Accelerometer Assessment of Physical Activity in Active, Healthy Older Adults

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Despite widespread use of accelerometers to objectively monitor physical activity among adults and youth, little attention has been given to older populations. The purpose of this study was to define an accelerometer-count cut point for a group of older adults and to then assess the group's physical activity for 7 days. Participants (*N* = 38, age 69.7 ± 3.5 yr) completed a laboratory-based calibration with an Actigraph 7164 accelerometer. The cut point defining moderate to vigorous physical activity (MVPA) was 1,041 counts/min. On average, participants obtained 68 min of MVPA per day, although more than 65% of this occurred as sporadic activity. Longer bouts of activity occurred in the morning (6 a.m. to 12 p.m.) more frequently than other times of the day. Almost 14 hr/day were spent in light-intensity activity. This study demonstrates the rich information that accelerometers provide about older adult activity patterns—information that might further our understanding of the relationship between physical activity and healthy aging.

Keywords: aging, Actigraph, sedentary time

The beneficial effects of physical activity on the health and quality of life of older adults are well established, yet 62% of Canadians 65 years or older are inactive (National Advisory Council on Aging, 2006), compared with 40% of individuals 20–24 years old (Canadian Fitness and Lifestyle Research Institute [CFLRI], 2006). Unlike other age groups in which there appear to have been improvements in activity levels over the past few years, the proportion of inactive senior men actually increased from 53% in 2001 to 55% in 2005. The rate of inactivity in senior women was stable but still exceptionally high at 67% in 2005 (National Advisory Council on Aging). These disturbing trends have resulted in the development of physical activity interventions and promotion tools targeted at older populations. One example is *Canada's Physical Activity Guide for Older Adults,* which recommends that adults over 55 years of age achieve 30–60 min of moderate activity on most days of the week (Health Canada, Active Living Coalition for Older Adults, & Canadian Society for Exercise Physiology, 1999).

Appropriate measurement tools are necessary to properly study physical activity in older adults and to evaluate the success of interventions. There are

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issues with the use of questionnaires in an older population, including vision and hearing impairments or disturbances to cognition and short- or long-term memory (Shephard, 2003). There might also be problems with accurately reporting the intensity of exercise, because perceptions of what is "hard" activity or "light" activity depend on the tolerance and fitness level of the individual, both of which are affected by age (Shephard).

Accelerometers are an effective way to obtain objective and detailed information about physical activity behavior (Esliger, Copeland, Barnes, & Tremblay, 2005), and they might overcome many of the problems with self-report in older adults. Because accelerometers are generally more sensitive than self-report measures, they might be ideal for use with populations who typically engage in very light or very brief activity, such as the elderly (Shephard, 2003). Despite the widespread use of these devices among adults and youth, however, there has been very little work using accelerometers to measure physical activity in older populations.

There are recognized limitations to the use of accelerometers, such as their inability to detect nonambulatory activity such as resistance training or cycling (Montoye, Kemper, Saris, & Washburn, 1996). There might also be other problems that pertain specifically to the use of accelerometers with older populations. For example, the quality of accelerometer data is affected significantly by the degree of participant compliance, such as remembering to wear the device, which could pose a problem to older adults facing memory loss or lacking the visual and manual dexterity to properly attach the device in the recommended position (Wilcox, Tudor-Locke, & Ainsworth, 2001). Finally, although there are many studies that have assessed the relationship between the raw accelerometer output and criterion levels of activity or energy expenditure, none of these "calibration" studies have been performed specifically with older adults (Welk, 2005). This is becoming an increasingly important issue, because several large population-based studies such as the National Health and Nutrition Examination Survey (NHANES; Troiano, 2005) and the Canadian Health Measures Survey (Tremblay & Connor-Gorber, 2007) are currently collecting objective measures of physical activity using accelerometers. The current study begins to address this issue.

The purpose of this study was to assess the relationship between accelerometer counts and walking in a group of older adults and establish a threshold count value that could be defined as moderate physical activity. The second objective was to employ this cut point to assess free-living physical activity for 1 week.

