Criterion Validity of the *activ*PAL Activity Monitor for Sedentary and Physical Activity Patterns in People Who Have Rheumatoid Arthritis

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Background. Accurate measurement of physical activity and sedentary behavior is an important consideration for health care professionals. The *activ*PAL activity monitor has not been validated against a criterion measure for people with rheumatoid arthritis (RA).

Objective. The objective of this study was to determine the criterion validity of the *activ*PAL activity monitor for measuring step counts, transition counts, and time spent in sedentary, standing, and walking behaviors in people with RA.

Design. A laboratory-based criterion validation study was conducted.

Methods. Participants with a confirmed medical diagnosis of RA were recruited from 2 outpatient rheumatology clinics. The testing procedure consisted of standardized testing components and tasks related to activities of daily living. Participants wore an *activ*PAL activity monitor and were video recorded throughout the testing procedure. Direct observation was used as the criterion measure. Data analysis consisted of validation analysis of the *activ*PAL activity monitor data and the criterion measure data.

Results. Twenty-four people participated in the study. Data from 20 participants were included in the final analysis. The *activ*PAL significantly underestimated step counts by 26% and transition counts by 36%. There was no significant difference between the *activ*PAL activity monitor and the criterion measure for time spent in sedentary, standing or light activity, and walking behaviors.

Limitations. Validation of activities of daily living in a laboratory environment is a limitation of this study.

Conclusions. The *activ*PAL activity monitor underestimated step and transition counts and, therefore, is not valid for measuring these outcomes in people with RA. Relative to direct observation, the *activ*PAL activity monitor is valid for measuring time spent in sedentary, standing, and walking behaviors in people with RA.

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Physical activity is recognized globally as a key factor in health, with guidelines recommending the amount and intensity of activity required for adults who are healthy.[1] At present, most people with rheumatoid arthritis (RA) do not meet these recommendations for achieving improved health outcomes.[2–4] Sedentary behavior is also a key factor in health and is an independent risk factor for cardiovascular disease and mortality.[5] Given that people with RA have a higher risk of cardiovascular disease than the general adult population,[6] investigating both sedentary and physical activity behavior patterns is important for establishing how these behavior patterns may contribute to the overall health of this population.

Measurement of physical activity and sedentary behavior patterns is complex. Subjective methods of measurement have been reported to be less accurate than objective methods.[7] Objective, wearable activity monitors are now widely used in research studies; they use physiological or mechanical responses to bodily movement as signals to estimate variables that reflect physical activity.[8] Accelerometers are devices that measure acceleration along an axis; they can be used to estimate the rate and intensity of body movement. Accelerometers can help in recording sedentary and physical activity behavior patterns and motivating people to achieve the recommended amounts of physical activity.

One such accelerometer, the *activ*PAL (PAL Technologies Ltd, Glasgow, United Kingdom) activity monitor, classifies an individual's free-living activity into periods spent in sedentary, standing, and walking behaviors through the use of proprietary algorithms. The *activ*PAL activity monitor has been found to be a reliable and valid measure of sedentary and physical activity behaviors and transition and step counts in other populations, including adults who are healthy and adults who are overweight and inactive.[9–11] The *activ*PAL also has been shown to be valid in another population with chronic musculoskeletal pain: people with chronic low back pain.[12] However, the *activ*PAL may not be sensitive enough to detect changes in gait in people with RA because of the functional problems often experienced by this population as a result of symptoms such as pain and fatigue.[13]

To date, the *activ*PAL activity monitor has not been validated in people with RA; therefore, its accuracy in this population has not yet been determined. Criterion validity may be examined with linear regression and correlation analyses and intermethod reliability. The *activ*PAL activity monitor was selected for a validation analysis because it records changes in sedentary and physical activity behaviors. These changes are important for improved health outcomes in people with RA. Given the variability in the reported levels of physical activity in people with RA,[2–4] objective measures used to assess both sedentary and physical activity behaviors must be reliable and valid. Thus far, only one objective measure of physical activity, the SenseWear Pro3 Armband (BodyMedia Inc, Pittsburgh, Pennsylvania),[14] has been validated in people with RA. The SenseWear Pro3 Armband[14] measures step counts and energy expenditure in activities of daily living (ADLs) for periods of up to 7 days. It is possible that the *activ*PAL activity monitor can be used as an objective measure of sedentary behavior and physical activity in people with RA because it measures both step counts and time spent in different ADL behaviors and can record for periods of up to 7 days.

