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ORIGINAL ARTICLE

Concurrent validity of a modified version of the International Physical Activity Questionnaire (IPAQ-A) in European adolescents: The HELENA Study

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Introduction: The International Physical Activity Questionnaire (IPAQ) was developed to measure health-enhancing physical activity in adult populations. This study explores the concurrent validity of a modified version of the long IPAQ (the IPAQ-A) for the assessment of physical activity among adolescents.
Participants and methods: In total, 248 healthy adolescents, divided into one older and one younger age group (aged 15–17 years ($N=188$) and 12–14 years ($N=60$), respectively) from nine Healthy Lifestyle by Nutrition in Adolescence (HELENA) Study centres across Europe, voluntarily participated in the study. Data on total physical activity, as well as activities in different intensities derived from the IPAQ-A, were compared using Spearman's correlation coefficient and Bland–Altman analysis, with data from an accelerometer. Tertiles of total physical activity for the IPAQ-A and the accelerometer were compared using Kendall's tau-b.
Results: For the older age group, significant correlations between the instruments were found for time spent walking, for moderate and vigorous activities as well as for total physical activity (Rs = 0.17–0.30, $P<0.05$). No significant correlations were found for any of the variables studied in the younger age group. Kendall's tau-b showed low but significant correlations for tertiles of total physical activity ($P<0.001$).
Conclusions: The IPAQ-A has reasonable validity properties for assessing activities in different intensities and for total physical activity in healthy European adolescents aged 15–17 years. For adolescents aged 14 years and younger, the correlations were unsatisfactorily low and objective methodology, such as accelerometry, may be the appropriate alternative.
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Keywords: accelerometry; assessment methodology; children; exercise; IPAQ

Introduction

The importance of physical activity for promoting health and preventing disease in the adult population is well known.[1,2] The dose-response relationship between physical activity and health outcomes in children and adolescents has not been studied to the same extent and is less clear. To describe the level and pattern of physical activity, to establish a dose-response relationship, and to be able to follow national and international trends, it is necessary to have standardized, reliable and valid instruments that can be used in many countries.[3,4]

One of the aims of the Healthy Lifestyle by Nutrition in Adolescence (HELENA) Study is to describe the level and patterns of physical activity in European adolescents.[5] Most of the physical activity instruments available for adolescents deal with a subset of total daily activity, that is, leisure time sports.[6] The International Physical Activity Questionnaire (IPAQ)[7] has been developed to enable the measurement of all

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[8]See Appendix at the end of the supplement on page S82.

dimensions of health-enhancing physical activity in the adult population (18–65 years of age) in different cultural milieus.[7,8] This questionnaire is available in a short (IPAQ-S) and a long (IPAQ-L) version and can be used to gather self-reported data or to structure a (telephone) interview. The time period of interest is the last 7 days. The IPAQ instrument, in particular the short version, has gained a wide acceptance. It has been used in a series of international and national studies, such as the WHO's World Health Survey, two EU Eurobarometers, the International Prevalence Study and many national surveys. The long version of IPAQ is used mainly in physical activity research and details the frequency, intensity and context of the activity reported.

The rationale and structure of IPAQ should also make it possible to measure a wide range of health-enhancing physical activities in a younger population, with some adaptations, but until now such a version has not been developed and tested for use in European adolescents.

The aim of this study was to test the concurrent validity of a modified, long, self-administered version of IPAQ using accelerometry in a group of adolescents (12–17 years of age) from the HELENA Study centres.

Participants and method

Study design

This is a cross-sectional study on adolescents comparing data on the level and patterns of physical activity obtained by a modified version of the self-administered version of IPAQ-L with that obtained from accelerometer measurements. The study is part of the HELENA Study.[5]

Participants

The study took place in nine centres: Athens (Greece), Dortmund (Germany), Ghent (Belgium), Lille (France), Pécs (Hungary), Rome (Italy), Vienna (Austria), Stockholm/Västerås (Sweden) and Zaragoza (Spain).