Methods

Participants

Volunteer participants for this study included 38 people (18 men, 20 women) ranging in age from 64 to 77 years, with a mean age of 69.7 ± 3.5 years. Their mean body-mass index was 26.6 ± 3.7 kg/m^2. Participants were recruited from newspaper advertisements, flyers, and word of mouth. The inclusion criterion was the ability to walk briskly on a treadmill without assistance. All participants were healthy and not taking any medications that would influence energy expenditure or their ability to perform walking exercise. When necessary, clearance for unre-

stricted physical activity was obtained from a physician. All participants provided written, informed consent.

Procedures

A preliminary laboratory-based assessment was conducted to establish the relationship between activity intensity and accelerometer counts in the sample population. Walking was chosen as the activity for the calibration because accelerometers are ideally suited for measuring locomotor activity (Welk, 2005) and walking is the most popular physical activity among older Canadians (CFLRI, 2006).

Participants first attended a familiarization session in which they were introduced to the laboratory procedures and practiced walking on the treadmill. They were then asked to walk until they felt comfortable doing so without continuously using the handrails. On the day of the experimental session participants were asked to refrain from caffeine or exercise before their scheduled session. Similar to the procedures of Freedson, Melanson, and Sirard (1998), the experimental session consisted of three 6-min conditions of walking on a motorized treadmill. The three speeds were 2.4, 3.2, and 4.8 km/hr. Initially we chose higher speeds, but during pilot testing not all of the participants could walk at speeds greater than 4.8 km/hr. Five minutes of rest were given between 6-min conditions, and the three conditions were performed in random order.

Oxygen consumption was determined using the Vista Mini CPX open-circuit spirometry system (VacuMed, Ventura, CA). It was calculated every 30 s using TurboFit version 5.4 software (VacuMed). Resting oxygen-consumption data were collected for at least 2 min before the start of exercise with participants in a seated position. Steady-state oxygen consumption was calculated by averaging the final 3 min of each treadmill walking condition.

During the laboratory assessment, each participant wore two Actigraph model 7164 accelerometers positioned side by side over the right hip using an adjustable nylon belt. The Actigraph is a uniaxial accelerometer that measures accelerations in the vertical plane ranging from 0.05 to 2.0 G with frequencies of 0.25–2.5 Hz (Tryon & Williams, 1996). Actigraph counts can be summed over user-defined epochs, which for the current study were set at 1 min. The average counts per minute were calculated for each 6-min walking condition. Twenty accelerometers were used for this study. All 20 devices were calibrated before use, using a mechanical shaker as outlined in Esliger and Tremblay (2007).

After the laboratory assessment, 34 of the 38 participants agreed to wear an accelerometer for 7 consecutive days. Participants were asked to record the times the monitor was attached and removed each day (i.e., on at waking and off at bedtime) for the purpose of distinguishing between device wear time and nonwear time. In order for the data to be included in the analyses, participants were required to wear the accelerometer for at least 10 hr/day for at least 5 of the 7 days. In total, data from 33 participants (15 men, 18 women) were included in the analysis (i.e., 31 files with 7 valid days, 2 files with 6 valid days, and 1 corrupt file).

After the 7 days of monitoring participants completed the self-report Physical Activity Recall (SR-PAR). The SR-PAR is a modified version of the interviewer-administered Physical Activity Recall. The SR-PAR is used to estimate recent physical activity participation in occupational, leisure, and home activities over

the previous 7-day period (Miller, Freedson, & Kline, 1994). With adults, the SR-PAR has been significantly related to Caltrac accelerometer scores ($r = .79$) and other self-report tools ($r = .37$; Miller et al.).

Data Analysis

For the laboratory assessment, the average counts per minute were calculated for each 6-min treadmill walking condition, and steady-state oxygen consumption was calculated by averaging the final 3 min of each condition. The mean accelerometer count and oxygen uptake for each walking speed were established. An intraclass correlation coefficient (ICC) was calculated for the counts from the two accelerometers worn by each participant.

