Gait & Posture 92 (2022) 135–143

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Concurrent validity of the International Physical Activity Questionnaire adapted for adults aged ≥ 80 years (IPAQ-E 80 +) - tested with accelerometer data from the SilverMONICA study

Öhlin Jerry [a,*], Toots Annika [b], Dahlin Almevall Albin [c], Littbrand Håkan [a], Conradsson Mia [a], Hörnsten Carl [a], Werneke Ursula [d], Niklasson Johan [e], Olofsson Birgitta [f], Gustafson Yngve [a], Wennberg Patrik [g], Söderberg Stefan [h]

[a] *Department of Community Medicine and Rehabilitation, Geriatric Medicine, Umeå University, SE-901 87 Umeå, Sweden*
[b] *Department of Community Medicine and Rehabilitation, Physiotherapy, Umeå University, SE-901 87 Umeå, Sweden*
[c] *Department of Development, Region Norrbotten, SE-972 41 Luleå, Sweden*
[d] *Department of Clinical Sciences, Division of Psychiatry, Sunderby Research Unit, Umeå University, SE-901 87 Umeå, Sweden*
[e] *Department of Community Medicine and Rehabilitation, Geriatric Medicine, Sunderby Research Unit, Umeå University, SE-901 87 Umeå, Sweden*
[f] *Department of Nursing, Umeå University, SE-901 87 Umeå, Sweden*
[g] *Department of Public Health and Clinical Medicine, Family Medicine, Umeå University, SE-901 87 Umeå, Sweden*
[h] *Department of Public Health and Clinical Medicine, Umeå University, SE-901 87 Umeå, Sweden*

ARTICLE INFO

Keywords:
Validity
Physical activity questionnaire
Sedentary behavior
Very old people
Accelerometry

ABSTRACT

Background: Physical activity and sedentary behavior vary across the life span, and in very old people activity behavior can vary considerably over 24 h. A physical activity questionnaire adapted for this age group is lacking. This study was conducted to validate such a newly developed questionnaire suitable for use in very old people.
Research question: Is the International Physical Activity Questionnaire adapted for adults aged ≥ 80 years (IPAQ-E 80 +) a valid measure of physical activity in very old people?
Methods: Seventy-six participants (55.3% women) with a mean age of 84.4 ± 3.8 years wore accelerometers for ≥ 5 consecutive days, and completed the IPAQ-E 80 +. Spearman's rho and Bland-Altman plots were used to analyze the validity of IPAQ-E 80 + against accelerometer measures. Analyses were conducted for the separate items sitting, laying down at daytime and nighttime, walking, moderate to vigorous (MV) walking, and moderate to vigorous physical activity (MVPA), and the summary measures: total inactive time, sedentary time (i.e. lying down at daytime + sitting), total active time, and total MVPA + MV walking.
Results: The IPAQ-E 80 + correlated with the accelerometer measures of total inactive- ($r = 0.55$, $p < 0.001$), sedentary- ($r = 0.28$, $p = 0.015$), walking- ($r = 0.54$ p < 0.001) and total active- ($r = 0.60$, $p < 0.001$) times, but not with measures of intensity of walking or physical activity; MV walking ($r = 0.06$, $p = 0.58$), MVPA ($r = 0.17$, $p = 0.13$).
Significance: In this study the IPAQ-E 80 + showed fair to substantial correlations with accelerometers, and it therefore seems able to rank very old people according to levels of PA (total inactive-, sedentary-, and total active time, and walking time). The IPAQ-E 80 + seems promising for use in studies investigating associations between activity behavior and health in this population. Further investigation is needed to determine whether the IPAQ-E 80 + can accurately measure PA intensity.

1. Introduction

Two important aspects of healthy aging are reduced sedentary behavior (SB) and increased physical activity (PA). According to the World Health Organization's (WHO's) updated guidelines [1], PA contributes to fall prevention, bone health, and mobility in older adults. In a systematic review of studies with a mean participant age of 62.6 years [2], higher PA levels and lower SB were associated with a decreased risk of premature death. PA is considered to protect against cardiovascular disease, stroke, diabetes [3], and depression [4], and

* Corresponding author.

https://doi.org/10.1016/j.gaitpost.2021.11.019
Received 17 May 2021; Received in revised form 15 October 2021; Accepted 15 November 2021
Available online 22 November 2021

may slow cognitive decline [5,6]. However, among very old people (age ≥ 80 years) less is known about these effects and associations, which may differ given the methodological challenges involved in PA measurement at this age [7]. Few studies have investigated the association between PA levels and health among older adults [8], but PA levels appear to decline with age [9–11] and be lower in people with dementia than in age- and sex-matched controls [12].

Accelerometers are considered to be a more accurate and reliable measure of PA compared to self-report questionnaires, but the use of accelerometers are not always feasible due to the higher costs, more administration and interpretation involved [13,14]. Although accelerometers are becoming more affordable and easier to use, a quick to administer, cost-effective, and valid PA questionnaire is still needed as it can provide information on PA behavior, including the type of activity, and where the activity takes place [7,13]. The International Physical Activity Questionnaire for elderly adults (IPAQ-E) enables acceptable estimation of PA in independently living people aged ≥ 65 years [15]. However, it may not fully capture the PA behavior of very old people, as its measure of inactive time includes only sitting (and not lying) time. A 24-hour measurement of (in)activity in this population is likely important, as aging is accompanied by increased nocturnal awakening and napping [16], leading to variable daytime activity patterns. A dose–response association between PA intensity and mortality has been reported among adults and older adults [2], and walking is the most frequently reported form of PA [17]. Thus, valid questionnaires for PA measurement should include measures of walking intensity [7,13]. Finally, as cognitive impairment is common in higher ages, and self-report questionnaires are sensitive to recall bias [13,18] the responses may need to be verified with close relatives or care personnel.

To improve self-reported PA measurement among very old people, we developed a modified IPAQ-E for people aged ≥ 80 years (IPAQ-E 80 +), taking into account PA behavior over 24 h, the perceived exertion when walking (intensity), and including the option for proxy confirmation of responses. This study was conducted to assess concurrent validity of the IPAQ-E 80 + in a sample of very old people using accelerometer data, with relevant subgroup analyses. A secondary aim was to investigate the ability of the IPAQ-E 80 + to correctly identify participants achieving recommended PA levels of 150 min of moderate PA or 75 min of vigorous PA per week.

2. Method

2.1. Design and setting

This cross sectional study used data from the SilverMONICA project. The SilverMONICA project included individuals who were aged ≥ 80 years in 2016–2019, and who through 1999 had participated twice in the MONICA study in northern Sweden [19], and still lived in the area. Participants were informed about the study, and written informed consent was provided. When cognitive impairment was suspected, participants' relatives or trustees were consulted. The study was performed in accordance with the Declaration of Helsinki and was approved by ethics review board (Dnr 0 29-2015 and Dnr 2017-322-32M). For the present cross sectional study, the SilverMONICA participants who during May 2017–October 2019 resided in Luleå and Boden municipalities were invited to participate.