The aim of this study was to determine the criterion validity of the *activ*PAL activity monitor for measuring step counts, transition counts, and time spent in sedentary, standing, and walking behaviors in people with RA.

Method

We used the *Guidelines for Reporting Reliability and Agreement Studies*[15] to guide reporting in this study.

Participants

Participants were people who had a confirmed medical diagnosis of RA—in accordance with the 1987 American College of Rheumatology (ACR) criteria[16] or the ACR/European League Against Rheumatism (EULAR) 2010 criteria[17]—who were 18 to 80 years of age, who could walk without an assistive aid, and who were recruited from 2 outpatient rheumatology clinics (1 urban and 1 rural) in the midwestern region of Ireland. People attending the clinic for routine appointments were identified from medical records and were provided with verbal and written information about the study by members of the research team (L.L. and B.N.). Those who expressed interest in the study were given an appointment for testing.

Procedure

We performed testing during a single 45-minute session in a laboratory at the University of Limerick, Limerick, Ireland, from December 2013 to June 2014. We informed participants about the testing procedure, and they signed an informed consent form. They completed a questionnaire detailing their age, sex, and disease duration (time since first symptoms). Because pain and fatigue can influence people's movement patterns, participants rated their pain and fatigue over the preceding week on a 100-mm visual analog scale[18,19] from 0 ("no pain or fatigue") to 100 ("most possible pain or fatigue"). We used measurements of height (centimeters) and weight (kilograms) to calculate the body mass index of participants because people with a higher body mass index can have altered movement patterns.[20,21]

We screened potential participants for suitability to participate in this study by using the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+).[22] This questionnaire is a 4-page form used to determine the suitability of a person to engage in physical activity. It consists of 2 sections, addressing general health and chronic medical conditions; the latter section includes additional questions on chronic conditions such as arthritis, cardiovascular disease, respiratory disease, and the management of these conditions.[22] We assessed general physical activity levels by using the General Practice Physical Activity Questionnaire.[23] This questionnaire is a validated screening tool used to assess adult physical activity levels.[23] It provides a simple, 4-level Physical Activity Index of active, moderately active, moderately inactive,

and inactive. We anticipated that chronic medical conditions, how active a participant was, or both might influence movement patterns during the testing procedure.

We placed the *activ*PAL activity monitor on the anterior, middle right thigh as advised by the manufacturer and secured it to the thigh with adhesive tape. We programmed the *activ*PAL activity monitor to start recording immediately before placement on the participant. We noted the time of *activ*PAL activation and the start and finish times of testing. Participants wore the *activ*PAL activity monitor and were video recorded for the duration of the testing procedure (up to 60 minutes).

The testing procedure consisted of standardized testing components and tasks related to ADLs. The standardized testing components were 4 activities: walking on a treadmill at a self-selected speed, sitting, standing, and lying down. The duration of the activity performance was randomly selected (2, 3, 4, or 5 minutes). The ADLs were 10 different activities and were set up in the laboratory setting to replicate ADLs in a free-living environment. The ADLs were watching a DVD, reading a newspaper, writing on paper, washing and drying dishes, folding clothes, placing bed linens on pillows and duvet, sweeping the floor, changing the trash bin liner, ironing clothes, and cleaning a mirror. Participants completed 7 ADLs, performed in random order. Three activities (watching a DVD, reading a newspaper, and writing on paper) had a defined finish point, and the duration of these activities was randomly selected (2, 3, 4, or 5 minutes). The finish points of the remaining activities were determined by completion of the task. Participants were permitted to use their upper limbs in transitions and were not advised on posture or movement patterns, so as to ensure that participants' activity patterns were reflective of a free-living environment.