After the 7-day monitoring period, data were downloaded using the manufacturer's software, producing a file containing minute-by-minute movement counts for each participant. The activity data were cleaned according to comprehensive procedures reported elsewhere (Esliger et al., 2005). The raw accelerometer counts were categorized as moderate to vigorous physical activity (MVPA) based on the results from the laboratory assessment (MVPA 1). For comparison purposes, the data were also analyzed using the count cutoffs for younger adults (MVPA 2) established by Freedson et al. (1998). Two indices of inactivity were generated: light activity time (all counts per minute less than the MVPA cut point) and sedentary time (a subdivision of light activity time equal to all counts per minute ≤50).

Total minutes of MVPA were further examined to determine how and when active minutes were accumulated. Minutes of MVPA were broken down by days of the week and by time of day, with morning defined as 6:00–11:59 a.m., afternoon defined as 12:00–5:59 p.m., and evening defined as 6:00–11:59 p.m. Long bouts of activity were defined as 20 or more consecutive minutes, short bouts were 10–19 min, and all remaining minutes of MVPA were labeled sporadic.

The SR-PAR scores were compared with the average minutes of MVPA per day using Pearson's product–moment correlations. All analyses were performed using SPSS version 15.0, and statistical significance was set at $p < .05$.

Results

Laboratory Assessment

The results of the laboratory assessment are shown in Table 1. The ICC between the activity counts from the two accelerometers worn by the participants was .956 ($p < .001$). For all subsequent analyses an average of the count values from the two devices was used. There was no significant difference between men and women for either activity counts or oxygen consumption, so the pooled data were used to establish an activity-count cut point for MVPA. There was a strong relationship between walking speed and accelerometer counts ($r = .878$), with a standard error of 0.48 km/hr. Figure 1 shows that accelerometer counts were also significantly related to oxygen consumption ($r = .60$, standard error of the estimate = 2.48 ml · kg^{-1} · min^{-1}).

Table 1   Activity Counts From Two Accelerometers and VO$_2$ at Three Walking Speeds, *M (SD)*

Speed, km/hr	Activity counts 1, counts/min	Activity counts 2, counts/min	Mean counts, counts/min	VO$_2$, ml · kg^{-1} · min^{-1}
2.4	517 (242)	514 (217)	515 (218)	11.4 (1.8)
3.2	1,050 (446)	1,032 (363)	1,041 (62)	13.0 (2.1)
4.8	2,481 (740)	2,527 (639)	2,504 (108)	16.6 (2.5)
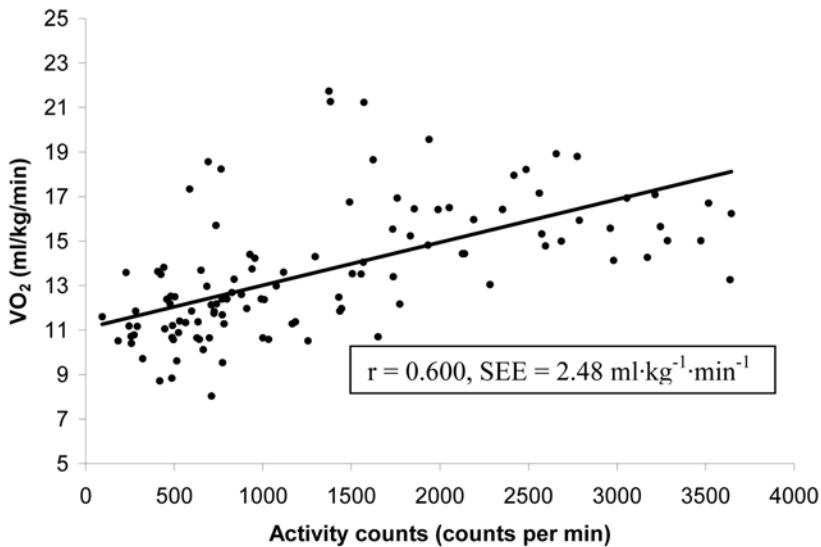
Figure 1 — The relationship between activity counts and oxygen consumption ($N = 38$). *SEE* = standard error of the estimate.