2.2. Procedure

Trained medical professionals (physiotherapists, physicians, and nurses) collected data during home visits, including data on sociodemographics, living conditions and health. Self-reported medical conditions and medications were collected, and later validated by medical record review. Height, weight, blood pressure and 2.4 m gait speed were measured. Cognitive function was measured using the Mini-Mental State Examination (MMSE) [20] and the Frontal Assessment Battery [21]. Depressive symptoms and malnutrition were measured with the 15-item Geriatric Depression Scale [22] and the Mini Nutritional Assessment [23], respectively. Dependence in instrumental and personal activities of daily living (I-ADL and P-ADL, respectively) was measured with the Katz ADL staircase [24]. Specialists in geriatric medicine validated dementia and depression diagnoses according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision [25].

2.3. Accelerometer use and data collection

During the first home visit, an accelerometer (activPAL3 Micro; PAL Technologies Ltd., Glasgow, UK) was fitted, which began recording at midnight of the next day, and continued recording for 7 consecutive days. The device was placed inside a waterproof nitrile sleeve, and secured to the right anterior mid-thigh with adhesive dressing. Participants were instructed to wear the accelerometer continuously except when swimming or bathing, and on the 8th day to remove and store it until the follow-up visit.

Valid days of accelerometer measurements were defined as ≤ 4 h of continuous zero movement. Participants with at least five valid days of measurement, representative of a week of measurement in adults [26], were included. Total inactive time was defined as the sum of sitting, nighttime-, and daytime lying down; sedentary time was defined as the sum of sitting and daytime lying down. Total active time was defined as total stepping time without any bout or cadence threshold according to the accelerometer. Time in moderate to vigorous intensive (MV) walking time was defined as time spent walking with a step cadence > 100, excluding bouts < 10 steps. The same definition, suggested as a threshold for MV activity in older adults [17], was used for moderate to vigorous physical activity (MVPA). According to the accelerometer software's standard validation algorithm, > 4 h of continuous stillness was classified as non-wear.

2.4. The IPAQ-E 80+

During the follow-up visit, and after having worn the accelerometer for 7 days prior, the participants PA levels of the previous week was measured using the IPAQ-E 80+, aided by proxy if needed. The original IPAQ-E comprises four questions related to levels of PA reported as time (in hours and minutes per day) spent sitting, walking (≥10 min bouts), and conducting moderate-, and vigorous PA, based on the last seven days [27]. The IPAQ-E 80 + has an additional four questions related to time spent 1) lying down (for example, on a couch or in bed) in connection with sleep at night, 2) lying down (for example, on a couch or in bed) in connection with rest during the day, 3) walking (moderate effort), and 4) walking (vigorous effort). Thus, lying down at night or during the day include time spent for example, reading a book or a newspaper, or watching television in a reclining position before going to sleep. In addition, in case of cognitive impairment (defined as a MMSE score <20), the option to verify the response with relatives or care personnel are provided.

2.5. Statistical analyses

Continuous variable distribution of the difference (*IPAQ-E 80+ minus accelerometry*) for all inactive and active measures was assessed, using the Shapiro–Wilk and Kolmogorov–Smirnov tests of normality, QQ plots, and histograms. Of these, only total inactive time was normally distributed. Thus, Spearman's coefficients were used to analyze the correlation between IPAQ-E 80+ and accelerometer measures. The Chi-square or Mann Whitney *U* tests was used to analyze differences in the proportions of men and women, age and years of education between the participants of this study and those who participated only in the Norrbotten SilverMONICA project.

Spearman's rho and Bland–Altman plots were used to analyze correlations and systematic and random errors between IPAQ-E 80+ and accelerometer measures of total inactive, nighttime- and daytime lying down, sitting, sedentary, total active time, walking and MV walking, MVPA, and total MVPA (MVPA + MV walking) times [28]. Strength of correlations were rated as poor (0–0.2), fair (0.21–0.4) moderate (0.41–0.6), substantial (0.61–0.8) and near perfect (0.81–1.0) [29].

The sensitivity and specificity of the IPAQ-E 80+ in identifying participants achieving recommended PA (150 min moderate or 75 min vigorous PA/week) [1] was analyzed using MVPA time (including MV walking) and two accelerometer conditions: > 100 and > 75 steps/min (SPM). The same variables were used to measure agreement beyond chance with Cohen's kappa. The impact of excluding the two most sedentary participants (>20 h/day of inactivity) was analyzed with a sensitivity analysis. Differences in correlations in subgroups defined by sex, proxy rating, a gait speed threshold of 0.5 m/s, dementia, and depression were analyzed with Fisher's *r–z* transformation test. Using normative data on step length in older people [30], the average daily kilometers walked was calculated as steps/day × 0.66 m for men and 0.57 m for women. All analyses were performed with SPSS software (ver.24 for Windows; IBM Corporation, Armonk, NY, USA), except Fisher's *r–z* transformation, which was performed using VassarStats [31]. All statistical tests were two tailed. *P* values < 0.05 were considered statistically significant.