***activ*PAL activity monitor.** The *activ*PAL is a small, lightweight activity monitor that classifies an individual's free-living activity into periods spent in sedentary, standing, and walking positions through the use of proprietary algorithms. The *activ*PAL is a uniaxial accelerometer that produces a signal related to thigh inclination and needs no calibration before use. The *activ*PAL interfaces with a Windows (Microsoft Corp, Redmond, Washington)-compatible PC, and the software package (*activ*PAL Professional Research Edition) analyzes the activity record through the use of proprietary algorithms. The software summarizes the activity over hour-long periods in graphic and numeric formats. The data can be saved and exported to Microsoft Excel; the epoch file allows for a more detailed analysis. The graphic format is easily interpreted and can be used as both an outcome measure and a motivational tool in a clinical setting. The numeric format provides more detailed information and therefore is most likely appropriate for use in a research setting.

The data in this study were downloaded from the *activ*PAL software (*activ*PAL Professional Research Edition, version 7.2.32) to Excel by a 15-second epoch. The epoch file was examined to identify the first transition from sedentary to upright (when testing began) and when the last transition from upright to sedentary was recorded (when the testing protocol was finished). This duration of time was cross-referenced with the length of time of the video recording.

Outcomes for the testing procedure were step counts, transition counts (ie, transition from a sedentary position [sitting or lying down] to upright and transition from upright to a sedentary position), and time spent in sedentary (sitting or lying down), standing or light activity, and walking (continuous walking or running) behaviors.

Direct observation (video recording). Direct observation for the entire testing procedure was used as the validation criterion. Direct observation has been used as the criterion measure in numerous activity monitor validation studies.[9–11,24] Three independent observers (L.L., B.N., and C.B.) conducted the direct observation analyses. Two independent observers (L.L. and C.B.) viewed the video recording of each participant's testing session individually and recorded the measurements in Excel. One independent observer (L.L.) is a physical therapist, and the other (C.B.) is a psychologist. The research team reached a consensus that a step would be defined as complete foot contact with the ground in the sagittal or frontal plane, with the foot having left the ground completely before contact with the ground.[23] The research team defined the behavior of standing on the basis of recent findings as standing or light activity[9] and defined walking as continuous stepping, such as when participants moved from one ADL task to another. A third member (B.N., a physical therapist) of the research team then reviewed the data for any anomalies; if any anomalies arose, B.N. reviewed the Excel and video data to clarify or correct them.

Data Analysis

Descriptive statistics were computed for participant characteristics as numbers (percentages) or means (standard deviations) as appropriate. All continuous variables were assessed for normality with formal tests and visual inspection of histograms. Linear regression analysis was used to assess the criterion validity of *activ*PAL. Regression plots included the diagonal validation line and 95% confidence and prediction bands. Residual plots and the Cook distance were used to assess the influence of any outliers on the fitted regression line. Points of high influence were indicated by a Cook distance greater than the .5 probability point of the central F distribution ($F_{2,n-2,0.5}$).[25] Pearson correlation coefficients were computed with 95% confidence intervals (CIs) (by use of the Fisher normality transformation). Correlation coefficients of greater than .5 were defined as high, those from .3 to .5 were defined as moderate, and those of less than .3 were defined as low.[26] Paired t tests were used to test the significance of differences between direct observation and *activ*PAL activity measurements. Intermethod reliability was assessed by use of the 2-way mixed intraclass correlation coefficient with absolute agreement (ICC [3,1]) and 95% confidence limits.[27] Intraclass correlation coefficients were interpreted with the guidelines of Portney and Watkins[28]; ICCs lower than .50 sug-

Table 1.
Characteristics of Participants[a]

