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Original research

Can the intensity of physical activity be accurately measured in older adults using questionnaires?

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ABSTRACT

Objectives: This study assessed the accuracy of two questionnaires for measuring the duration of physical activity (PA) by intensity compared to an objective measure in older adults.
Design: Cross-sectional observation
Methods: A total of 169 (female = 43.8%) participants aged 73–78 years (mean: 75.1 y; SD: 1.3) wore a SenseWear™ Armband (SWA) for seven-days and reported the duration of PA by intensity with a Physical Activity Recall (PAR) questionnaire and the Active Australia Survey (AAS). In addition, the duration of moderate-to-vigorous-PA (MVPA) and overall active time, weighted for intensity (Total PA; MET: min/week) was assessed. Univariate general linear models were used to compare the questionnaire and SWA measures of PA while controlling for age, sex and education.
Results: The PAR was associated with SWA moderate intensity PA (b = 0.19; 95% CI 0.03–0.35), MVPA (b = 0.19; 95% CI 0.02–0.37) and Total PA (b = 0.33; 95% CI 0.11–0.55). Although significant correlations were present, the models explained a small proportion of the variance in the SWA variables. The AAS was not associated with the SWA for any PA outcome. There was also significant under-reporting of PA duration for both questionnaires in comparison to the SWA.
Conclusions: The PAR questionnaire may be suitable for determining the effect of greater levels of PA on health outcomes. However, neither questionnaire can be considered valid in determining the duration of PA divided by intensity. In addition, questionnaire and objectively measured PA are not equivalent and absolute measures of PA derived from questionnaires should be interpreted with caution.

Practical implications

- Moderate intensity, MVPA, and Total PA from the Physical Activity Recall questionnaire were all significantly associated with the objective measure and may be suitable to determine the effect of different levels of PA on health.
- The Active Australia Survey questions were not a valid method of determining the duration of PA by intensity in older adults.
- Both the Physical Activity Recall and the Active Australia Survey consistently and substantially under-estimated PA levels in comparison to an objective measure.
- The self-report questionnaires are not equivalent to objectively measured PA, and this is important when classifying people as active or inactive based on current PA recommendations.

1. Introduction

The accurate measurement of physical activity (PA) in older adults is necessary to better understand the relationship between PA and improved health outcomes to inform population health policy. Although self-reported PA is still the most commonly used measurement method due to its ease of use and cost-effectiveness[1] it tends to be poorly correlated with PA estimates derived from objective PA monitors in adults.[2] Although seemingly obvious, this limitation is often not considered in the interpretation of the literature in this area. For example, a recent study using self-reported

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PA concluded that obtaining the recommended 150 min/week of moderate to vigorous PA (MVPA)[3] at mid-life is not associated with a reduction in dementia risk.[4] As findings such as this have serious implications for the development and communication of evidence-based PA recommendations, it is important to understand the precision of self-report PA measures.

The level of agreement between PA measures in adults may be further diminished with increasing age, due in part to the wide individual variability of older adults.[5] This presents a problem as the proportion of adults over the age of 65 is rapidly increasing, resulting in population-based studies measuring PA in increasingly older cohorts.[6] Although few studies have examined the over-65 age group, available evidence indicates that correlations between self-report of the total duration of PA with an objective measure range between 0.10 and 0.42.[7–9] Although significant correlations exist, there tend to be substantial absolute differences in the duration of self-reported and objectively measured PA,[10] limiting the ability to correctly define individuals as active or inactive based on existing PA guidelines.[11] Although measuring the total duration of PA to estimate overall activity levels is important in this population,[11] it does not take into account the different physiological and health responses to PA by intensity.[3,12] Further, the recall of more intense PA may be more memorable for older adults to recall than lighter intensity activities which may be accumulated incidentally throughout the day.[13,14] Presently, the few available studies in this age group have not investigated the relationship between the duration of self-report and objectively measured PA while considering different intensity levels.

To address these limitations the current study had three objectives: (1) characterise the weekly duration of PA, including when divided by light, moderate, and vigorous intensity; (2) determine the agreement between PA measured by two commonly used questionnaires and an objective PA measure while controlling for sociodemographic confounding variables; and (3) investigate the effect of age, sex, and education level on the agreement between questionnaire and objectively measured PA.