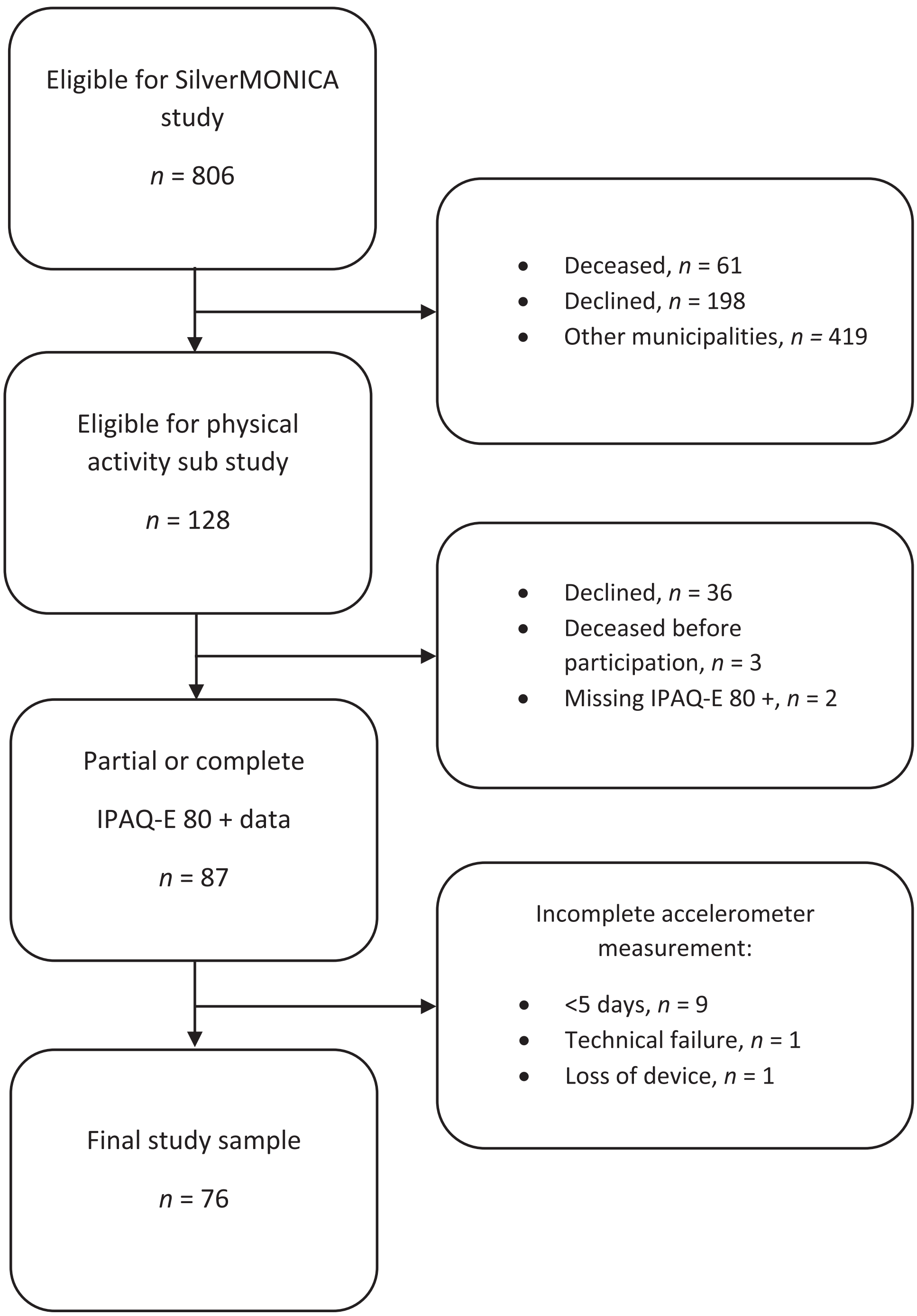

Fig. 1. Flow of study inclusion. SilverMONICA, monitoring of trends and determinants of cardiovascular disease (Participants Aged ≥ 80 years); IPAQ-E 80 +, International Physical Activity Questionnaire adapted for adults aged ≥ 80 years.

Table 1
Participants' background characteristics.

Characteristic	All (n = 76)	Men (n = 34)	Women (n = 42)
Age, years	84.4 ± 3.8	84.2 ± 4.3	84.5 ± 3.5
Sex, female	42 (55.3)	0 (0)	42 (100)
Nursing home resident	2 (2.6)	1 (2.9)	1 (2.4)
Living alone	32 (42.1)	3 (8.8)	29 (69.0)
Years of education (n = 75)	10.0 ± 3.7	10.0 ± 3.9	10.1 ± 3.6
Diagnoses			
Dementia	17 (22.4)	9 (26.5)	8 (19.0)
Depressive disorder	14 (18.4)	4 (11.8)	10 (23.8)
Cerebrovascular disease	2 (2.6)	0 (0)	2 (4.9)
Myocardial infarction	4 (5.3)	3 (8.8)	1 (2.4)
Hypertension	56 (73.7)	25 (73.5)	31 (73.8)
Heart failure	9 (11.8)	4 (11.8)	5 (11.9)
Hip fracture	4 (5.3)	2 (5.9)	2 (4.8)
Diabetes	8 (10.5)	6 (17.6)	2 (4.8)
Osteoarthritis	41 (53.9)	13 (38.2)	28 (66.7)
Prescribed medications			
Benzodiazepines	13 (17.1)	2 (5.9)	11 (26.2)
Antihistamines	3 (3.9)	1 (2.9)	2 (4.8)
Antidepressants	8 (10.5)	2 (5.9)	6 (14.3)
Analgesics	49 (64.5)	16 (47.1)	33 (78.6)
Total	6.3 ± 3.7	6.3 ± 3.8	6.3 ± 3.6
Hearing impairment (n = 75)	25 (33.3)	16 (47.1)	9 (22.0)
Vision impairment (n = 75)	24 (32.0)	8 (23.5)	16 (39.0)
Mini Nutritional Assessment (0–30; n = 75)	25.9 ± 2.2	25.7 ± 2.2	26.0 ± 2.2
Body mass index (n = 75)	25.1 ± 4.1	25.0 ± 4.2	25.3 ± 4.1
Systolic blood pressure, mm/hg (n = 74)	144 ± 21	139 ± 16	149 ± 24
Diastolic blood pressure, mm/hg (n = 74)	77 ± 10	74 ± 9	79 ± 10
Independence in I-ADL	36 (47.4)	11 (32.4)	25 (59.5)
Independence in P-ADL	68 (89.5)	30 (88.2)	38 (90.5)
Geriatric Depression Scale (0–15; n = 75)	2.0 ± 1.7	2.0 ± 1.7	2.0 ± 1.7
Mini-Mental State Exam (0–30; n = 75)	26.1 ± 3.1	26.0 ± 3.4	26.3 ± 2.8
Frontal Assessment Battery (0–18; n = 75)	13.4 ± 3.2	13.2 ± 3.4	13.6 ± 3.2
Gait speed, m/s (n = 74)	0.74 ± 0.19	0.73 ± 0.17	0.75 ± 0.21
Use of walking aid indoors (n = 75)	18 (24.0)	7 (21.2)	11 (26.2)

Values are presented as the mean ± standard deviation or n (%). For the Mini Nutritional Assessment, Mini-Mental State Examination, and Frontal Assessment Battery, higher scores indicate better nutritional status, global cognitive function, and frontal lobe function, respectively. For the Geriatric Depression Scale, higher scores indicate more depressive symptoms. Diagnoses and medical conditions refer to the previous 5 years. Prescribed medications include scheduled and pro re nata drugs. I-ADL, instrumental activities of daily living; P-ADL, personal activities of daily living.

3. Results

3.1. Background characteristics

IPAQ-E 80 + responses (at least partial) and valid accelerometry data were available for 76 of 128 eligible participants (Fig. 1). The mean ± SD age was 84.4 ± 3.8 (range 79–96) years, and 42 (55.3%) were women (Table 1). The sex distribution, age, and years of education did not differ between participants included in the present study and individuals who participated only in the Norrbotten SilverMONICA project.

