to evaluate the practicality of the ActiGraph for use in a naturalistic environment with older adults at risk for mobility disability. To date, most accelerometer studies have been conducted in controlled, supervised or laboratory settings (Brage, Wedderkopp, Franks, Andersen, & Froberg, 2003; Freedson, Melanson, & Sirard, 1998; Melanson & Freedson, 1995; Nichols, Morgan, Chabot, Sallis, & Calfas, 2000); thus, they have not directly addressed the issue of practicality. Our results suggest that the ActiGraph is a viable way to collect objective physical activity data in a free-living environment with older, functionally limited adults; only 10% of the data were not available for use because of monitor- and participant-related factors. In addition, compliance to the protocol was good, with only 5 participants excluded for not meeting requirements for the number of days or hours per day that the monitor was worn. Although “usable data” might constitute only one aspect of the practicality of an instrument, our findings are promising given a protocol that required older adults to wear a monitor for \( 7 \) consecutive days while keeping concurrent logs. A similar level of compliance was reported by Davis and Fox (2006) in an accelerometry study of 203 adults ≥70 years old with protocol and log requirements comparable to those in the current study. They report retaining 80% of participants after accounting for monitor malfunction, participant-related factors, and data-inclusion...
Table 3  Physical Activity Self-Report (CHAMPS Questionnaire) and Accelerometry Variables: Spearman’s Correlations (N = 91)

<table>
<thead>
<tr>
<th>CHAMPS Variable</th>
<th>Accelerometry Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Activity counts/hr</td>
</tr>
<tr>
<td>Calories expended (all activities)</td>
<td>0.42***</td>
</tr>
<tr>
<td>Calories expended (mod+)</td>
<td>0.31**</td>
</tr>
<tr>
<td>Frequency of all activities</td>
<td>0.33**</td>
</tr>
<tr>
<td>Frequency of mod+</td>
<td>0.27**</td>
</tr>
</tbody>
</table>

Note. Thresh\text{IND} = individualized activity count threshold; mod+ = activities of a moderate intensity level or greater.
*p < .05. **p < .01. ***p < .0001.
criteria. This compares favorably with our observation that 87% of participants provided usable data for the current study.

Our findings provide preliminary insight regarding the capability of the ActiGraph worn at the hip to detect a significant difference in physical activity level between participants assigned to a PA group versus a SA health-education intervention. We found that accelerometry variables related to individualized thresholds were more effective than accelerometry variables of overall activity (e.g., activity counts/day) in differentiating activity levels in this group of older adults. The ability to detect group differences using this individualized approach might prove useful in determining the efficacy of interventions aimed at increasing PA in older adults. Furthermore, it might serve as an indication of whether PA recommendations based on relative intensity levels have been met.

The lack of significant group difference in overall measures of activity might have been partially attributable to the relatively large variances associated with these measures. Matthews et al. (2007) found accelerometry to be effective at differentiating groups in response to a 12-week walking intervention in breast cancer survivors \( (n = 23) \) age \( >45 \) years. They reported a significantly greater change in overall activity (activity counts \( \cdot \) min\(^{-1} \cdot \) day\(^{-1} \)) for the PA group \( (72.2 \pm 114.6) \) than in a control group \( (-16.8 \pm 51.5; \ p = .01) \). Intensity-related accelerometry variables (i.e., mean change in time spent in moderate activity) reached marginal significance \( (9.4 \pm 12 \) min PA vs. \( 1.9 \pm 6.7 \) min control; \( p = .07) \).

We conducted an “individualized calibration” of participants to determine an activity-count threshold associated with walking at a usual to brisk pace that was representative of meaningful activity for our analytic sample. The 400-m-walk test was designed to limit intensity to less than or equal to somewhat hard. This relatively narrow range in relative intensity during the 400-m walk produced a wide range of individualized activity-count thresholds \( (149–3,133 \) counts/min). The observed variability in activity-count thresholds might have been at least partially associated with the variability in 400-m walking speed. During post hoc analysis, we found a significant correlation between walk speed and individualized activity-count threshold \( (r = .67, \ p < .0001) \). Furthermore, altered gait patterns often observed in older adults or variability in walking mechanics might have contributed to the variability in individualized activity-count thresholds (Bianchi, Angelini, & Lacquaniti, 1998; Gabell & Nayak, 1984; Herman, Giladi, Gurevich, & Hausdorff, 2005; McGibbon & Krebs, 2001).