2. Methods

Participants were sampled from the magnetic resonance imaging (MRI) sub-study[15] of the Personality and Total Health through life (PATH) project, a large longitudinal survey which is described in detail elsewhere.[16] Two thousand five hundred and fifty-five participants were enrolled at baseline (the year 2001) into the PATH study. Of those, 622 randomly selected participants were offered an MRI scan, and 478 underwent a structural MRI scan. At the fourth assessment (12 years after baseline testing), 325 participants in the MRI group aged 73–78 years of age were available for follow up and were offered to participate in a cross-sectional substudy examining the cognitive, PA, and diet habits of older adults. Participants completed the PATH survey under the supervision and with the assistance of a trained interviewer, before returning on a subsequent day for their MRI scan. Of those participants, 184 participants accepted and were provided with a SenseWear™ Armband following their MRI scan (SWA; BodyMedia, PA, USA) for a continuous seven-day period to objectively record PA patterns.

Participants (n = 8) who scored less than 24 on the Mini-Mental State Examination or had a history of stroke, Parkinson's disease, or epilepsy[17] were excluded from the analyses in line with previous studies.[6] Additionally, participants (n = 5) who had less than 5 valid days (>20 h on-body time) of SWA data were excluded from the study and data for two of the participants were not available due to a technical error with the SWA. As a result, 169 participants had data available for analysis. The study was approved by the Australian National University Human Research Ethics Committee and participants provided written informed consent.

Two questionnaires are used to assess PA in the PATH study. The first is a short physical activity recall (PAR) questionnaire using items adapted from the U.K Whitehall II study.[6,18] To the best of our knowledge, this questionnaire has not been validated against an objective measure of PA in older adults, although several examples exist of its use in previous publications.[4,6] In the PAR, participants were asked to recall time in the past seven-days engaging in PA of light, moderate and vigorous intensity. Each question asked the participants to report the time spent on average undertaking PA at intensity levels comparable to particular sports or activities. The three questions provided examples of common activities and sports for light (e.g. walking), moderate (e.g. dancing) and vigorous (e.g. running) intensities. Weekly totals (min/week) were computed for time spent in light, moderate, and vigorous intensities, and MVPA was calculated.

The second PA questionnaire used in the PATH study is the Active Australia Survey (AAS). Participants reported the frequency and duration of walking briskly, other moderate-intensity PA (excluding walking), and vigorous intensity PA, as described in the AAS manual.[19] Examples and explanations were provided for each type of activity. Participants were asked to only recall activities that occurred for ≥10 min in the previous seven-days. The method by which PA outcomes are calculated with the AAS varies.[9,20,21] For example, in validating the AAS against a pedometer in older adults, Heesch et al.[9] analysed walking minutes and other moderate-intensity PA as two variables. Brown et al.[21] subsequently used the AAS in older adults to investigate its role in predicting mortality, however, they combined walking minutes and other moderate intensity PA as a single variable that was equivalent in terms of intensity. Given this variability, we have referred to the AAS manual,[19] which considers walking and moderate intensity PA as equivalent in terms of intensity, and is in line with its use by Brown et al.[21] We, therefore, computed weekly totals (min/week) for moderate intensity PA (moderate intensity PA = walking + other moderate intensity PA) and vigorous intensity PA, and subsequently calculated MVPA.

To objectively record PA patterns, participants wore a SWA over the triceps muscle of their left arm for a continuous seven-day period. The SWA incorporates a tri-axial accelerometer with galvanic skin response, skin temperature, near-body ambient temperature, and heat flux to noninvasively measure PA[22] with greater accuracy than accelerometry alone.[23–25] The SWA was set to record data at 1-min intervals and was only removed during water submersion and for daily ablutions. Data from the SWA were downloaded to the proprietary software (SenseWear™ Professional version 8.0, BodyMedia, PA) where energy expenditure was calculated.[22] PA was classified using MET-values for light (1.5–2.99 METs), moderate (3.00–5.99 METs), and vigorous (6.00 or greater METs). Subsequently, every minute-by-minute data point was coded by its intensity. Weekly totals (min·week^{1}) were created for light, moderate and vigorous intensity PA, and MVPA was subsequently calculated.

In addition to calculating the weekly duration of intensity divided PA for each measure, we also calculated summary PA variables by combining the duration of PA intensity weighted by its MET-value. For the PAR, Total PA (MET: min/week) was calculated with the formula MET: min/week = (1.5× light min/week) + (3× moderate min/week) + (6× vigorous min/week). For the PAR, MVPA (MET: min/week) was calculated with the formula, MET: min/week = (3× moderate min/week) + (6× vigorous min/week). Both summary values theoretically account for moderate being twice the intensity of light, and vigorous being twice the intensity of moderate.[19,26] For the SWA, MET-values ≥ 1.5 were summed

Table 1
Characteristics of weekly SenseWear™ and self-report derived physical activity for the study sample. Data are mean (95% CI).

