



## Validation of the long international physical activity questionnaire: Influence of age and language region

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### ABSTRACT

**Objective.** Little is known about the influence of age, gender and language on the measurement properties of the long International Physical Activity Questionnaire (IPAQ). The aim was to validate the long IPAQ in adults aged 18–84 in the German-, French- and Italian-speaking parts of Switzerland, focusing on differences between gender, age groups and language regions.

**Methods.** This cross-sectional study was conducted in the frame of SAPALDIA (Swiss Cohort Study on Air Pollution and Lung and Heart Disease in Adults) in 2011. 346 participants (54.6% women, mean age 54.6 years) wore an Actigraph GT3X accelerometer during 8 days and completed the IPAQ. IPAQ and accelerometer data on total physical activity and on different intensities as well as sitting time were compared using Spearman correlations and Bland–Altman plots.

**Results.** Correlations were highest for vigorous physical activity ( $r = 0.41$ ) and sitting time ( $r = 0.42$ ). Significant gender differences were apparent for leisure-time physical activity (men:  $r = 0.35$  versus women:  $r = 0.57$ ,  $p = 0.012$ ) and for sitting time (men:  $r = 0.28$  versus women:  $r = 0.53$ ,  $p = 0.007$ ). Differences between age groups were present for sitting time (youngest:  $r = 0.72$  versus middle:  $r = 0.36$ ,  $p < 0.001$ ; youngest versus oldest:  $r = 0.34$ ,  $p = 0.001$ ). Differences between language regions were present for vigorous physical activity (German:  $r = 0.28$  versus Italian:  $r = 0.53$ ,  $p = 0.033$ ). IPAQ overestimated physical activity but underestimated sitting time.

**Conclusion.** The long IPAQ showed moderate validity similar to other studies when compared to accelerometer data in a diverse sample of individuals. Some sex, age and regional differences were observed but do not seem to limit its applicability in population sub groups.

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## 1. Introduction

Physical activity questionnaires are commonly used tools that are practicable in large samples (Westerterp, 2009), and therefore questionnaires with known measurement properties in different populations are needed. The International Physical Activity Questionnaire (IPAQ) was developed for adults aged 18 to 65 years with the aim to assess population levels of physical activity across countries (Craig et al., 2003). Its short version (7 items) provides information on the time spent walking, in moderate- and vigorous-intensity physical activity and sitting and is recommended for country-level monitoring (Craig et al., 2003). The long IPAQ (27 items) collects data in different domains (job-related, transport-related, domestic and leisure-time physical

activity) and intensities (moderate, vigorous, walking) and includes sitting time. This long format is recommended for research requiring more detailed assessment (Craig et al., 2003).

Initially, the IPAQ has been validated in different countries (Craig et al., 2003). A recent review has summarized 23 validation studies targeting the short IPAQ with mixed results (Lee et al., 2011). Fewer studies have assessed the validity of the long IPAQ, showing conflicting results (Boon et al., 2010; Criniere et al., 2011; De Cocker et al., 2009; Gauthier et al., 2009; Hagstromer et al., 2010; Hallal et al., 2010; Johnson-Kozlow et al., 2006; Macfarlane et al., 2011; Maddison et al., 2007; Nang et al., 2011). A large Swedish study reported significant low to moderate correlations ( $r = 0.07$ – $0.36$ ) between IPAQ and accelerometer data (Hagstromer et al., 2010). Other studies have reported correlations in a similar range. A meta-analysis which included studies on the validity of both the short and the long IPAQ reported overall weighted mean correlation coefficients between 0.27 for moderate

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physical activity and 0.49 for vigorous physical activity (Kim et al., 2013).

Because self-assessment of physical activity is culture-dependent, it is important to provide IPAQ validation results in different language regions. Furthermore, most of the previous IPAQ validation studies were conducted in adults up to 65 years and little is known about its measurement properties in older adults. The short version has been validated only in few studies with older adults (Grimm et al., 2012; Hurtig-Wennlof et al., 2010; Kolbe-Alexander et al., 2006), while to our knowledge no such study exists for the long IPAQ.

The German IPAQ has been validated in its short version in a small sample in Switzerland (Mader et al., 2006) and in an adapted long version in German adolescents (Hagstromer et al., 2008). The IPAQ long in French has been validated in France (Criniere et al., 2011) and the French-speaking part of Canada (Gauthier et al., 2009). No validation study of the long IPAQ in Italian has been found.