Characteristic	No. of Participants	Value
Age (y), $\bar{X}$ (SD)	20	55 (14)
Sex, women	20	17 (85)
Disease outcome		
Disease duration (y), $\bar{X}$ (SD)	20	8.9 (6)
Pain, measured with VAS from 0 to 100 mm, $\bar{X}$ (SD)	18	39 (29)
Fatigue, measured with VAS from 0 to 100 mm, $\bar{X}$ (SD)	18	46 (31)
BMI (kg/m^2)	19	
Healthy, 18.5–24.9		11 (58)
Overweight, 25–29.9		2 (10)
Obese, ≥30		6 (32)
Comorbidities (PAR-Q+)	20	
Cardiovascular disease		4 (20)
Respiratory disease		1 (5)
Mental health		2 (10)
None		13 (65)
Physical activity (GPPAQ)	20	
Inactive		14 (70)
Moderately inactive		2 (10)
Moderately active		0 (0)
Active		4 (20)
Work activity (GPPAQ)	20	
Retired		14 (70)
Sitting at work		1 (5)
Standing or walking at work		3 (15)
Work with physical effort		2 (10)

[a] Data are reported as number (percentage) of participants unless otherwise indicated. VAS=visual analog scale, BMI=body mass index, PAR-Q+=Physical Activity Readiness Questionnaire for Everyone, GPPAQ=General Practice Physical Activity Questionnaire.

gest poor reliability, ICCs between .50 and .75 suggest moderate reliability, and ICCs higher than .75 suggest good reliability. Statistical analyses were conducted with IBM SPSS Statistics, version 21.0 (IBM Corp, Armonk, New York), and the .05 level of significance was used throughout.

Sample size calculations determined that a sample size of at least 19 is required to detect a true intermethod reliability of 0.9 from a null value of 0.7 with 80% power when reliability is measured with ICCs.[29] In addition, a sample size of 19 will have 90% power to detect a large effect size (Cohen d=0.8) when a paired t test with a 2-sided significance level of .05 is used, and a sample size of 20 will have 80% power to detect a Pearson correlation coefficient of .9 when a 2-sided Fisher z test is used with the null hypothesis r=.65 (calculations done with nQuery Advisor 7 software, Statistical Solutions Ltd, Cork, Ireland).

Results

Of 102 potential participants, 35 agreed to participate in the study, 9 required further time to consider, and 58 declined participation in the study. Reasons for not participating included time constraints, difficulty traveling to the testing center, lack of interest in participating, mobility limitations because of pain or injury, and current or previous participation in other research studies. Ultimately, 24 people participated in the study. Participant characteristics are shown in Table 1. Data from 20 participants were included in the final analysis. Reasons for exclusion (n=4) were that data from 2 participants' *activ*PAL activity monitors were not recorded because of a technical fault when data were downloaded from the activity monitors, 1 participant failed to complete all 7 ADLs, and full video recording data were not available for 1 participant.

Step Counts

The regression analysis (Fig. 1) showed *activ*PAL values to be consistently lower than direct observation values, with a 95% confidence band below the diagonal validation line. Correlation analysis revealed that *activ*PAL step counts were strongly correlated with direct observation values (r=.94; 95% CI=.86, .98). The results of the paired t test revealed that the *activ*PAL activity monitor significantly underestimated step counts (P<.001), and the sample percentage mean difference was 26% (Tab. 2). The intermethod reliability was moderate (ICC=.7; 95% CI=−.06, .93).

Transition Counts

Regression and correlation analyses were not appropriate because of the low variance in the direct observation transition counts (SD=1.0). The paired t test revealed a significant difference (P<.001) between the *activ*PAL activity monitor and direct observation (Tab. 2). The *activ*PAL activity monitor underestimated transition counts (total number of transitions) for the total testing session by 36%. A review of the *activ*PAL data indicated that the *activ*PAL activity monitor recorded less than 50% of the observed transitions for 35% of the participants (n=7).

Sedentary Time

Regression analysis (Fig. 2) showed the fitted line to be close to the validation line. However, residual diagnostics revealed the presence of outliers with a small influence on the regression slope (Cook distances were less than $F_{2,18,0.5}$=0.72). The effect of the outliers was reflected in the wide confidence and prediction bands in the regression plot.