	SWA	PAR	AAS
Light PA (min/week)	1540 (1452–1628)	597 (506–688)	–
Moderate PA (min/week)	365 (320–410)	200 (159–241)	318 (247–390)[a]
Vigorous PA (min/week)	37 (25–49)	26 (14–39)	43 (27–59)
MVPA (min/week)	402 (350–455)	226 (18–271)	361 (285–437)
Total PA (MET: min/week)	4403 (4057–4749)	1654 (1423–1885)	1213 (959–1467)
>150 min MVPA, n (%)	126 (74.5)	72 (42.6)	37 (21.9)

Notes: SWA: SenseWear™ Armband; PAR: Physical Activity Recall questionnaire; AAS: Active Australia Survey; MVPA: moderate to vigorous physical activity; PA: physical activity.

[a] AAS moderate intensity PA is calculated as the sum of walking and other moderate intensity PA.

across the 7-day period to create an overall metric of Total PA (MET: min/week).

Statistical analysis was conducted in R version 3.5.1.[27] Separate univariate general linear models were used to compare the PAR and AAS to SWA for each PA outcome. For each model the dependent variable was SWA and the independent variable was PAR or AAS with the variables age, sex and self-reported years of education[8] included as covariates. Both age and education were mean centred. Initially, the interaction terms between the independent variable and the covariates were included in each model. A significant interaction term indicated that the association between PAR or AAS and SWA may be confounded by that covariate. Non-significant interaction terms were dropped from the final models for ease of interpretation. Visual inspection of QQ-plots generated for each model showed no obvious deviations from normality. However, the model which compared the SWA and PAR for vigorous intensity PA showed evidence of deviation from normality which could not be corrected through transformation of the independent or dependent variables. As with the remaining comparisons which showed no deviance from normality, the model without transformation has been interpreted for vigorous intensity PA as it showed the most ideal distribution of residuals. To reduce the risk of Type I error associated with multiple comparisons, p-values from the general linear models underwent a Simes–Benjamini–Hochberg false discovery rate adjustment.[28] Statistical significance was accepted at adjusted $p < 0.05$.

3. Results

Participants (n = 169; female = 43.8%) included in this analysis ranged in age from 73–78 y (mean: 75.1 y; SD: 1.3). The participants mean years of education (mean: 14.4 y; SD: 2.6) was greater than the number required to complete the final year of high school in Australia. The study sample was slightly younger than the larger PATH sample (75.1 vs. 75.7 years; $p < 0.001$) but did not differ on the proportion of females or years of education. The health and sociodemographic variables for the study sample are available in the Supplementary material (Table A). The descriptive data for weekly PA outcomes is presented in Table 1. As shown in Table 1, participants were more likely to be classified as meeting the recommended 150 min·week[1] of MVPA with the SWA than with either questionnaire.

The models comparing the PAR with SWA derived PA variables are shown in Table 2. For all PAR models, the interaction terms were non-significant. The final models for the PAR show neither light nor vigorous intensity PA are associated with the SWA. On the other hand, moderate intensity, MVPA and Total PA are associated with SWA for the PAR. The models comparing the AAS with the SWA are shown in Table 3. For the initial AAS moderate intensity model, the interaction term was significant for age and education. All other interaction terms were non-significant and dropped from the final models. The AAS was not associated with the SWA for any of the measures. As shown by the significance of the intercepts for all models of the PAR and AAS, the PA variables derived from the self-report questionnaires were significantly different to the SWA.

Because there are differences in the way the AAS variables are calculated within the literature, we conducted several sensitivity analyses (see Supplementary material). When separating walking minutes and other moderate intensity, neither variable was associated with either light or moderate intensity SWA variables (Table B). When comparing the AAS to weekly steps from the SWA to allow comparison with Heesch et al.,[9] there was a significant association for the walking variable as well as the MVPA and Total PA variables (Table C).