In the present study, the long version of the self-administered IPAQ has been validated in adults aged 18–84 years in the German-, French- and Italian-speaking parts of Switzerland, focusing on overall and activity category-specific differences between gender, age groups and language regions. The age range was selected to assess the influence of age on the validity of the IPAQ throughout adulthood. 18 to 84 years corresponds also to the age range of the participants across the three assessments of the SAPALDIA cohort (Swiss Cohort Study on Air Pollution and Lung and Heart Disease in Adults), which forms the basis for this study. At the lower and upper end of the age distribution, a convenience sample was recruited to optimize statistical power.

## 2. Methods

### 2.1. Study design, procedure and participants

In Switzerland, the long IPAQ has been introduced in the second follow-up of SAPALDIA (Ackermann-Lieblich et al., 2005). The cohort started in 1991 with 9'651 randomly selected adults aged 18–61 years from eight different regions in Switzerland (Martin et al., 1997). The data for the present cross-sectional validation study were collected within the second follow-up of SAPALDIA 3 in 2010/11. Participants' age range was between 37 and 82 years. In order to include younger age groups and to increase the sample size for those over 65 years, an additional convenience sample of individuals aged 18 to 40 and 65+ was included. Individuals were eligible if they were able to walk, so no individuals in wheel chairs included.

A subsample of the more than 6000 SAPALDIA 3 participants in four of the eight examination centres was asked to participate in the validation study. As the validation study started after the main part of the second SAPALDIA follow-up, not all SAPALDIA participants had the opportunity to participate in this sub study. Participation included wearing an accelerometer during 8 days and completing the long IPAQ. First instructions were given by the field workers in the study centres in the context of participation in the overall study. The convenience sample was recruited by mouth-to-mouth advertising and distribution of written study information. Willing participants completed a consent form. The aim was to include 100 individuals in each language region based on a rule of thumb that at least 50 subjects are considered adequate in studies on the measurement properties of questionnaires (Terwee et al., 2010) and on the interest for further subgroup analyses.

Interested individuals were contacted by telephone. They received detailed instructions on the study and the handling of the accelerometer. The accelerometer and the IPAQ were sent by postal mail. Participants were instructed to complete the IPAQ directly after finishing the accelerometer data assessment and to return the material using a prepaid envelope. Data assessment took place between February 2011 and April 2012. The study was approved by the ethical committees of the Cantons of Aargau, Ticino, Wallis and Zurich and all participants provided written informed consent.

### 2.2. Measurements

Demographic data was available from the consent form (age, sex, language region) and from the SAPALDIA database, respectively.

#### 2.2.1. Accelerometers

Accelerometer data was collected using Actigraph GT3X (Actigraph, Pensacola, FL, USA) devices with an epoch time of 60 s (Troost et al., 2005). The normal filter option was applied (Wanner et al., 2013). The Actilife 5 software was used to initialize and download the accelerometers. The device was attached to an elastic belt and individuals were asked to wear it on the right hip during waking hours for 8 consecutive days. Individuals were included in the analyses if valid data was available for at least 4 days (Troost et al., 2005) including at least one weekend day. A day was considered valid if at least 10 h of data were recorded. A maximum of 7 days were included in the analyses; if 8 valid days were available ( $N = 321$ , 92.5%), the first day of wearing was omitted because wearing the device may affect physical activity behaviour at the beginning of data collection (Esliger et al., 2005).

#### 2.2.2. Questionnaire

The long IPAQ was used in German, French and Italian in a paper-and-pencil version. The German version was based on the Austrian translation (available at [https://sites.google.com/site/theipaq/questionnaire\\_links](https://sites.google.com/site/theipaq/questionnaire_links)). The French version was based on the translation used in France (Criniere et al., 2011). The Italian version was kindly provided by the Department of Neuroscience, Section of Kinesiology, School of Exercise and Sport Science at the University of Verona. The questionnaires underwent minor cultural adaptations to the respective Swiss context. For example, instead of "Strassenbahn" (Austria) we used the word "Tram" (Switzerland) for tramway. The German, French and Italian IPAQ that we used are provided in Supplementary Material Document 1.