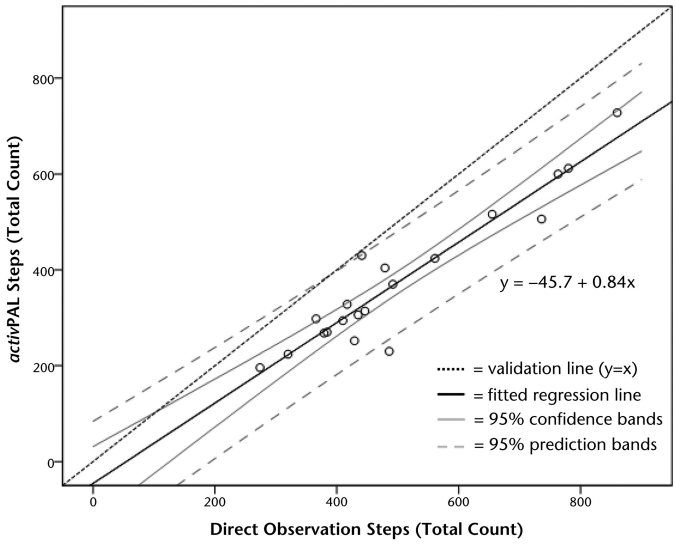

Figure 1.
Regression analysis of *activ*PAL on direct observation for step counts (n=20).

The correlation of *activ*PAL sedentary times with direct observation values was not strong enough to reject a null hypothesis correlation value of .65 (r=.74; 95% CI=.44, .89). The paired t test revealed no significant difference (P=.57) between the *activ*PAL activity monitor and direct observation for time (total number of seconds) spent in sedentary behavior for the total testing session (Tab. 2), and the mean percentage difference was small (<5%). The intermethod reliability was moderate/good (ICC=.75; 95% CI=.46, .89).

Standing or Light Activity Time

The regression analysis (Fig. 3) showed that the majority of points were close to the fitted regression line and the diagonal validation line, with outliers having a small influence (Cook distances were less than $F_{2,18,0.5}$=0.72). Correlation analysis revealed that *activ*PAL measurements were strongly correlated with direct observation values (r=.94; 95% CI=.86, .98). The paired t test revealed no significant difference (P=.08) between the *activ*PAL activity monitor and direct observation for time (total number of seconds) spent in standing or light activity behavior for the total testing session (Tab. 2), and the mean percentage difference was less than 10%. The intermethod reliability was good (ICC=.84; 95% CI=.64, .94).

Walking Time

Regression analysis (Fig. 4) showed that the observed points were close to the fitted line and the diagonal validation line. The width of the 95% confidence and prediction bands also reflected the accuracy of the *activ*PAL measurements. Correlation analysis found that *activ*PAL measurements were strongly correlated with direct observation values (r=.93; 95% CI=.83, .97). The paired t test revealed no significant difference (P=.20) between the *activ*PAL activity monitor and direct observation for time (total number of seconds) spent walking for the total testing session (Tab. 2), and the mean percentage difference was small (<5%). The intermethod reliability was good (ICC=.92; 95% CI=.82, .97).

Discussion

To our knowledge, this is the first study to examine the criterion validity of the *activ*PAL activity monitor for estimating step counts, transition counts, and time spent in sedentary, standing or light activity, and walking behaviors in people with RA. The *activ*PAL activity monitor was not a valid measure of step counts or transition counts in people with RA because it underestimated the total number of steps and transitions taken by participants in our sample. However, the *activ*PAL activity monitor was a valid measure of time spent in sedentary, standing or light activity, and walking behaviors on the basis of the reasonable agreement demonstrated in our statistical analyses.