3.2. Inactivity and activity measures

Correlations between IPAQ-E 80 + and accelerometry measures were significant for the items total inactive (moderate, $r = 0.55$ $p < 0.001$), lying down (night) (substantial, $r = 0.65$ $p < 0.001$), lying down (day) (fair, $r = 0.26$, $p = 0.025$) and sedentary (fair, $r = 0.28$, $p = 0.015$) times, but not for sitting time ($r = 0.09$, $p = 0.42$) (Table 2). The BA-plots for inactive time (Fig. 2) showed a mean underestimation of total inactive time (−18.56 h/week), and overestimation of lying down (night) (1.28 h/week) and lying down (day) (2.04 h/week), with heteroscedasticity, i.e. systematic error in under- or over reporting, indicated for the latter. The BA plots for sitting and sedentary time showed similar underestimations (−22.74 and −20.86, respectively) (Fig. 2). The correlations were significant for total active (moderate, $r = 0.60$ $p < 0.001$) and walking (moderate, $r = 0.54$, $p < 0.001$) but not MV walking, MVPA, or MVPA + MV walking times (Table 2). The BA-plot for total active time (Fig. 3) showed underestimation (−0.66 h/week). Walking time was underestimated (−4.05 h/week), as were MV walking (−1.16 h/week), the latter with heteroscedasticity indicated. MVPA and MW walking + MVPA were overestimated (2.08 and 2.29 h/week, respectively), both with heteroscedasticity. Of the 76 participants, 41 reported time spent in MVPA (48 when MV walking was included).

3.3. Sensitivity and subgroup findings

Sensitivity and specificity of the IPAQ-E 80 + were 61% and 59% for 100 SPM, and 55% and 70% for 75 SPM (Table 3). Measure of agreement beyond chance was significant only for 75 SPM (Cohen's $\kappa = 0.228$, $p = 0.033$).

In sensitivity analyses the exclusion of the two most sedentary participants indicated similar results as the main analysis. In subgroup analyses, the correlation coefficient for total inactive time was larger in the subgroup with proxy than without proxy ($z = -2.9$, $p = 0.0037$; Supplementary Table A), and the coefficient for walking time was larger in the group with depression than in the group without depression ($z = -2.67$, $p = 0.0076$; Supplementary Table B). No differences in degree of correlation related to sex, gait speed threshold, or dementia diagnosis was observed.

4. Discussion

4.1. Main findings

The IPAQ-E 80 + and accelerometer measures of total active time, total inactive time, lying down at night and during the day, and sedentary time showed fair to substantial correlations. Total active time and total inactive time were underreported. An underestimation of

Table 2
Self-reported and accelerometer-measured (in) activity (hours/week) of participants ($n = 76$), and correlation between measures.

Measure	IPAQ-E 80 +	Accelerometry	Spearman's *r* (*p*)
Total inactive time[a] ($n = 69$)	109.0 ± 23.8 [101.5 (73.5–167.4)]	127.9 ± 15.4 [126.9 (96.3–166.8)]	**0.55 (<0.001)**
Nighttime lying down[a] ($n = 70$)	59.7 ± 10.2 [59.5 (42.0–85.7)]	58.5 ± 15.4 [57.7 (26.3–139.4)]	**0.65 (<0.001)**
Daytime lying down[a]	6.9 ± 8.1 [3.5 (0–35.0)]	4.8 ± 6.9 [2.0 (0–30.5)]	**0.26 (0.025)**
Sitting ($n = 75$)	41.3 ± 15.5 [41.3 (14.0–84.0)]	64.5 ± 15.5 [65.9 (20.9–100.9)]	0.09 (0.42)
Sedentary time (daytime lying down + sitting; $n = 75$)	48.1 ± 17.2 [45.5 (19.2–92.2)]	69.4 ± 14.4 [69.6 (20.9–100.9)]	**0.28 (0.015)**
Total active time[a] ($n = 75$)	9.19 ± 9.3 [6.1 (0–45.5)]	9.9 ± 5.5 [9.3 (0.01–25.7)]	**0.60 (<0.001)**
Walking	5.7 ± 6.2 [3.9 (0–35.0)]	9.7 ± 5.6 [9.3 (0–25.7)]	**0.54 (<0.001)**
MV walking[a]	0.3 ± 0.7 [0.0 (0–3.7)]	1.4 ± 1.9 [0.5 (0–7.1)]	0.06 (0.58)
MVPA ($n = 75$)	3.5 ± 6.1 [0.6 (0–35.0)]	1.4 ± 1.9 [0.5 (0–7.1)]	0.17 (0.13)
Total MVPA (MVPA + MV walking[a]; $n = 75$)	3.8 ± 6.2 [1.0 (0–35.0)]	1.4 ± 1.9 [0.5 (0–7.1)]	0.17 (0.16)
Daily steps	–	6200 ± 3763 [5743 (4–16.947)]	
Estimated daily distance walked, km	–	3.79 ± 2.34 [3.56 (0.002–11.19)]	

Values presented as mean ± standard deviation [median (range)]. Bold type indicates significant values.
[a]Addition to the original IPAQ-E.
IPAQ-E 80 +, International Physical Activity Questionnaire adapted for adults aged ≥ 80 years; MV, moderate to vigorous; PA, physical activity

sedentary time was indicated, primarily time in sitting, which also showed signs of systematic error. Correlations of total active and walking times were moderate, but not significant for sitting, MV walking, and MVPA. Systematic errors were observed in assessments of MV walking and MVPA. The sensitivity and specificity of the IPAQ-E 80 + for the accurate identification of participants (not) attaining the recommended PA level with the two SPM thresholds tested were low.

4.2. Comparison with other studies

To the best of our knowledge, this is the first study to evaluate the validity of IPAQ-E 80 +, a questionnaire that measures PA over 24 h to more fully capture the PA behavior in very old people. The IPAQ-E 80 + showed substantial to fair correlations to accelerometer measures of lying down (at night and during the day) with only a slight overestimation. The systematic errors of over- and underreporting observed were similar to those previously reported for MVPA [32,33]. Furthermore, the IPAQ-E 80 + showed moderate correlations to accelerometer measures and led to underestimation of total inactive- and slight underestimation of total active time. All in all, while the results suggests that the IPAQ-E 80 + can be used to rank individuals' levels of PA, the accuracy of absolute values in hours and minutes may be lacking.

The limited correlation between IPAQ-E 80 + and accelerometer-derived sitting observed in this study is in line with a study of adults where the long-form IPAQ was used [34]. In both questionnaires, the item order (with the sitting item following lying items and appearing last, respectively) may have led participants to underestimate sitting time. In contrast, fair to substantial correlations between IPAQ/IPAQ-E– and accelerometer-measured sitting have been reported in older adults (Spearman's $r = 0.26$– 0.70) [15,32,33]. Thus, a valid questionnaire-based measurement of sitting time appears possible, but may be more challenging with increasing age. Furthermore, all adults are prone to underestimate time in sitting, which likely increases with age. The limited correlation of sitting time in this study seems not to be attributable to symptoms of dementia, as indicated by the subgroup analysis.