#### 2.3. Statistical analyses

The individual Actigraph files were cleaned using the MeterPlus software (Santech Inc., version 4.2). Non-wear time was defined as 60 or more minutes of consecutive zeros. In order to classify accelerometer output data into different physical activity intensity categories, cut points were used as follows. We calculated minutes per week spent in sedentary (<150 cpm) (Kozey-Keadle et al., 2011), light (150–2019 cpm), moderate (2020–5998 cpm) and vigorous ( $\geq 5999$  cpm) physical activity (Metzger et al., 2008) as well as the number of steps per day. The cut points for moderate and vigorous activities were based on those used to analyse NHANES data (Metzger et al., 2008; Troiano et al., 2008).

IPAQ data were processed, cleaned and truncated according to the IPAQ protocol (International Physical Activity Questionnaire team, 2005). Minutes per week spent in moderate- and vigorous-intensity activities, the time spent walking and sitting were calculated. MET-minutes per week (Metabolic Equivalent) were calculated for different intensities and domains of physical activity and for total activity. One MET is equal to the energy expended during rest ( $3.5 \text{ ml O}_2 \text{ kg}^{-1} \text{ min}^{-1}$ ). Based on frequency, duration and intensity of self-reported physical activity, individuals were categorized into low, moderate and high physical activity groups as suggested by the IPAQ scoring protocol (International Physical Activity Questionnaire team, 2005).

IPAQ and accelerometer outcome variables were reported as means and standard deviations (SD). Spearman correlations were used to compare IPAQ and accelerometer data. 95% confidence intervals (95% CI) based on Fisher's  $z$  transformation were calculated and differences between sub groups according to sex, age and language region tested (command "cortesti" in STATA). Bland-Altman plots show the extent of agreement between the two measures.

Different accelerometer output measures (cpm, total min/week in moderate-to-vigorous physical activity, moderate-intensity physical

activity, and sitting time) were displayed according to the IPAQ physical activity categories using box plots and one-way analyses of variance to test the differences between activity categories. The level of statistical significance was set to  $p < 0.05$ . STATA IC version 12 was used for analyses (StataCorp LP, College Station, Texas, 2011).

### 3. Results

#### 3.1. Characteristics of study population

351 participants had valid accelerometer data. Of these, 346 individuals provided a completed IPAQ and were included in the present study (SAPALDIA 3:  $N = 230$  (66.5%), convenience sample:  $N = 116$  (33.5%)). The characteristics of the participants are described in Table 1.

#### 3.2. Objective and self-reported physical activity and sitting time

Table 2 shows the physical activity levels for IPAQ and accelerometer data. The differences were considerable with physical activity being over-reported and sitting time under-reported in the IPAQ. Time spent in moderate-to-vigorous physical activity was 4.2 times higher according to the IPAQ than to accelerometers. Accelerometer sitting time was almost twice as high as IPAQ sitting time. According to both IPAQ and accelerometers, men spent more time in vigorous-intensity activities. With regard to the IPAQ, women spent more time in moderate-intensity activity, however, this difference was not apparent in the accelerometer data. Sitting time was slightly higher in men than in women for both self-reported and objectively measured variables. The overestimation factor of total physical activity in the IPAQ compared to accelerometer data was 3.8 in men and 4.5 in women.

Accelerometer data revealed that those over 65 years were less active than younger individuals for all physical activity variables. However, according to the IPAQ, this age group appeared to be the most active one regarding moderate-intensity and total physical activity. Thus overestimation in the IPAQ compared to accelerometer data was highest in the oldest age group (5.9) and lowest in the youngest age group (2.6). Both IPAQ and accelerometer data showed that the youngest age group was more active in vigorous-intensity activities compared to the older age groups. At the same time, the youngest age group engaged in more sitting time than the older age groups according to both instruments.

Total self-reported physical activity was highest in the Italian speaking part and similar in the German and the French speaking regions. Similar patterns were seen for moderate-intensity physical activity. According to accelerometer data, individuals in the German speaking part were the most active. Overestimation was lowest in the German speaking part (3.4) and highest in the Italian speaking part (5.0). Vigorous-intensity physical activity was highest in the German speaking part according to both instruments. Sitting time was highest in the German speaking part according to the IPAQ but similar according to accelerometer data.