Profile of Physical Activity

We used the 7 days of direct monitoring to profile the activity patterns of the participants. On average, participants wore the accelerometer for 15.0 ± 1.3 hr/day.

We used the data from the laboratory assessment to create a count "cut point" for defining physical activity. Unlike many previous studies using accelerometers, we did not develop a series of cut points to define various intensity categories; one cut point was identified based on the counts associated with a reference activity, which was walking at 3.2 km/hr. The cut point was set at counts per minute ≥1,041 (MVPA 1), which corresponded to a mean VO$_2$ of 13 ml · kg^{-1} · min^{-1}. For comparison we also used Freedson et al.'s (1998) young-adult criteria for MVPA of counts per minute ≥1,964 (MVPA 2). Table 2 shows the average counts per minute for the 7-day period and the minutes of MVPA per day using the two different count cutoffs for defining physical activity. There was a significant difference in minutes of MVPA per day using the two different cut points

Table 2 Objective and Self-Reported Physical Activity Data for 1 Week, *M* (*SD*)

	MVPA 1, min/day	MVPA 2, min/day	Mean counts/min	SR-PAR score
Men	74.6 (39.2)	33.3 (28)	313 (153)	39.6 (8.0)
Women	62.9 (25.5)	25.3 (13.7)	294 (88)	39.0 (4.8)
Mean	68.2 (32.5)	29.0 (21.5)	302 (120)	39.3 (6.3)

Note. MVPA = moderate to vigorous physical activity, MVPA 1 = cut point developed in preliminary assessment, counts/min >1,041; MVPA 2 = previously published cut points for younger adults, counts/min >1,952; SR-PAR = Self-Report Physical Activity Recall.
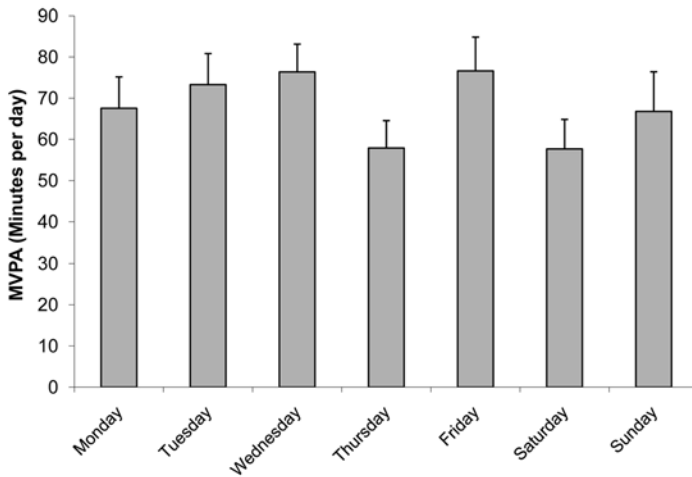

Figure 2 — Average minutes of moderate to vigorous physical activity (MVPA) per day across days of the week ($M \pm SE$, $N = 33$).

(MVPA 1 and MVPA 2; $p = .000$). All subsequent outcome variables were determined using the MVPA 1 criteria.