While walking time showed a moderate correlation in this study, the items for intensity (MV walking or MVPA) did not. In contrast, Cleland et al. [32] found a correlation (Spearman's $r = 0.43$–0.56) between MVPA measures from accelerometer and IPAQ. In addition, correlations of measures of intensity may be influenced by whether or not a threshold of activity is used. Ryan et al. [33] reported a correlation (Spearman's $r = 0.19$) between self-reported and accelerometer-measured MVPA without accelerometer bout threshold, while no correlation was found when a 10-min bout threshold was used. Furthermore, both studies included participants who were on average 10 years younger than those in our study. As time participating in MVPA decreases with age, and apparent in our study where only 41 of the participants (48 when including MV walking), low power may explain the lack of correlation this study. Furthermore, evidence regarding the step cadence required to attain moderate intensity in older people is scarce and appear contradictory; the cadence may be greater [35] or lesser [36] than that required in younger adults. A threshold of > 100 SPM has been proposed for adults [17], and was used in this study as no recommendation for very old people were found.

Our findings regarding sensitivity and specificity of the IPAQ-E 80 + are inconclusive, possibly due to the methodological limitations of accelerometers pertaining to PA intensity thresholds [37]. Furthermore, although the examples of MVPAs provided in the questionnaire (i.e. gardening, window cleaning, biking, swimming, wood chopping, construction work, aerobics, and running) can be strenuous, the activities may not generate sufficient step cadences > 100 or > 75 SPM.

Stronger correlations were indicated for total inactive time in the subgroup with proxy compared to without proxy, and for walking time in the subgroup with depression compared to without depression. The results suggest that the IPAQ-E 80 + enables more precise total inactive time measurement using proxy consultation. The result also indicate that people with depression more accurately recall time spent walking than those without depression. As the subgroups were small, however, the results should be interpreted with caution. The sensitivity analyses conducted with exclusion of the two most sedentary participants yielded essentially the same results as the main analyses. Thus, the subgroup and sensitivity analyses suggest that the scale is valid for use within these common subgroups of very old people.

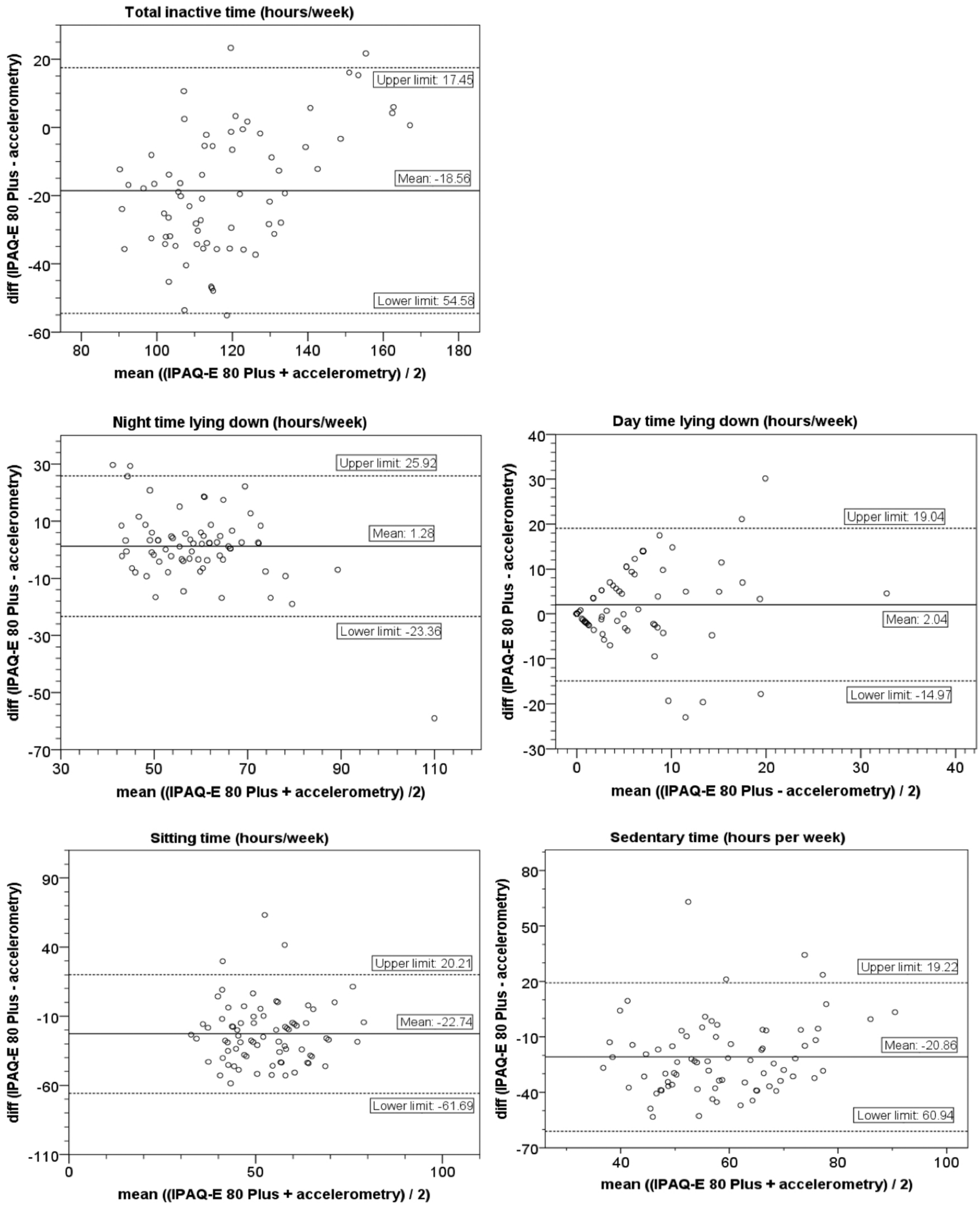

Fig. 2. Bland–Altman plots of differences (in hours per week) in inactive time between IPAQ-E 80 + and accelerometer measures. IPAQ-E 80 +, international physical activity questionnaire adapted for adults aged ≥ 80 years; PA, physical activity.

4.3. Strengths, limitations, and methodological considerations

The heterogeneity of PA levels is a strength of this study, and reflects the varying activity patterns in very old people. The concurrent PA measurement by accelerometer and self-report, which reduces the potential for PA fluctuation affecting self-reporting precision, is another strength. A limitation is that while the IPAQ-E 80 + uses a threshold of > 10-min bouts to measure time spent walking and performing MVPA, the accelerometer does not. Figs. 2 and 3 illustrates upward and downward slopes for daytime lying down, MV walking, MVPA and Total MVPA. The upward slope illustrates participants that reported time in an activity that the accelerometer did not, and vice versa for downward slopes. This highlights a measurement error of IPAQ-E 80 + regarding time spent lying down during the day and intensity of walking and physical activity, which warrants further investigation. Another limitation is the small number of participants, especially in the subgroups, in combination with the low number of participants reporting MVPA. This may have led to type 2 errors for MV walking and MVPA measures. Although test-retest reliability of the IPAQ have been shown to be adequate [38], reliability tests of the IPAQ-E 80 +, and IPAQ-E, are yet to be conducted. Finally, we measured intensity using accelerometer step counts, which could have resulted in misclassification bias for eight of our participants, as accuracy is low for people with walking speeds < 0.5 m/s [39].