**Table 1**  
Characteristics of study population (Switzerland, 2011,  $N = 346$ ).

	All participants	Men	Women	p
N	346	157	189	
Gender (%)	100	45.4	54.6	
Mean age (years)	54.6	57.0	52.6	0.01
Age category (%)				
18–39 years	17.1	13.4	20.1	
40–65 years	52.6	49.0	55.6	
>65 years	30.3	37.6	24.3	0.02
Language region (%)				
German-speaking	40.2	48.4	33.3	
French-speaking	30.9	30.6	31.2	
Italian-speaking	28.9	21.0	35.5	0.004

#### 3.3. Agreement between self-reported and objective physical activity and sitting time

Table 3 shows the Spearman correlations between IPAQ and accelerometer data. A version of Table 3 including the 95% CI based on Fisher's z transformation is available in Supplementary Material Table 1. Correlations were highest for vigorous-intensity activities, sitting time and leisure-time physical activity (IPAQ). No correlations for moderate-intensity activities between IPAQ and accelerometer data were observed, however, self-reported walking was correlated with objectively measured moderate-intensity physical activity. Furthermore, self-reported moderate-intensity physical activity showed correlations with light activities (accelerometer).

Significant gender differences were apparent for leisure-time physical activity (men:  $r = 0.35$  versus women:  $r = 0.57$ ,  $p = 0.012$ ) and for sitting time (men:  $r = 0.28$  versus women:  $r = 0.53$ ,  $p = 0.007$ ). For vigorous physical activity, the differences between men ( $r = 0.31$ ) and women ( $r = 0.48$ ) were not significant ( $p = 0.087$ ). Differences between age groups were present for sitting time between the youngest ( $r = 0.72$ ) and the middle ( $r = 0.36$ ,  $p < 0.001$ ) as well as between the youngest and the oldest age group ( $r = 0.34$ ,  $p = 0.001$ ). For leisure-time physical activity, differences between age groups were not significant (youngest ( $r = 0.34$ ) versus middle ( $r = 0.56$ ),  $p = 0.082$ ; middle versus oldest ( $r = 0.37$ ),  $p = 0.069$ ). The correlation between self-reported moderate-intensity activities and objectively measured light activities was highest in the oldest age group (but not significantly different to the younger age groups). Differences between language regions were present for vigorous physical activity (German:  $r = 0.28$  versus Italian:  $r = 0.53$ ,  $p = 0.033$ ).

#### 3.4. Comparison between different accelerometer output measures and IPAQ activity categories

Fig. 1a–d shows different accelerometer output measures by IPAQ physical activity category (low, moderate, high). For all measures, there was a significant difference between the means according to the three activity categories. Mean accelerometer counts/min were 228 in the low, 320 in the moderate and 379 in the high physical activity category ( $F = 14.1$ ,  $p < 0.001$ ). Mean moderate-to-vigorous accelerometer min/week were 118 in the low, 250 in the moderate and 299 in the high activity group ( $F = 10.4$ ,  $p < 0.001$ ). For sitting time according to accelerometers, mean min/week were lower in higher physical activity categories: 4410 min/week in the low, 4326 in the moderate and 4038 in the high activity category ( $F = 8.7$ ,  $p < 0.001$ ).

#### 3.5. Bland Altman plots

Fig. 2 shows the Bland–Altman plots for the agreement of data assessed with accelerometers and with the IPAQ. The plots for total, moderate and vigorous-intensity physical activity with mostly negative differences between accelerometer and IPAQ data support the fact that these activities were overestimated in the IPAQ. For sitting time, the differences are more often greater than zero indicating that sitting time tended to be underestimated in the IPAQ. The plots show furthermore that there is an association between the mean and the difference, with higher means resulting in larger (negative) differences.

In addition, Supplementary Material Fig. 1 shows the Bland–Altman plot for total physical activity (corresponding to Fig. 2a) by region, showing that the patterns are very similar irrespective of the region.

## 4. Discussion

The correlation coefficients found in the present study were in the same range as reported in other studies (Craig et al., 2003; Criniere et al., 2011; Gauthier et al., 2009; Hagstromer et al., 2010; Kim et al., 2013; Lee et al., 2011; Mader et al., 2006; Rosenberg et al., 2008),

**Table 2**  
Objective and self-reported physical activity behaviour (mean (SD)) by gender, age group and language region (Switzerland, 2011, N = 346).