The detailed nature of time-stamped accelerometer data enables a closer examination of physical activity patterns, including when and how activity is accumulated. Figure 2 shows the minutes of physical activity per day across the days of the week, and Figure 3 shows when during the day activity occurred. On average, significantly less activity was accumulated in the evening hours than in the morning or afternoon ($p < .001$). Most physical activity (66%) was accumulated as sporadic activity (bouts less than 10 min in length), as shown in Figure 4. The remaining 34% of MVPA was consistent with physical activity recommendations to accumulate activity in bouts of 10 or more minutes. Men accumulated 4.3 ± 4.0 long bouts of activity during the 7 days, and women accumulated 3.0 ± 2.4 long bouts. Figure 4(B) demonstrates that most MVPA accumulated in long bouts of activity occurred during the morning hours (6:00–11:59 a.m.).
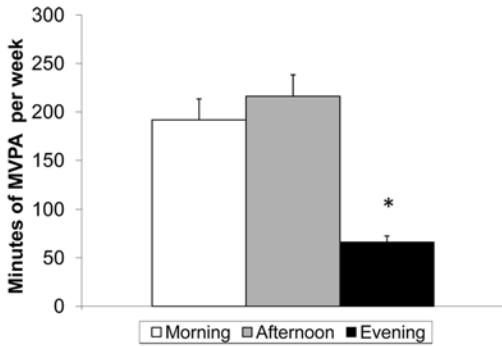
Figure 3 — Weekly minutes of moderate to vigorous physical activity (MVPA) by time of day ($M \pm SE$, $N = 33$). *Evening minutes of MVPA significantly less than morning or afternoon, $p < .001$.

Accelerometers can also provide information about physical inactivity. Table 3 shows the time spent in light activity (counts/minute <1,041). We then further subdivided light activity into sedentary time (counts/minute ≤50). Fifty counts per minute has been used previously as the threshold to classify sedentary time (Esliger et al., 2005), but it should be noted that there is no consensus in the literature at this time on the appropriate cut point for sedentary activity.

A total of 31 participants completed the self-report 7-day SR-PAR at the end of the monitoring period. The mean scores on the SR-PAR are shown in Table 2. Scores on the SR-PAR were significantly related to minutes per day of MVPA 1 with a Pearson's correlation coefficient of .484 ($p = .006$) and also to minutes of MVPA 2 per day with a Pearson's correlation coefficient of .363 ($p = .045$). SR-PAR scores were significantly correlated to the average accelerometer counts per minute (Pearson's correlation = .489, $p = .005$).

Discussion

To date there has been little work using accelerometry to examine activity profiles in older Canadians. This study provides accelerometer data from a group of active, healthy individuals between 64 and 77 years of age that can be used for comparison in future studies. These results demonstrate the valuable information that can be obtained from objective monitoring of physical activity in older adults.