The measurement of physical activity and sedentary behavior is a key concern for health care professionals. Studies of the validation of objective tools for measuring physical activity and sedentary behavior in people with RA are limited. Thus far, only one other objective

Table 2.
Paired t-Test and Correlation Results[a]

Parameter	$\bar{X}$ (SD)		Δ (95% CI)	*P*	% Δ	*r* (95% CI)
	*activ*PAL	Direct Observation				
No. of steps	378.5 (147.1)	505.7 (165.6)	127.2 (101.3, 153.0)	<.001	25.9	.94 (.86, .98)
No. of transitions	6.8 (1.6)	10.8 (1.0)	4.0 (3.0, 4.9)	<.001	36.0	N/A
Sedentary time	842.1 (229.0)	830.7 (209.0)	−11.5 (−85.5, 62.6)	.75	−3.1	.74 (.44, .89)
Standing and light activity time	724.3 (223.0)	667.9 (195.9)	−46.40 (−99.1, 6.3)	.08	−7.6	.86 (.74, .96)
Walking time	242.1 (87.6)	251.7 (79.7)	9.6 (−5.5, 24.6)	.20	4.5	.93 (.83, .97)

[a] Δ=mean difference (direct observation − *activ*PAL), CI=confidence interval, r=Pearson correlation coefficient, N/A=correlation was not applicable (low variance in direct observation values).

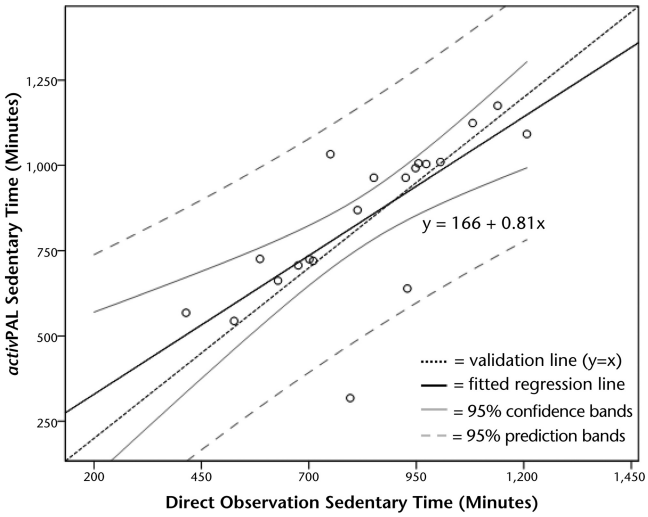

Figure 2.
Regression analysis of *activ*PAL on direct observation for sedentary time (n=20).

measure of physical activity, the SenseWear Pro3 Armband, which measures step counts and energy expenditure, has been validated in people with RA.[14] The present study provides unique findings on the validity of an objective measurement tool, the *activ*PAL activity monitor, for measuring both physical activity and sedentary behavior in people with RA.

The present study suggests that the *activ*PAL activity monitor can be used to measure time spent in sedentary and physical activity behaviors. These data are important given that participation in both sedentary and physical activity behaviors is an independent indicator of health.[5] The importance of monitoring sedentary behavior is reflected by recent studies focusing on the use of the *activ*PAL activity monitor for measuring both sedentary and physical activity behaviors.[9,10,30] Because our results provide strong evidence that the *activ*PAL activity monitor is a valid measure of time spent in standing or light activity and walking behaviors and moderate evidence that the *activ*PAL activity monitor is a valid measure of time spent in sedentary behavior, consideration should be given to the selection of the *activ*PAL activity monitor as a measure of sedentary and physical activity behaviors in intervention studies of people with RA.

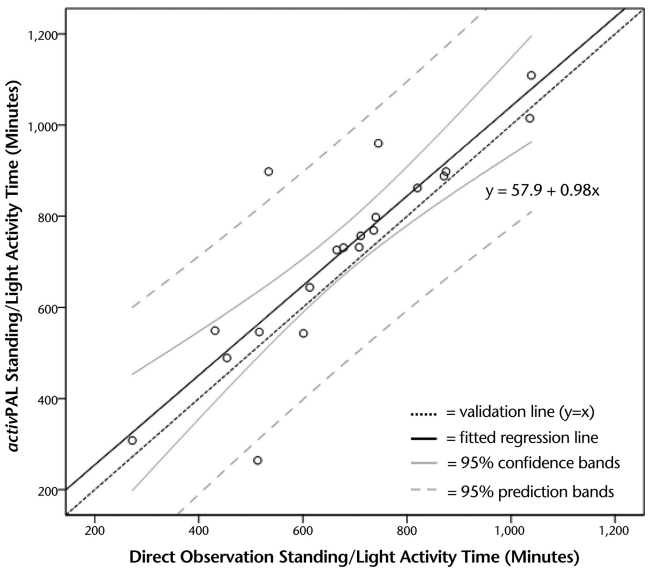

Figure 3.
Regression analysis of *activ*PAL on direct observation for standing or light activity time (n=20).