	All	Gender		Age group			Language region		
		Men	Women	18–39 years	40–64 years	≥65 years	German	French	Italian
<b>Total physical activity</b>									
IPAQ long (MET-min/week)	4989 (4422)	5306 (4826)	4704 (4020)	4688 (4419)	4780 (4262)	5692 (4748)	4774 (4135)	4740 (4569)	5569 (4655)
IPAQ long (min/week mvpa)	1064 (749)	1064 (766)	1064 (737)	938 (779)	1054 (751)	1190 (712)	984 (697)	1032 (723)	1213 (834)
Actigraph (counts/min)	338 (144)	345 (150)	332 (139)	393 (140)	347 (149)	290 (123)	355 (149)	319 (142)	333 (137)
Actigraph (min/week mvpa)	256 (188)	277 (193)	239 (183)	360 (183)	254 (190)	201 (163)	289 (191)	225 (190)	243 (176)
<b>Vigorous physical activity</b>									
IPAQ long (min/week)	150 (253)	219 (322)	89 (150)	214 (255)	134 (264)	138 (224)	188 (288)	131 (246)	117 (200)
Actigraph (min/week)	14 (35)	16 (34)	12 (35)	40 (54)	11 (30)	5 (18)	19 (34)	10 (33)	11 (37)
<b>Moderate physical activity</b>									
IPAQ long (min/week)	514 (439)	455 (411)	566 (458)	370 (391)	510 (431)	629 (462)	508 (433)	447 (390)	592 (487)
IPAQ long (min/week incl. walking)	919 (663)	869 (627)	963 (693)	731 (643)	931 (677)	1043 (623)	816 (602)	894 (622)	1090 (757)
Actigraph (min/week)	241 (174)	259 (182)	226 (166)	319 (161)	242 (180)	195 (156)	268 (179)	214 (176)	231 (160)
<b>Sitting time</b>									
IPAQ long (h/week)	37.0 (19.8)	37.7 (20.6)	36.5 (19.1)	40.4 (18.5)	37.4 (20.3)	34.2 (19.2)	41.2 (20.2)	33.4 (15.7)	35.2 (22.3)
IPAQ long (h/week incl. motorized transport)	43.2 (20.5)	44.1 (21.8)	42.5 (19.4)	48.2 (18.3)	43.3 (21.2)	39.9 (20.1)	47.0 (20.7)	39.1 (17.6)	42.6 (22.6)
Actigraph (h/week)	69.3 (11.0)	71.4 (11.0)	67.6 (10.7)	72.7 (8.7)	68.3 (12.4)	69.2 (9.1)	70.9 (11.1)	68.2 (9.3)	68.2 (12.2)

mvpa = moderate-to-vigorous physical activity.

indicating modest validity of the IPAQ. Furthermore, highest correlations between IPAQ and accelerometer data for vigorous-intensity physical activity (Kim et al., 2013) and for sitting time (Craig et al., 2003) were described elsewhere. We observed some differences in the correlations by gender (for leisure-time physical activity and sitting time), age group (for sitting time) and language region (for vigorous physical activity). For all other correlations and especially for total physical activity, there were no significant differences between sub groups. Total physical activity was 4.2 times higher according to the IPAQ than to accelerometer data; this overestimation was highest in the oldest age group and lowest in the youngest age group.

Differences between sub groups were most apparent for those correlations that were high in the total population (vigorous-intensity activities, leisure-time activities, sitting time). Most gender differences showed a tendency of higher correlations in women, which was not reported elsewhere (Hagstromer et al., 2010), except for sitting time (Rosenberg et al., 2008). Correlations for sitting time were higher in the youngest age group. Estimating sitting time may be easier for younger adults with a daily job routine than for retired individuals. The lower correlations in older individuals for some variables and the highest overestimation may be related to problems identified when administering the IPAQ to older adults (Heesch et al., 2010). Qualitative research has reported difficulties for this population group to complete the short IPAQ, especially with regard to moderate-intensity items, walking

and sitting time (Heesch et al., 2010). However, the authors concluded that there might be similar problems when the IPAQ is used in younger populations. Furthermore, the short IPAQ has been validated against accelerometers in older adults in South Africa (Kolbe-Alexander et al., 2006), Sweden (Hurtig-Wennlof et al., 2010) and the US (Grimm et al., 2012) with acceptable correlations around 0.20–0.50.