Accelerometers are ideally suited for measuring ambulatory activity, although Welk (2005) points out that there are many challenges to converting counts to meaningful outcome data. Typically, regression equations are used to define different intensity classifications including light (<3 METs), moderate (3–6 METs), and hard activity (6 METs; Freedson et al., 1998; Troiano, 2006). The narrow range of walking speeds that was possible with our participants, however, posed a problem in developing a regression equation. With no vigorous activity included in the calibration protocol the resulting regression equation would have a large intercept term, in this case greater than 10 ml · kg^{-1} · min^{-1}. An equation with an
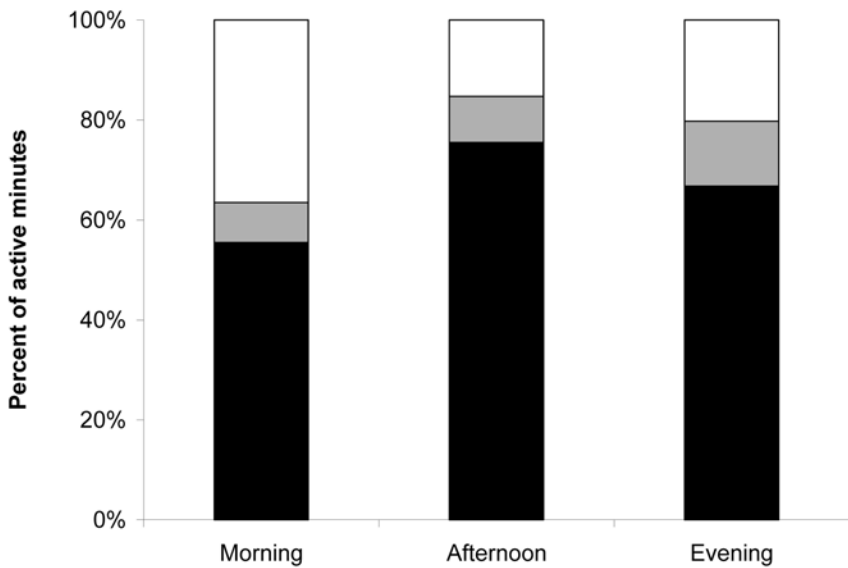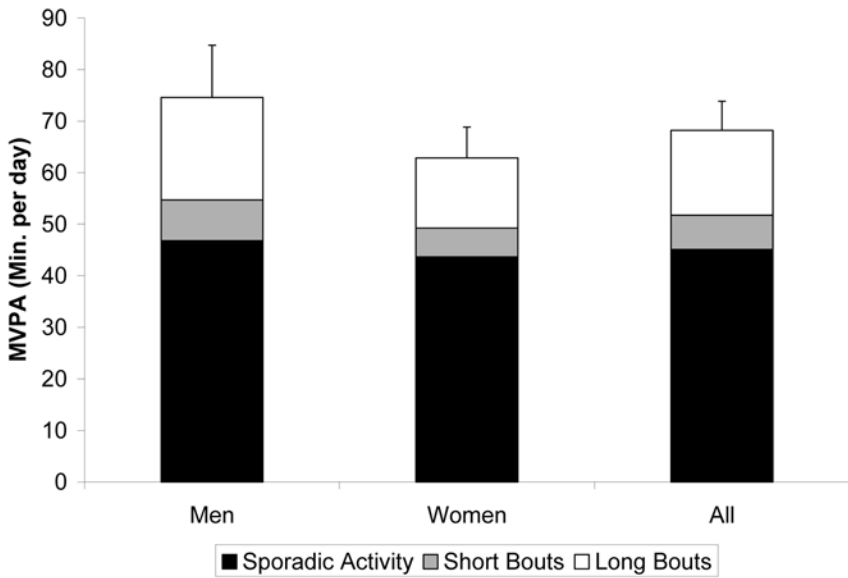
Figure 4 — (A) Minutes of moderate to vigorous physical activity (MVPA) per day that occurred in long bouts (>20 min), short bouts (10–19 min), and as sporadic activity (<10 min). (B) Percent of active minutes during the morning, afternoon, and evening that occurred in long bouts, short bouts, and as sporadic activity ($N = 33$).

Table 3   Light Activity and Sedentary Time by Gender, *M (SD)*

	Men, *n* = 15	Women, *n* = 18
Light activity, hr/day	13.8 (1.4)	13.9 (1.0)
Sedentary time, hr/day	8.9 (1.5)	7.4 (1.2)

Note. Light activity = all activity <MVPA cut point of 1,041 counts/min; sedentary time (a subset of light activity) = all activity <50 counts/min.

elevated intercept term would generally overestimate the time spent in moderate activity (Matthew, 2005). Unfortunately, including vigorous activity in calibration protocols is a significant challenge when working with older adults; although some older individuals can and do participate in high-intensity activities, they are not likely to be a representative sample of the population. For these reasons, we chose to use a simplified approach to define physical activity from accelerometer counts by using a reference activity to establish a single threshold count value, above which all time is labeled as active. This is consistent with the methods of Andersen et al. (2006), who used a single count threshold (2,000 counts/min) for participants in the European Youth Heart Study. A similar strategy was also proposed by Schutz, Weinsier, and Hunter (2001), whereby accelerometer-based activity time would be calculated based on a participant's steady-state accelerometer counts during a reference activity task such as walking or running at a given speed. We chose walking as our reference activity because it is reported as the most popular physical activity among Canadians 65 years of age or older (CFLRI, 2006). Sixty-five percent of older adults report participating in walking during their leisure time, compared with only 34% who report participating in organized sport, 7% who participate in bicycling, and fewer than 10% who participate in swimming or weight training (CFLRI).