In the present study, the *activ*PAL activity monitor underestimated both step counts and transition counts. These results conflict with previous research in which the *activ*PAL activity monitor was reported to be a reliable and valid measure of step counts in adult populations.[31] Shortened stride lengths, prolonged stance phase, and lower walking speed have been observed in people with RA[32]; these observations may explain our contradictory findings because the *activ*PAL activity monitor senses both static acceleration due to gravity (ie, 9.8 m/s^2) and dynamic acceleration due to body movements. The *activ*PAL activity monitor underestimated the total number of transitions in our study population. A plausible explanation for this result relates to the achievement of "good" transitions of sitting posture; participants who slouched or slumped in the sitting position or did not achieve a position of 90 degrees of hip flexion in sitting transitions were not recorded. We anticipated that this scenario might influence the validity of the *activ*PAL activity monitor for measuring time spent in sedentary, standing or light activity, and walking behaviors; however, such was not the case. Because there was only a small amount of movement time between the activities, this scenario did not influence the overall validity of the *activ*PAL activity monitor. If longer walking periods between sedentary activities had been incorporated into the testing procedure, then perhaps the results would have been different.

As alluded to earlier, the *activ*PAL activity monitor senses both static acceleration due to gravity (ie, 9.8 m/s^2) and dynamic acceleration due to body movements.[9] The empirical bench tests of

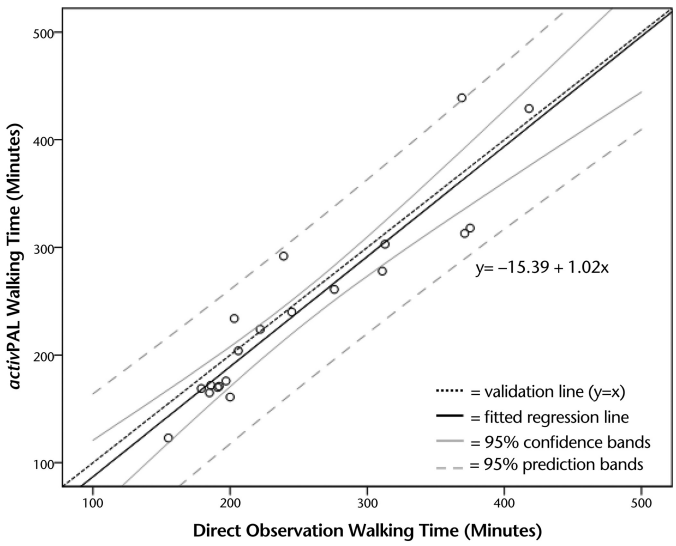

Figure 4.
Regression analysis of *activ*PAL on direct observation for walking time (n=20).

Bassett et al[9] suggested that when the angle of inclination exceeds approximately 20 degrees from horizontal (0°), the device predicts the upright position. These data suggested that if a person fails to achieve an appropriate angle of inclination or if the speed at which a person performs a transition is too low (eg, due to pain, fatigue, or stiffness), the *activ*PAL activity monitor may fail to record. Dowd et al[33] reported that the *activ*PAL activity monitor accurately measured transitions in an adolescent population, but participants in that study were advised on their sitting position, in contrast to our study protocol. These data are important given that in a free-living environment, people with RA are unlikely to constantly achieve and maintain a "good" or ideal sitting posture. The use of 2 monitors, on the thigh and trunk, is a possible method for improving the accuracy of the measurement of transitions with the *activ*PAL activity monitor in research settings.[9]

Our findings regarding step counts and transition counts conflict with previous research; it is possible that the present study was conducted with a clinical population of participants whose chronic disease affected movement patterns.[20,21] We gave due consideration to the characteristics of the participants in our sample, including their pain and fatigue, and how these might have influenced the participants' movement patterns. Pain and fatigue are common symptoms experienced by people with RA, and these symptoms were demonstrated in our sample population. Participants reported moderate levels of pain and fatigue, and it is possible that their gait patterns were affected by these symptoms.