Some differences between sub groups were apparent. However, the correlations were all in an acceptable range indicating that the use of the IPAQ is not limited to specific sub groups. The fact that some correlations differed by gender, age and language region may point out the need for considering potential bias when estimating associations between physical activity and health in epidemiological studies. However, there were no differences between sub-groups for total physical activity which is the variable most commonly used in such studies. Misclassification of physical activity levels when investigated in relation to health outcomes will tend to dilute effects.

While there were no correlations between moderate-intensity physical activities, IPAQ walking was significantly correlated with objectively measured moderate activities. This may be due to the fact that accelerometers are especially useful for measuring ambulatory activities but have limitations when assessing non-ambulatory activities such as cycling (Corder et al., 2007).

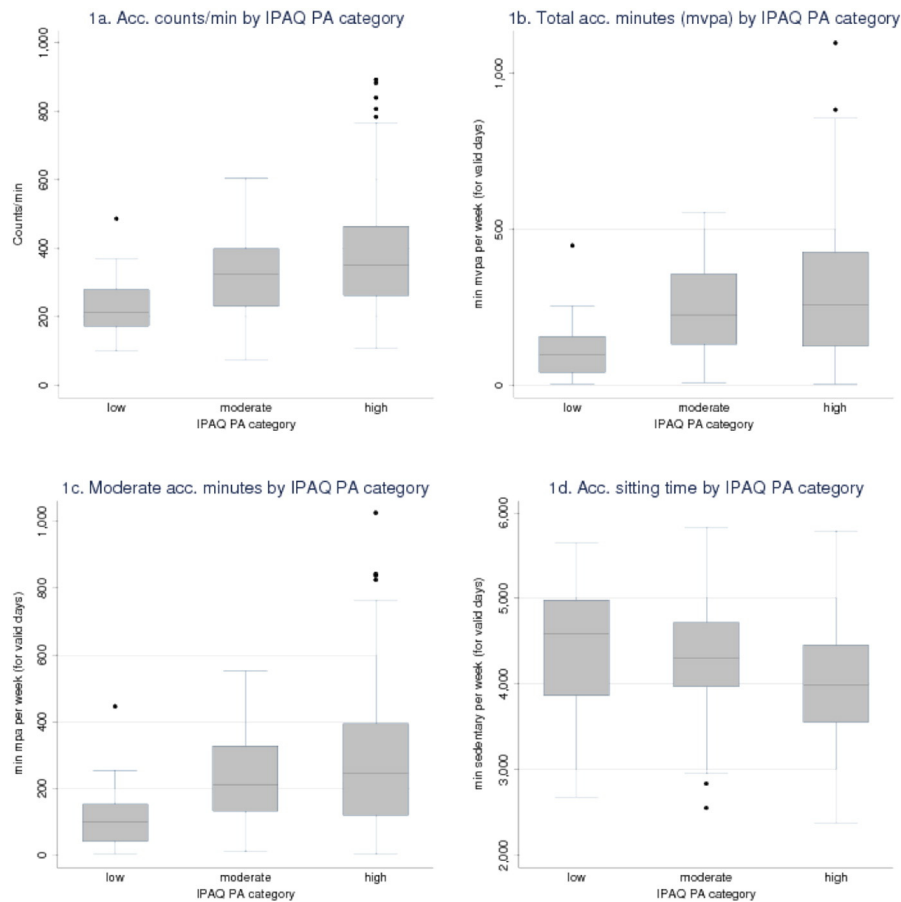
Self-reported moderate-intensity activity seemed to better correlate with objectively measured light activities. This may reflect the problem

**Table 3**  
Spearman correlations (r) for time spent in different physical activity intensities and domains as recorded by IPAQ long and Actigraph accelerometers (Switzerland, 2011, N = 346).