4. Discussion

This study examined the ability of older adults to accurately self-report the duration of PA with the PAR and the AAS questionnaires when divided by intensity. Although the two questionnaires employed here are regularly reported within the literature, to our knowledge this is the first study to examine the validity of the PAR in older adults and the first to examine the validity of the AAS in predicting the duration of PA by intensity. The AAS was not associated with the SWA for any of the PA outcomes, whilst the PAR was able to predict the duration of moderate intensity PA only. Although participants did not self-report PA intensity well with either questionnaire, there was a significant, but weak association between the PAR and the SWA for Total PA, and this is consistent with prior studies in adults over the age of 65.[7,8] Although this demonstrates the usefulness of the PAR to investigate the effect of overall PA level on healthy ageing outcomes in epidemiological research, neither questionnaire can be considered valid in determining the duration of PA by intensity.

There are several potential explanations as to why the recall of PA by intensity was limited with both questionnaires. Firstly, when examining the SWA data in Table 1, the majority of active time was spent doing light intensity PA, which is consistent with prior research[8] and likely to include tasks such as household chores.[29] These types of tasks are known to be short in duration and intermittent and may make them difficult to accurately recall for older adults in particular.[13,14] In addition, previous research suggests the subjective nature of asking older participants to report the duration of light, moderate and vigorous activities is heavily dependent upon the participant's fitness, prior PA experience, and functional capacity and may lead to misclassification of PA intensity.[30]

The models in the current study, although significant, were weak and explained a small proportion of the variance in the SWA (all $R^2 \leq 0.11$). Whilst previous studies report significant correlations between PA questionnaires and activity monitors, they are small in magnitude (r = 0.10 to 0.42).[7–9] This range of correlation coefficients indicates self-report questionnaires, which are previously validated and used within epidemiological research, are typically predicting no more than 18% of the variance in objective PA measures. It is likely that a substantial portion of this unexplained variance can be attributed to the reporting error of PA level by

Table 2
Summary of univariate models examining the association between PAR questionnaire and SWA measured physical activity.

	Light		Moderate		Vigorous		MVPA		Total PA	
	b (SE)	p[#]	b (SE)	p[#]	b (SE)	p[#]	b (SE)	p[#]	b (SE)	p[#]
Gender[a]	−77.21 (93.76)	0.51	−174.44 (45.89)	<0.01	−15.82 (12.24)	0.39	−187.03 (54.07)	<0.01	−997.12 (354.76)	<0.01
Age	8.74 (34.06)	0.80	−20.06 (16.52)	0.28	−2.22 (4.40)	0.61	−22.63 (19.39)	0.31	−44.07 (127.64)	0.73
Education	24.33 (17.84)	0.29	−4.45 (8.53)	0.60	−2.31 (2.28)	0.39	−6.81 (10.01)	0.50	40.23 (66.24)	0.68
PAR	0.15 (0.08)	0.13	**0.19 (0.08)**	**0.04**	0.08 (0.07)	0.39	**0.19 (0.09)**	**0.04**	**0.33 (0.11)**	**<0.01**
Intercept	1485.25 (77.40)	<0.01	404.60 (34.93)	<0.01	41.27 (8.28)	<0.01	440.04 (41.71)	<0.01	4291.20 (307.26)	<0.01
Model	$F_{4,164} = 1.6$; $p = 0.18$; $R^2 = 0.01$		$F_{4,164} = 6.0$; $p < 0.01$; $R^2 = 0.11$		$F_{4,164} = 0.94$; $p = 0.44$; $R^2 = 0.00$		$F_{4,164} = 5.24$; $p < 0.01$; $R^2 = 0.09$		$F_{4,164} = 5.2$; $p < 0.01$; $R^2 = 0.09$	

MVPA: moderate to vigorous physical activity; PA: physical activity; b, regression coefficient; SE, standard error.
Bold values signifies P-values are provided as part of this table under the columns p.
[#] adjusted for multiple comparisons.
[a] compared to males.

Table 3
Summary of univariate models examining the association between AAS questionnaire and SWA measured physical activity.

	Moderate		Vigorous		MVPA		Total PA	
	β (SE)	p[#]	β (SE)	p[#]	β (SE)	p[#]	β (SE)	p[#]
Gender[a]	−176.93 (46.39)	<0.01	−17.21 (12.25)	0.41	−199.11 (57.97)	<0.01	−1048.30 (367.76)	0.01
Age	−35.18 (17.32)	0.09	−2.00 (4.42)	0.81	−24.88 (19.63)	0.34	−67.39 (130.25)	0.76
Education	−18.17 (10.53)	0.12	−2.25 (2.32)	0.56	−7.62 (10.15)	0.55	9.65 (67.33)	0.89
AAS*Age	0.15 (0.06)	0.02	–		–		–	
AAS*Education	0.04 (0.02)	0.12	–		–		–	
AAS	0.14 (0.10)	0.19	0.01 (0.06)	0.89	0.05 (0.08)	0.55	0.12 (0.11)	0.40
Intercept	406.82 (37.19)	<0.01	43.66 (8.42)	<0.01	482.16 (38.66)	<0.01	4711.05 (284.36)	<0.01
Model	$F_{7,161} = 4.46$; $p < 0.01$; $R^2 = 0.13$		$F_{4,164} = 0.6$; $p = 0.64$; $R^2 = 0.00$		$F_{4,164} = 4.0$; $p < 0.01$; $R^2 = 0.07$		$F_{4,164} = 3.2$; $p = 0.01$; $R^2 = 0.05$	