Furthermore, just under half of the participants in the present study were either overweight or obese, and the majority of the participants were deemed to be inactive in their daily lives. Research has suggested that obesity is associated with reduced muscular strength, impaired postural control, and altered limb mechanics during walking and rising from a chair.[20,21,34] However, being overweight or obese or having low levels of daily physical activity did not affect the recording and subsequent results for the *activ*PAL activity monitor in the present study. This positive finding suggests that the *activ*PAL activity monitor is appropriate for monitoring time spent in sedentary or physical activity behaviors in the wider population of people with RA, regardless of body mass index or physical activity levels.

Limitations and Practical Considerations

The present study has some limitations, many of which relate to the practical nature of conducting a validation study. We were successful in obtaining initial agreement for participation from 35 people with RA. Thirteen participants withdrew their initial consent. We tested 24 participants and excluded 4 from the final analysis. Our final sample size was reflective of that in other studies in which the validity of the *activ*PAL activity monitor was examined.[9–11,33,35] The practical nature of the present study, that is, recruiting participants and setting up ADLs in a laboratory environment to accommodate video recording, proved challenging and should be considered in the planning of future validation studies.

Some issues arose regarding the analysis of data, namely, difficulties in defining what a "step" is. This definition is rarely reported in physical activity measurement studies and should be considered in future research. The problem is that the definition may not match how the *activ*PAL activity monitor registers a step; that is, if there is no thigh movement but a person lifts his or her foot and places it completely on the floor again, then the *activ*PAL activity monitor may not register a step. Although direct observation was considered a criterion measure in the present study and the observer was a trained physical therapist with experience in movement analysis, difficulties encountered in the analysis of the video data were manually counting the time necessary to take a step and deciding whether this time should be included in walking time or in standing or light activity time. In addition, we were unsure how to categorize a small number of steps taken during ADLs, such as sweeping the floor. To address these challenges, we decided to base our observation criteria on the research of Bassett et al,[9] who reported that activities such as sweeping the floor resulted in the accumulation of few or no steps. We observed that this finding holds true for other ADL activities, such as washing dishes, cleaning a mirror, and placing a duvet cover and a pillowcase on bedding.

Furthermore, validating ADLs performed in a laboratory setting was a limitation. Other ADLs, such as climbing stairs and walking along a corridor, were consid-

ered but presented challenges in terms of how they would be video recorded. In addition, because the present study demonstrated stronger evidence of validity for standing or light activity and walking behaviors than for sedentary behavior, further research may be warranted to confirm our findings.

We found that the *activ*PAL activity monitor was not a valid measure of step counts and transition counts for participants in our sample. However, we found that the *activ*PAL activity monitor was a valid measure of time spent in sedentary, standing, and walking behaviors in people with RA, relative to direct observation. Thus, we recommend the use of the *activ*PAL activity monitor for measuring time spent in physical activity and sedentary behavior only.

Ms Larkin, Dr Nordgren, Dr Fraser, and Dr Kennedy provided concept/idea/research design, project management, and consultation (including review of manuscript before submission). Ms Larkin, Dr Nordgren, Dr Purtill, and Dr Kennedy provided writing and data analysis. Ms Larkin, Dr Nordgren, Mr Brand, and Dr Fraser provided data collection. Dr Nordgren and Dr Fraser provided participants. Ms Larkin and Dr Kennedy provided facilities/equipment. Ms Larkin, Dr Fraser, and Dr Kennedy provided institutional liaisons. Ms Larkin provided administrative support. The authors thank the participants in the study for facilitating this research. The authors also thank Professor Ailish Hannigan and Dr Kieran Dowd for their assistance in analyzing and interpreting the study findings.

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