IPAQ long	Actigraph	All	Gender		Age group			Language region		
			Men	Women	18–39 years	40–64 years	≥65 years	German	French	Italian
Total (MET-min/week)	Total (counts/min)	0.27***	0.27**	0.28**	0.27	0.34***	0.32**	0.33***	0.30**	0.19
Total (min mvpa/week)	Total (min mvpa/week)	0.09	0.16	0.04	0.09	0.21*	−0.01	0.12	0.14	0.04
Vigorous (min/week)	Vigorous (min/week)	0.41***	0.31***	0.48***	0.40**	0.40***	0.28**	0.28**	0.36***	0.53***
Moderate (min/week)	Moderate (min/week)	−0.12*	−0.06	−0.13	−0.15	−0.03	−0.11	−0.16	−0.08	−0.09
Moderate (min/week)	Light (min/week)	0.37***	0.34***	0.38***	0.32*	0.37***	0.42***	0.43***	0.26*	0.40***
Moderate + walking (min/week)	Moderate (min/week)	0.03	0.10	−0.01	0.00	0.13	−0.02	0.08	0.07	0.00
Moderate + walking (min/week)	Light (min/week)	0.34***	0.33***	0.33***	0.35**	0.31***	0.39***	0.47***	0.21	0.27*
Walking (min/week)	Moderate (min/week)	0.27***	0.29***	0.25**	0.24	0.33***	0.29**	0.35***	0.32**	0.21*
Sitting time (h/week) incl. motorized transport	Sitting time (h/week)	0.42***	0.28***	0.53***	0.72***	0.36***	0.34**	0.39***	0.46***	0.32**
Physical activity at work (MET-min/week)	mvpa (min/week)	0.03	0.10	−0.05	−0.03	0.02	−0.07	0.07	0.04	0.00
Physical activity for transport (MET-min/week)	mvpa (min/week)	0.25***	0.22**	0.28***	0.32*	0.28***	0.26*	0.19*	0.28**	0.27**
Domestic physical activity (MET-min/week)	mvpa (min/week)	−0.20***	−0.16	−0.20*	0.04	−0.13	−0.12	−0.25**	−0.16	−0.13
Leisure-time physical activity (MET-min/week)	mvpa (min/week)	0.48***	0.35***	0.57***	0.34**	0.56***	0.37***	0.44***	0.51***	0.45***

mvpa = moderate-to-vigorous physical activity.

\* p < 0.05.  
\*\* p < 0.01.  
\*\*\* p < 0.001.



**Fig. 1.** Different accelerometer output measures by IPAQ physical activity category (Switzerland, 2011, N = 346).

Acc = accelerometer, mpa = moderate physical activity, mvpa = moderate-to-vigorous physical activity, PA = physical activity, IPAQ = International Physical Activity Questionnaire. Box includes the range from 25th to 75th percentile (line = median), whiskers display the upper and lower adjacent values, dots display outside values; adjacent values = most extreme values within 1.5 IQR of the nearer quartile.

of estimating the intensity of physical activity. Especially in older adults, moderate activities reported in the IPAQ seemed to better reflect light activities measured objectively. However, the classification of activity intensities using accelerometer data is also dependent on the cut points used (Strath et al., 2003). Accelerometer cut points specifically developed for older populations may be useful in the future (Hall et al., 2013).

Overestimation of physical activity and underestimation of sitting time has been described elsewhere (Grimm et al., 2012), therefore absolute physical activity levels measured by the IPAQ have to be interpreted with caution. However, the IPAQ seems to be able to produce a ranking in the study population which is comparable to the one based on objective physical activity. This is supported by the illustrations in Fig. 1 showing significantly higher objectively measured activity levels in higher IPAQ activity categories.