The accelerometer counts per minute associated with walking at 3.2 km/hr was used as the cut point for defining moderate-intensity activity. Although this walking speed is less than the 4.0 km/hr that is defined as moderately intense physical activity in the compendium of physical activities, Ainsworth et al. (2000) point out that individual differences in fitness and age can alter the energy cost of activity. Although we can only estimate the relative intensity of this walking speed, we believe that this reference activity is a reasonable marker of moderate-intensity activity for this age group. For these older adults, walking at 3.2 km/hr resulted in a mean VO_2 of 13 ml · kg^{-1} · min^{-1}, equivalent to 3.7 METs, assuming that a standard oxygen consumption of 3.5 ml · kg^{-1} · min^{-1} equals 1 MET. This is consistent with the 4-MET intensity of activity that is associated with reduced risk of morbidity and mortality in older adults (Paterson, Jones, & Rice, 2007). It should be noted that there are limitations to assuming a fixed value of 3.5 ml · kg^{-1} · min^{-1} for 1 MET. For example, Kwan, Woo, and Kwok (2004) found that in men and women over the age of 65, 1 MET was actually 2.8 ml · kg^{-1} · min^{-1}. If we were to use this value, walking at 3.2 km/hr would equate to 4.6 METs for the older adults in the current study. In this case the 1,041-count cut point we used would be a conservative delineation of MVPA for these older adults (i.e., there is little chance that a minute of light activity will be inappropriately labeled as MVPA).

Oxygen consumption and Actigraph counts were only moderately related in this sample of older adults (r = .600). In young adults the relationship between counts per minute and VO_2 has been shown to be stronger, with r values greater than .8 (Freedson et al., 1998; Nichols, Morgan, Chabot, Sallis, & Calfas, 2000), but the errors of estimates are smaller. Our results are similar to those of Swartz et al. (2000), who used participants across a wide age range (19–74 years) to assess the relationship between energy expenditure and Actigraph counts and reported an r value of .563. Caution is needed when using accelerometer counts to predict energy expenditure in older adults because the relationship between VO_2 and accelerometer counts tends to be weaker in older adults than in younger adults with several different devices and device placements (Brandon, Ross, Sanford, & Lloyd, 2004; Fehling, Smith, Warner, & Dalsky, 1999; Nichols, Patterson, & Early, 1992). To avoid this problem we did not attempt to define count cut points for varying levels of exercise intensity; we simply chose a threshold count value that was associated with a reference activity (walking at 3.2 km/hr) for our participants. This approach is reinforced by the fact that the relationship we observed between walking speed and counts was strong (r = .878).

The number of counts associated with walking at 3.2 km/hr was 1,041 counts/min, which was similar to the results of Nichols et al. (2000), who reported a mean of 920 counts/min for young adults walking at 3.2 km/hr. This is substantially lower, however, than the cut point of 1,952 counts/min that is typically used for moderate activity in younger adults (Freedson et al., 1998). It is known that age influences the relationship between accelerometer counts and activity, and, as a result, different cut points are used for children than for adults. This variability highlights the need to develop cut points that are specific to the population being assessed, which was the approach taken in the current study. To our knowledge this is the first study that has attempted to define an Actigraph cut point for MVPA in older adults.

Profile of Physical Activity

We found that over 7 days of monitoring the mean number of counts per minute was 302. There is a large variation in mean counts-per-minute values reported in the literature that might be partially explained by differences in data-reduction procedures and, in particular, different methods of dealing with sleep time, which can dilute counts-per-minute values (Esliger et al., 2005). Previous studies using the same data-reduction procedures as the current study found an average of 394 counts/min in adults (mean age 38 years; Copeland, Kowalski, Donen, & Tremblay, 2005) and 561 counts/min in contemporary children (mean age 11 years; Tremblay, Barnes, Copeland, & Esliger, 2005). Dinger, Oman, Taylor, Vesely, and Able (2004) reported an average of 168 counts/min for 56 older adults (mean age 75 years); however, they did not specify their data-reduction procedures or how they controlled sleep time or accelerometer "off time." Washburn and Ficker (1999) reported an average of 206 counts/min for 20 older adults (mean age 72 years). The 2003–2004 NHANES results showed that 769 White adults 60 years and older achieved an average of 215 counts/min (Troiano et al., 2008).