Individualized thresholds indicative of meaningful activity proved valuable in identifying group differences in activity level in our sample of older adults, whereas the application of published accelerometer cut points associated with beneficial health outcomes (i.e., moderate-intensity PA) might have lead to misleading conclusions. Figure 1 displays an array of moderate-intensity cut points developed in adults along with the range of values from the current study. This figure highlights the considerable span of values associated with moderate-intensity activity both within and across studies. Furthermore, with the exception of the cut-point range reported by Swartz et al. (2000), the overlap of our meaningful-activity range with the moderate-intensity ranges of other published studies is minimal. Thus, the application of such cut points to data in the current study would have compromised our ability to detect important group differences in meaningful activity. Our results support published findings that the choice of cut-
Figure 1 — ActiGraph activity-count ranges associated with moderate-intensity activity in adults. Note. Numbers in parentheses represent activity-count ranges. aTrack walking. bBased on walking-only equation.
point threshold has a considerable impact on outcomes related to time spent engaging in activity thought to promote health (Ham, Reis, Strath, Dubose, & Ainsworth, 2007; Matthew, 2005; Strath, Bassett, & Swartz, 2003). It may be that such values are most effective when derived in a group performing activities that are most similar to the analytic sample in which they will be applied. Given the lack of consistent intensity cut-point values, an individualized approach to determining intensity-related thresholds appears to be a reasonable method to use for older adults with compromised physical function. Recent work in middle-aged adults shows that an individualized calibration approach with accelerometry strengthens the association with over-ground walking speed and improves the prediction of free-living walking speed using accelerometry (Barnett & Cerin, 2006).

The accelerometer-based overall measure of activity (activity counts per day) was modestly correlated with CHAMPS measures of overall activity (calories expended in all activities, frequency of all activities) and CHAMPS intensity-related measures (calories expended in mod+ activities, frequency of mod+ activities). No significant association was found between intensity-related accelerometry measures and measures of moderate-intensity activity from the CHAMPS questionnaire (calories expended in mod+ activities, frequency of mod+ activities). This suggests that the activities captured using the individualized threshold are somewhat different than those captured as overall counts per day. The lack of association between measures with regard to intensity might be a result of the fact that these instruments do not measure the same activity patterns. The CHAMPS items that compose the mod+ intensity score are much more varied (e.g., housework, gardening, light strength training) than the prime activity (walking) that would have contributed to counts exceeding the accelerometer-based individualized threshold. Given the lack of a definitive criterion with which to evaluate time spent at different intensities (LaMonte, Ainsworth, & Tudor-Locke, 2003), a prudent approach might be to include both self-report and objective measures of PA when attempting to characterize activity patterns.

This investigative, cross-sectional study included 6- and 12-month (n = 13) participants. This might have introduced selection bias or self-report differences with regard to the CHAMPS questionnaire. The influence of these factors on our primary aims is likely low, however, although it cannot be completely discounted. Data-collection time point in this cross-sectional study is not likely to significantly influence compliance and practicality issues, nor should it play a major role in establishing an individualized accelerometry cut point or its use in subsequent analyses. It is possible that the 12-month participants were more accurate in their self-report of PA using the CHAMPS, by having completed the measure twice, whereas the 6-month participants had completed the CHAMPS at least once (at baseline). The relatively long time span between assessments (6 months) might have mitigated the chance of a repeated exposure to the CHAMPS having a strong influence on the CHAMPS versus accelerometry relationship in this group of older adults. Including 12-month participants might have actually reduced the ability to determine between-arm differences using the ActiGraph in that exercise-class participation rates actually declined in the PA group, from 70.7% during the early part of the LIFE-P study to 60.9% during the latter stages of the study (Pahor et al., 2006).
Despite several methodological limitations, the current study provides preliminary evidence that accelerometry is a viable means of measuring PA in older adults at risk for mobility disability. Accelerometry was effective in differentiating PA levels between groups, particularly when applying individualized thresholds to identify activity relevant to beneficial health outcomes. In light of the emerging importance of light- to moderate-intensity PA to overall energy expenditure and health benefits (Abbott et al., 2004; Manini et al., 2006; Pescatello, Murphy, & Costanzo, 2000; Weuve et al., 2004), the identification of such activity is warranted, especially in older adult populations with low physical functioning. The individualized threshold proved useful for this group, whereas the application of published cut points primarily derived in younger populations would likely have resulted in a misrepresentation of activity profiles in the current sample of older adults. Convergent validity with the CHAMPS questionnaire was modest using overall activity accelerometry values and low using accelerometry variables related to intensity. This suggests that the intensity-related variables of the two measures might be capturing different activity profiles and highlights the importance of further work in this area. Accelerometry can provide valuable objective data with regard to duration and intensity of activity. The development and validation of creative strategies (and further validation of this approach) with regard to intensity-related cut points is central to optimizing the use of accelerometry among older, somewhat frail adults.

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**Appendix: Research Investigators for the Pilot Phase of LIFE**

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Dr. Fielding’s contribution is partially supported by the U.S. Department of Agriculture, under agreement No. 58–1950–4-401. Any opinions, findings, conclusion, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Dept of Agriculture.

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Data Management, Analysis and Quality Control Center (DMAQC): Michael E. Miller, PhD—DMAQC Field Principal Investigator; Mark Espeland, PhD—DMAQC Co-Principal Investigator; Fang-Chi Hsu, PhD; Walter J. Rejeski, PhD; Don P. Babcock, Jr., PE; Lorraine Costanza; Lea N. Harvin; Lisa Kaltenbach, MS; Wei Lang, PhD; Wesley A. Roberson, MS; Julie Rushing, MS; Scott Rushing; and Michael P. Walkup, MS

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