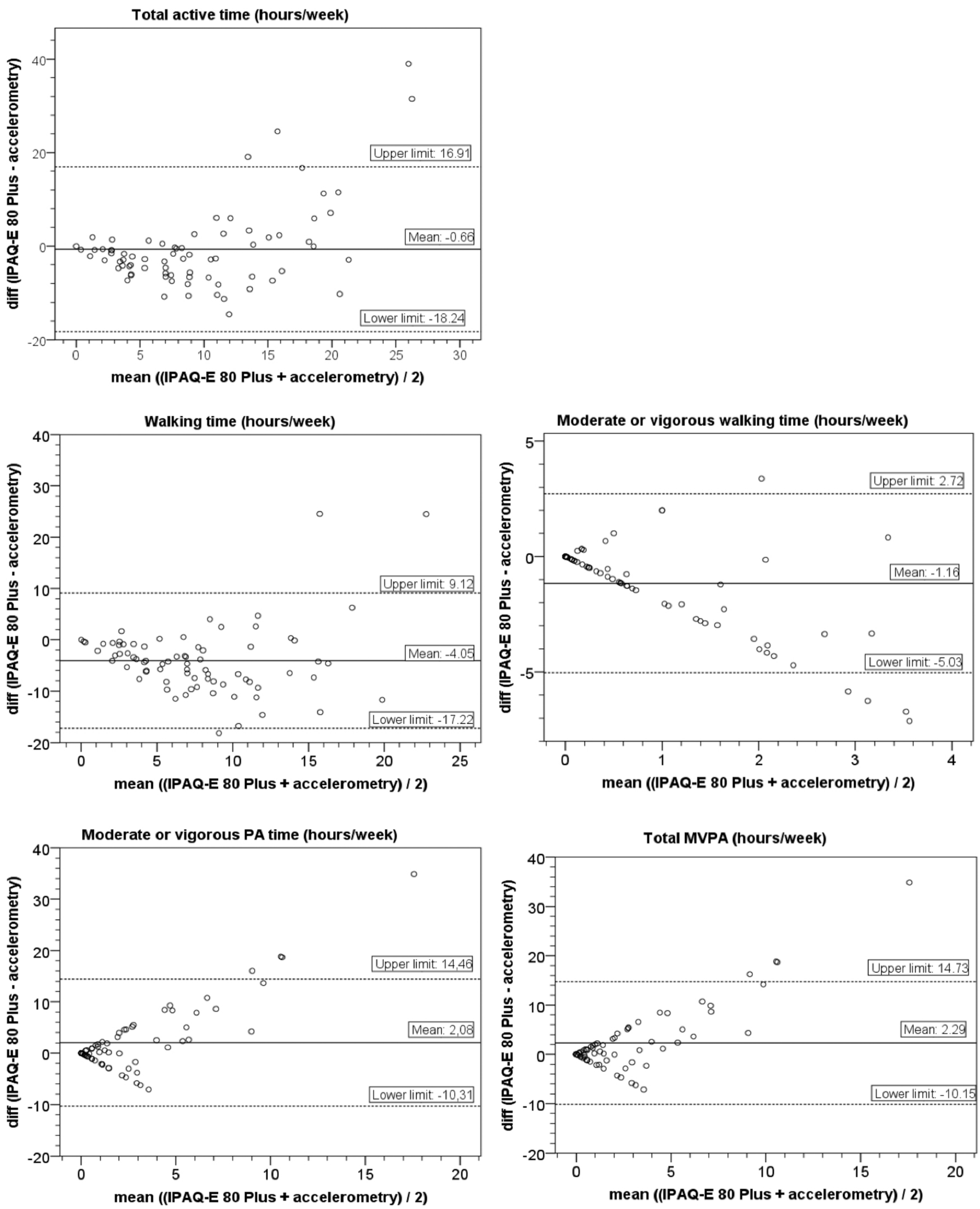

Fig. 3. Bland-Altman plots of differences (in hours per week) in active time between IPAQ-E 80 + and accelerometer measures. IPAQ-E 80 +, international physical activity questionnaire adapted for adults aged ≥ 80 years; PA, physical activity.

Table 3
Proportions of participants achieving the recommended PA level, and IPAQ-E 80 + sensitivity and specificity.

	Achieved recommended PA level [*n* (%)]					
SPM threshold	Accelerometry	IPAQE-80 +[a]	Sensitivity	Specificity	κ	*p*
≥ 100	18 (23.7)	35 (46.1)	61.1%	58.6%	0.149	0.142
≥ 75	49 (64.5)	35 (46.1)	55.1%	70.4%	0.228	0.033

[a] MV walking + MVPA. PA, physical activity; IPAQ-E 80 + , International Physical Activity Questionnaire adapted for adults aged ≥ 80 years; SPM, steps/minute; MV, moderate to vigorous.

5. Conclusions

This study shows that the IPAQ-E 80 + seems able to rank individuals aged 80 years and over into PA levels (inactive, sedentary, active, and walking). The IPAQ-E 80 + seems promising for use in studies of relationships between PA behavior and health in this population. Given the option for proxy confirmation for respondents with impaired cognition, the IPAQ-E 80 + may also be suitable for people with dementia. Further investigation is needed to determine whether this scale can accurately measure PA intensity.

Funding

The SilverMONICA study was funded by FORTE – the Swedish Research Council for health, working life and welfare (2016-01074), Vetenskapsrådet - The Swedish Research Council (K2014-99X-22610-01-6), the County Councils in Norr- and Västerbotten (Visare Norr and ALF), the Borgerskapet in Umeå Research Foundation, the Swedish Dementia Association, the Ragnhild and Einar Lundström Memorial Fund, the Erik and Anne-Marie Detlof Research Foundation, the Swedish Society of Medicine, Thuréus, The Strategic Research Program in Care Sciences (SFO-V, Sweden), and the King Gustaf V and Queen Victoria's Foundation of Freemasons. The funders had no role in study design, data collection and analyses, decision on whether to publish or not, or in preparation of this manuscript.