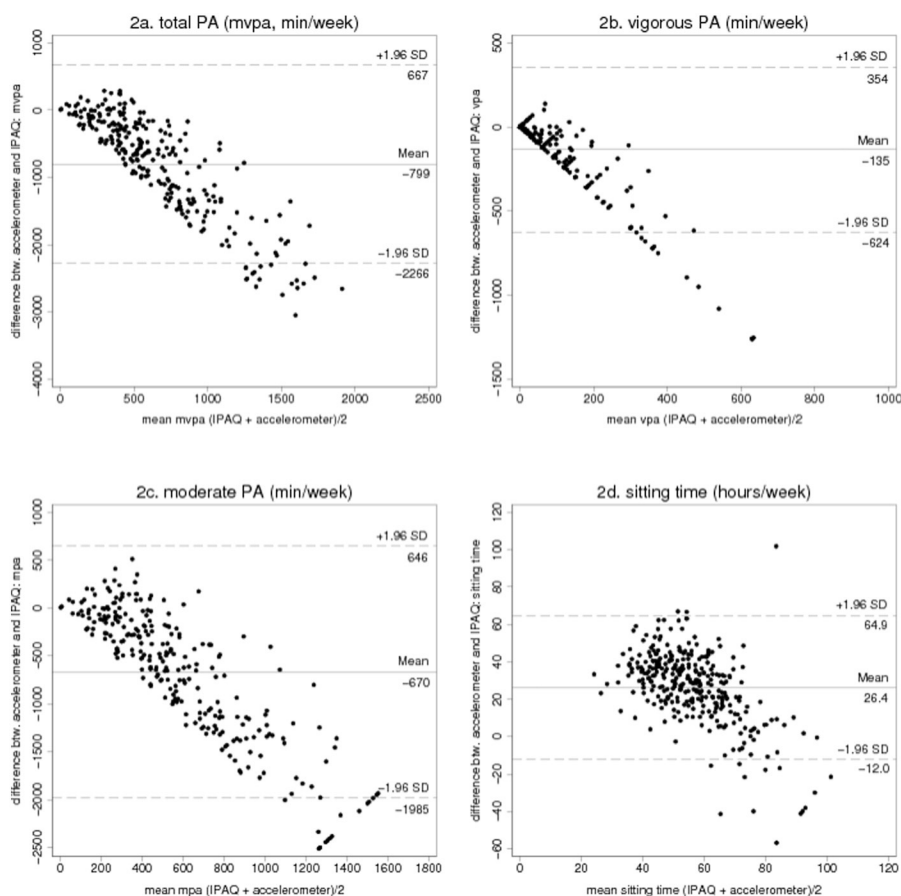
The validation of questionnaires with objective measurements was considered as the best level of evidence in a systematic review of measurement properties of physical activity questionnaires (van Poppel et al., 2010). Nevertheless, we have to keep in mind that questionnaires and accelerometers are distinct methods: While accelerometers quantify acceleration resulting from bodily movement at a fixed point of the body, self-report instruments reflect reported time periods engaged in specific behaviours (Troiano et al., 2014).

Strengths of this study are the relatively large sample size and the inclusion of individuals from diverse backgrounds regarding age and language region. Furthermore, accelerometers as objective measures were used for comparison and compliance was high (>90% of the included sample had eight valid days of accelerometer assessment). A limitation is that the IPAQ is not directly comparable to physical activity levels

assessed with short questionnaires, and a reference to the physical activity guidelines of 150 min per week of moderate-to-vigorous activities (World Health Organization, 2010) (which are historically based on evidence from short questionnaires) is difficult. Furthermore, the results may be influenced by selection bias. The SAPALDIA sample included in this study was considerably smaller than the overall SAPALDIA study sample, in part because the recruitment into this validation study started after the general recruitment for the second study follow-up. Yet, as the recruitment into the second study follow-up was unselected with regard to participant characteristics, we do not expect that the belated implementation of the validation study contributed considerably to bias. Baseline (SAPALDIA 1) and 2nd follow-up (SAPALDIA 3) characteristics of participants in the validation study compared to non-participants demonstrate that the validation study sample was slightly younger and had less doctor diagnosed cardiovascular disease (Supplementary Material Table 2). However, these differences would only bias the results if the correlation between IPAQ and accelerometer derived measures varied between included and excluded participants. Finally, it is possible that due to wearing an accelerometer, participants were more aware of their physical activities which could have had an impact on completing the IPAQ.

## 5. Conclusions

This study, including a diverse sample of adults from a wide age range and different language regions, showed moderate validity of the long IPAQ when compared to accelerometer data with correlations in a similar range as reported in other studies. Highest correlations were



**Fig. 2.** Bland–Altman plots for the agreement of data assessed with accelerometers and with the IPAQ (Switzerland, 2011, N = 346). mpa = moderate physical activity, mvpa = moderate-to-vigorous physical activity, PA = physical activity, vpa = vigorous physical activity.

reported for vigorous-intensity and leisure-time activities as well as for sitting time. Differences between sub groups do not seem to limit the applicability of the IPAQ in specific population groups, especially as there were no differences regarding total physical activity. However, it has to be kept in mind that compared to accelerometer data, physical activity was generally overestimated and sitting time generally underestimated in the IPAQ.

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.pmedr.2016.03.003>.

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### Conflict of interest

The authors declare that there are no conflicts of interest.

### Transparency document

The [Transparency document](#) associated with this article can be found in the online version.

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