MVPA: moderate to vigorous physical activity; PA: physical activity; b, regression coefficient; SE, standard error.
[#] adjusted for multiple comparisons.
[a] compared to males.

older adults. Looking beyond the results of this study, these findings have implications for the large body of literature which use questionnaire-based measures of PA to investigate relationships with health outcomes and by which most PA guidelines are based upon. The findings of this study provide further evidence that a move towards implementing objective PA measures within epidemiological research, especially in older adults, is likely to provide more accurate and reliable information on physiologically meaningful PA[11] and in-turn inform the development of PA guidelines.

There were significant absolute differences for both questionnaires in comparison to the SWA, with a tendency toward under-reporting of PA, as indicated by the significant and positive intercepts for each model (see Tables 2 and 3). Previous validation studies show both over- and under-reporting of PA[2] and this study provides further evidence that self-reported and objectively measured PA are not equivalent in terms of absolute quantity.[11,31] These differences are consequential when surveying populations to determine adherence to PA guidelines, as shown in Table 1. For instance, in the current study an average male (age: 75.1 years; education: 15.0 years) who reported obtaining 100 min/week of MVPA with the PAR, is estimated to record four times as much MVPA with the SWA. Therefore, this individual would be classified as not meeting the recommended 150 min/week of MVPA with the PAR, but would meet this cut-off and be considered active when measured objectively by the SWA. The potential consequences of this are highlighted if applied in the context of recent work by Sabia et al.[4] They used a self-report questionnaire similar to the PAR in middle-aged adults and concluded there was no difference in dementia risk between groups divided on whether they obtained 150 min/week of MVPA, and therefore met the current PA guidelines. Based on the results of the current study which showed the PAR tends to under-report MVPA, it is likely that a group classified as not meeting the PA guidelines with this questionnaire would contain substantial portion of active individuals that are adhering to these recommendations. In turn, this would reduce the magnitude of any potential health differences between reported adherers and non-adherers to the PA guidelines. The use of an objective measure to determine adherence to the PA guidelines may change the conclusions and the recommendations that arise from such research.

The findings of this study should also be considered with a number of further limitations in mind. Whilst the SWA is a validated measure of PA, it is still an estimate and is known to underestimate MVPA by 2.9%.[26] However, the SWA is more accurate than accelerometry alone at measuring PA, particularly when activity is of a low-intensity and intermittent[32] which makes it ideal for PA monitoring in older adults in comparison to previous studies.[9] Secondly, as the precision of self-report can differ between populations, even with the same self-report and objective measure,[11] the findings of this study should be considered in the context of the study sample. This also highlights the importance of validating self-report measures in the context they are being used and the caution that must be taken if using PA questionnaires in a manner in which they have not been validated.[21] Finally, as we asked the AAS questions as part of the wider PATH survey and following the PAR, it is possible that survey fatigue was a factor. However, we were able to replicate the findings of Heesch et al.[9] when we compared the AAS to step counts from the SWA, indicating that our results are comparable to those reported in the literature and unlikely to have been substantially influenced by survey fatigue. This also seems to indicate the AAS may have convergent validity with step counts, however, is not appropriate for determining the duration of PA by intensity which is required to provide an evidence base for PA guidelines.

5. Conclusion

The findings of this study indicate that the PAR questionnaire used may be suitable for determining the effect of greater levels of PA in a cohort of older adults in their 70's. However, neither the PAR nor the AAS were able to consistently estimate the duration of PA by intensity and there was substantial under-reporting of PA with both questionnaires. When using a self-report PA question-

naire to assess PA duration, especially when the research focus is on assessing whether PA guidelines or cut-offs are met, caution must be taken. Incorporating objective measures of PA into epidemiological research may provide additional information on the duration and intensity of PA to guide the development of evidence-based recommendations in this age group.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jsams.2019.01.004.

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