CRediT authorship contribution statement

All authors fulfilled the CRedit statement and significantly contributed to the process of this study in regards to their respective profession and experience. **Jerry Öhlin:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Annika Toots:** Conceptualization, Methodology, Writing – review & editing, Resources, Supervision. **Albin Dahlin Almevall:** Conceptualization, Methodology, Validation, Investigation, Data curation, Writing – review & editing, Supervision, Project administration. **Håkan Littbrand:** Conceptualization, Methodology, Writing – review & editing, Resources, Supervision. **Mia Conradsson:** Conceptualization, Methodology, Validation, Resources, Writing – review & editing. **Carl Hörnsten:** Conceptualization, Methodology, Writing – review & editing. **Ursula Werneke:** Conceptualization, Methodology, Resources, Writing – review & editing. **Johan Niklasson:** Conceptualization, Methodology, Data curation, Writing – review & editing, Funding acquisition. **Birgitta Olofsson:** Conceptualization, Methodology, Writing – review & editing, supervision, Funding acquisition. **Yngve Gustafson:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition. **Patrik Wennberg:** Conceptualization, Methodology, Software, Validation, Resources, Data curation, Writing – review & editing. **Stefan Söderberg:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Conflict of interest statement

No competing interests was reported by the authors.

Acknowledgements

We would like to thank the MONICA study and its participants, the unit for Biobank Research at Umeå University, our research assistants (Lena Backgård, Angelica Hurtig, Josefin Fhärm, Margot Johansson, Maja Sondell and Maja Söderberg) and Regions Norr- and Västerbotten. We also thank Gisela Lilja, (Neurology, Department of Clinical Sciences Lund, Lund University, Skane University Hospital, Lund, Sweden), for providing the Swedish translation of the Frontal Assessment Battery.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gaitpost.2021.11.019.

References

[1] F.C. Bull, S.S. Al-Ansari, S. Biddle, K. Borodulin, M.P. Buman, G. Cardon, C. Carty, J.-P. Chaput, S. Chastin, R. Chou, P.C. Dempsey, L. DiPietro, U. Ekelund, J. Firth, C. M. Friedenreich, L. Garcia, M. Gichu, R. Jago, P.T. Katzmarzyk, E. Lambert, M. Leitzmann, K. Milton, F.B. Ortega, C. Ranasinghe, E. Stamatakis, A. Tiedemann, R.P. Troiano, H.P. van der Ploeg, V. Wari, J.F. Willumsen, World Health Organization 2020 guidelines on physical activity and sedentary behaviour, Br. J. Sport. Med. 54 (2020) 1451–1462, https://doi.org/10.1136/bjsports-2020-102955.

[2] U. Ekelund, J. Tarp, J. Steene-Johannessen, B.H. Hansen, B. Jefferis, M. W. Fagerland, P. Whincup, K.M. Diaz, S.P. Hooker, A. Chernofsky, M.G. Larson, N. Spartano, R.S. Vasan, I.-M. Dohrn, M. Hagströmer, C. Edwardson, T. Yates, E. Shiroma, S.A. Anderssen, I.-M. Lee, Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: systematic review and harmonised meta-analysis, BMJ 366 (2019), https://doi.org/10.1136/bmj.l4570.

[3] B. Langhammer, A. Bergland, E. Rydwik, The importance of physical activity exercise among older people, Biomed. Res. Int. 2018 (2018), https://doi.org/10.1155/2018/7856823.

[4] F.B. Schuch, D. Vancampfort, J. Firth, S. Rosenbaum, P.B. Ward, E.S. Silva, M. Hallgren, A. Ponce De Leon, A.L. Dunn, A.C. Deslandes, M.P. Fleck, A. F. Carvalho, B. Stubbs, Physical activity and incident depression: a meta-analysis of prospective cohort studies, Am. J. Psychiatry 175 (2018) 631–648, https://doi.org/10.1176/appi.ajp.2018.17111194.

[5] A.S. Buchman, P.A. Boyle, L. Yu, R.C. Shah, R.S. Wilson, D.A. Bennett, Total daily physical activity and the risk of AD and cognitive decline in older adults, Neurology 78 (2012) 1323–1329, https://doi.org/10.1212/WNL.0b013e3182535d35.

[6] Z.S. Tan, N.L. Spartano, A.S. Beiser, C. DeCarli, S.H. Auerbach, R.S. Vasan, S. Seshadri, Physical activity, brain volume, and dementia risk: the framingham study, J. Gerontol. A Biol. Sci. Med. Sci. 72 (2017) 789–795, https://doi.org/10.1093/gerona/glw130.

[7] K. Kowalski, R. Rhodes, P.-J. Naylor, H. Tuokko, S. MacDonald, Direct and indirect measurement of physical activity in older adults: a systematic review of the literature, Int. J. Behav. Nutr. Phys. Act. 9 (2012) 148, https://doi.org/10.1186/1479-5868-9-148.

[8] F. Sun, I.J. Norman, A.E. While, Physical activity in older people: a systematic review, BMC Public Health 13 (2013) 449, https://doi.org/10.1186/1471-2458-13-449.

[9] M. Hagströmer, L. Kwak, P. Oja, M. Sjöström, A 6 year longitudinal study of accelerometer-measured physical activity and sedentary time in Swedish adults, J. Sci. Med. Sport 18 (2015) 553–557, https://doi.org/10.1016/j.jsams.2014.07.012.

[10] J.S. McPhee, D.P. French, D. Jackson, J. Nazroo, N. Pendleton, H. Degens, Physical activity in older age: perspectives for healthy ageing and frailty, Biogerontology 17 (2016) 567–580, https://doi.org/10.1007/s10522-016-9641-0.

[11] S. Musich, S.S. Wang, K. Hawkins, C. Greame, The frequency and health benefits of physical activity for older adults, Popul. Health Manag. 20 (2017) 199–207, https://doi.org/10.1089/pop.2016.0071.

[12] M.E. Taylor, M.A. Brodie, K.S. van Schooten, K. Delbaere, J.C.T. Close, N. Payne, L. Webster, J. Chow, G. McInerney, S.E. Kurrle, S.R. Lord, Older people with dementia have reduced daily-life activity and impaired daily-life gait when compared to age-sex matched controls, J. Alzheimers Dis. 71 (2019) S125–S135, https://doi.org/10.3233/JAD-181174.

[13] R.S. Falck, S.M. McDonald, M.W. Beets, K. Brazendale, T. Liu-Ambrose, Measurement of physical activity in older adult interventions: a systematic review, Br. J. Sport. Med. 50 (2016) 464–470, https://doi.org/10.1136/bjsports-2014-094413.

[14] I.-M. Lee, E.J. Shiroma, Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges, Br. J. Sport. Med. 48 (2014) 197–201, https://doi.org/10.1136/bjsports-2013-093154.

[15] A. Hurtig-Wennlöf, M. Hagströmer, L.A. Olsson, The international physical activity questionnaire modified for the elderly: aspects of validity and feasibility, Public Health Nutr. 13 (2010) 1847–1854, https://doi.org/10.1017/S1368980010000157.

[16] J. Li, M.V. Vitiello, N.S. Gooneratne, Sleep in normal aging, Sleep. Med. Clin. 13 (2018) 1–11, https://doi.org/10.1016/j.jsmc.2017.09.001.