Using our cut point to classify counts, the participants obtained on average 68 min of MVPA per day, and this number was significantly related to the self-report measure of activity over the same 7 days (SR-PAR). Using Freedson et al.'s (1998) cut point (MVPA 2), the average number of minutes of MVPA per day was 29 and the relationship to self-reported activity was not as strong ($p = .363$ vs. $p = .484$ for MVPA 1). We found that the SR-PAR scores and average accelerometer counts per minute were moderately related, with a correlation of .489. This is consistent with the results of Washburn and Ficker (1999), who reported a correlation of .49 between Actigraph counts and scores on the Physical Activity Scale for the Elderly in 20 older adults. In general, both the mean counts per minute and the minutes of MVPA suggest that this group of older adults was active. This is supported by the mean SR-PAR score of 39.3, which is comparable to the SR-PAR score of 42.3 we obtained from 247 undergraduate kinesiology students (Copeland et al., 2005).

If one were to include all minutes of MVPA in the analysis, the vast majority of participants (30 out of 33) would easily meet Canada's Physical Activity Guide recommendations for older adults to obtain at least 30 min of moderate-intensity activity on most days of the week (Health Canada, Active Living Coalition for Older Adults, & Canadian Society for Exercise Physiology, 1999). It is important to note, however, that these guidelines recommend that physical activity be accumulated in bouts of at least 10 min, and most (66%) MVPA occurred as "sporadic activity" in bouts of less than 10 min. If we only include minutes of MVPA that were accumulated in bouts of at least 10 min, as per the guidelines, only 8 of the 33 participants met the physical activity recommendations. This suggests that not many older adults are complying with the recommendation of accumulating activity in 10-min bouts, which might indicate a need for better education on the guidelines. The possible health benefits associated with sporadic activity of less than 10 min in duration are unknown (Hardman, 2001) but should be explored, because this type of activity might contribute substantially to total daily energy expenditure.

The activity profile obtained from direct monitoring can provide valuable information for developing targeted activity interventions. In this group of older adults, significantly more minutes of activity occurred in the morning and afternoon hours than in the evening hours. Furthermore, more longer bouts of activity were observed in the morning than in the afternoon. This might suggest that older adults in this community are more likely to participate in purposeful, continuous activities in the morning hours, which would be useful to know when scheduling activity programs to appeal to as many people as possible. Most participants were retired, so it was not surprising that there were no significant differences in activity levels across the days of the week or on weekdays versus weekends.

The overall "light" activity (which includes sedentary time) was approximately 14 hr/day, which means more than 90% of the time monitored was spent in low-intensity activities. Meijer, Goris, Wouters, and Westerterp (2001) examined a group of European older adults and found that they spent 82% of their time engaging in low-intensity activity (<3 METs). They found that more time spent in low-intensity activities was significantly related to a lower overall daily physical activity level because older adults appear to compensate for an exercise-training program by reducing nontraining physical activity. It also appears that the percentage of time spent in low-intensity activities increases with age (Meijer et al.).

This suggests that interventions targeted at older adults might need to emphasize engaging in activities of at least moderate intensity and on reducing inactive time. Furthermore, our results show that there might also need to be greater emphasis on accumulating activity in bouts of at least 10 min in length.

There are limitations to this study. This was a small sample of older adults, so the accelerometer-count cut point or physical activity profile might not be generalizable to all older adults. Activity levels might have been underestimated because accelerometers cannot detect resistance exercise, cycling, or upper body work. In addition, 2 of the participants reported swimming during the 7-day period, and this activity was not captured. Despite these limitations, this study demonstrates the potential of using accelerometers to provide a detailed physical activity profile of active older adults. The compliance rates were very high for participants in this study; more than 90% of participants wore the accelerometer for the entire 7 days and kept an accurate log sheet. Accelerometers can provide valuable information about the activity patterns of older adults. This information is useful in guiding program development and assessing the impact of physical activity interventions and will allow us to further our understanding of the relationship between physical activity and healthy aging.

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