[17] C. Tudor-Locke, H. Han, E.J. Aguiar, T.V. Barreira, J.M. Schuna, M. Kang, D. A. Rowe, How fast is fast enough? Walking cadence (steps/min) as a practical estimate of intensity in adults: a narrative review, Br. J. Sport. Med. 52 (2018) 776–788, https://doi.org/10.1136/bjsports-2017-097628.

[18] N.D. Harada, V. Chiu, A.C. King, A.L. Stewart, An evaluation of three self-report physical activity instruments for older adults, Med Sci. Sport. Exerc. 33 (2001) 962–970, https://doi.org/10.1097/00005768-200106000-00016.

[19] H. Tunstall-Pedoe, Monitoring trends in cardiovascular disease and risk factors: the WHO "Monica" project, WHO Chron. 39 (1985) 3–5.

[20] S.T. Creavin, S. Wisniewski, A.H. Noel-Storr, C.M. Trevelyan, T. Hampton, D. Rayment, V.M. Thom, K.J.E. Nash, H. Elhamoui, R. Milligan, A.S. Patel, D.

V. Tsivos, T. Wing, E. Phillips, S.M. Kellman, H.L. Shackleton, G.F. Singleton, B. E. Neale, M.E. Watton, S. Cullum, Mini-mental state examination (MMSE) for the detection of dementia in clinically unevaluated people aged 65 and over in community and primary care populations, Cochrane Database Syst. Rev. (2016), CD011145, https://doi.org/10.1002/14651858.CD011145.pub2.
[21] B. Dubois, A. Slachevsky, I. Litvan, B. Pillon, The FAB: a frontal assessment battery at bedside, Neurology 55 (2000) 1621–1626.
[22] A.J.M. de Craen, T.J. Heeren, J. Gussekloo, Accuracy of the 15-item geriatric depression scale (GDS-15) in a community sample of the oldest old, Int. J. Geriatr. Psychiatry 18 (2003) 63–66, https://doi.org/10.1002/gps.773.
[23] B. Vellas, Y. Guigoz, P.J. Garry, F. Nourhashemi, D. Bennahum, S. Lauque, J.L. Albarede,. The Mini Nutr. Assess. (MNA) its Use Grading Nutr. State Elder. Patients, Nutr., 15, 1999, pp. 116–122 doi: 10.1016/s0899-9007(98)00171-3.
[24] U. Sonn, K.H. Asberg, Assessment of activities of daily living in the elderly. A study of a population of 76-year-olds in Gothenburg, Sweden, Scand. J. Rehabil. Med. 23 (1991) 193–202.
[25] American Psychiatric Association, Diagnostic and statistical manual of mental disorders., IV-Text revision, Am. Psychiatr. Assoc. (2000).
[26] N. Aguilar-Farias, P. Martino-Fuentealba, N. Salom-Diaz, W.J. Brown, How many days are enough for measuring weekly activity behaviours with the ActivPAL in adults? J. Sci. Med Sport 22 (2019) 684–688, https://doi.org/10.1016/j.jsams.2018.12.004.
[27] International Physical Activity Questionnaire, (n.d.). ⟨https://sites.google.com/site/theipaq/⟩ (accessed May 4, 2021).
[28] J.M. Bland, D.G. Altman, Measuring agreement in method comparison studies, Stat. Methods Med. Res. 8 (1999) 135–160, https://doi.org/10.1177/096228029900800204.
[29] J.R. Landis, G.G. Koch, The measurement of observer agreement for categorical data, Biometrics 33 (1977) 159–174.
[30] J.H. Hollman, F.M. Kovash, J.J. Kubik, R.A. Linbo, Age-related differences in spatiotemporal markers of gait stability during dual task walking, Gait Posture 26 (2007) 113–119, https://doi.org/10.1016/j.gaitpost.2006.08.005.
[31] R. Lowry, VassarStats: Statistical Computation Web Site, (2021). ⟨http://vassarstats.net/index.html⟩ (accessed January 25, 2021).
[32] C. Cleland, S. Ferguson, G. Ellis, R.F. Hunter, Validity of the international physical activity questionnaire (IPAQ) for assessing moderate-to-vigorous physical activity and sedentary behaviour of older adults in the United Kingdom, BMC Med. Res. Methodol. 18 (2018) 176, https://doi.org/10.1186/s12874-018-0642-3.
[33] D.J. Ryan, J.A. Wullems, G.K. Stebbings, C.I. Morse, C.E. Stewart, G.L. Onambele-Pearson, Reliability and validity of the international physical activity questionnaire compared to calibrated accelerometer cut-off points in the quantification of sedentary behaviour and physical activity in older adults, PLoS One 13 (2018), e0195712, https://doi.org/10.1371/journal.pone.0195712.
[34] S.F.M. Chastin, B. Culhane, P.M. Dall, Comparison of self-reported measure of sitting time (IPAQ) with objective measurement (activPAL), Physiol. Meas. 35 (2014) 2319–2328, https://doi.org/10.1088/0967-3334/35/11/2319.
[35] J. Slaght, M. Sénéchal, T.J. Hrubeniuk, A. Mayo, D.R. Bouchard, Walking cadence to exercise at moderate intensity for adults: a systematic review, J. Sport. Med. 2017 (2017), 4641203, https://doi.org/10.1155/2017/4641203.
[36] L. Peacock, A. Hewitt, D.A. Rowe, R. Sutherland, Stride rate and walking intensity in healthy older adults, J. Aging Phys. Act. 22 (2014) 276–283, https://doi.org/10.1123/japa.2012-0333.
[37] J.H. Migueles, C. Cadenas-Sanchez, C. Tudor-Locke, M. Löf, I. Esteban-Cornejo, P. Molina-Garcia, J. Mora-Gonzalez, M. Rodriguez-Ayllon, E. Garcia-Marmol, U. Ekelund, F.B. Ortega, Comparability of published cut-points for the assessment of physical activity: implications for data harmonization, Scand. J. Med. Sci. Sport. 29 (2019) 566–574, https://doi.org/10.1111/sms.13356.
[38] C.L. Craig, A.L. Marshall, M. Sjöström, A.E. Bauman, M.L. Booth, B.E. Ainsworth, M. Pratt, U. Ekelund, A. Yngve, J.F. Sallis, P. Oja, International physical activity questionnaire: 12-country reliability and validity, Med. Sci. Sport. Exerc. 35 (2003) 1381–1395, https://doi.org/10.1249/01.MSS.0000078924.61453.FB.
[39] B. Stansfield, M. Hajarnis, R. Sudarshan, Characteristics of very slow stepping in healthy adults and validity of the activPAL3TM activity monitor in detecting these steps, Med. Eng. Phys. 37 (2015) 42–47, https://doi.org/10.1016/j.medengphy.2014.10.003.