Adolescents from the first two randomly chosen school classes of each study centre were invited to take part in the study. For a class to be eligible, at least 70% of the class had to participate. The ethics committee of each study centre approved the study protocol and the adolescents and parents provided a written informed consent.

Measurement of physical activity

The modified IPAQ instrument. Interviews with adolescents and other experiences from the study centres led to the identification of several necessary adaptations. First, the 'work' domain was changed to the 'school' domain. It asked about physical activity in physical education classes and during breaks. Physical activity during class hours was not considered as the adolescents were mainly sitting or standing during this period of time. Second, to avoid overreporting, the household domain was shortened to include only one question (cf. three in IPAQ) about physical activities in the garden or at home, such as carrying loads, washing windows, scrubbing floors or sweeping. Third, the order of activity intensities was changed so that walking was investigated first, followed by moderate and then vigorous activities. Experience with the adult version has shown more over-reporting with the original order (vigorous, moderate and walking) than with the revised order.[9]

After adaptation, the questionnaire was translated into French, Flemish, German, Greek, Hungarian, Italian, Spanish and Swedish and back-translated into English following the instructions given in the IPAQ manual.[7]

The modified questionnaire, hereafter referred to as the International Physical Activity Questionnaire for Adolescents (IPAQ-A), covered four domains of physical activity: (1) school-related physical activity, including activity during physical education classes and breaks, (2) transportation, (3) housework and (4) leisure time. In each of the four domains, the numbers of days per week and time periods per day spent walking, in moderate activity and in vigorous activity were recorded. Moderate intensity was defined in absolute terms as 3–6 metabolic equivalents (METs) and vigorous intensity was defined as more than six METs.[10] One MET is resting metabolic rate during quiet sitting, and is equal to 3.5 ml of O_2 $kg^{-1} min^{-1}$ in adults. Practical examples of culturally relevant moderate and vigorous activities were given.

The data were cleaned and truncated following the guidelines provided by the IPAQ group.[7] Minutes at each intensity exceeding 180 per day were truncated to 180, to avoid extreme outliers. Outcome measures were minutes per day reported in vigorous, moderate and walking activities, as well as MET minutes per day as a measure of total health-enhancing activity. Before comparison with moderate intensity (3–6 MET) from the accelerometer, minutes in walking and moderate activity were combined. For calculation of the total physical activity, the data were transformed into energy expenditure estimated as METs using published values and recommendations from the IPAQ scoring protocol.[11,12] To calculate the daily physical activity (MET minutes per day), the number of minutes reported in each activity level was multiplied by the specific MET score for that activity.[8]

The accelerometer. The accelerometer used (Actigraph MTI, model GT1M, Manufacturing Technology Inc., Fort Walton Beach, FL, USA) measures accelerations (G) from 0.05 to 2.1 G in the vertical axis. It is equipped with a filter, which discriminates human movements from vibrations. The output from the monitor is sampled 10 times per second and summed over a selected time interval or epoch.[13] The sum of accelerations was transformed into counts. The monitor was secured underneath clothing at the lower back using an elastic belt and was worn for 7 consecutive days. It was initialized as described by the manufacturer and a 15-s epoch was used.

The data were uploaded onto a computer and analysed by software based on Visual Basic. To reduce the possibility of

the activity monitor not being worn during the day skewing the results, periods of zero values for more than 10 min were excluded from the analysis. Potential accelerometer malfunction was identified when more than 20 000 counts per minute were recorded. All spurious data were set to missing values and excluded from the analyses. The measures obtained were time spent on low, moderate and vigorous intensity physical activity, and average daily intensity.

Age-specific cutoff points for the different intensities were used to calculate the time per day (minutes per day) spent at these intensity levels.[14] An average of the 12-, 13- and 14-year-old cutoff points and the 15-, 16- and 17-year-old cutoff points was used for the two age groups. A measure for total activity as average intensity was expressed as counts per recorded time (counts per minute) and was thereafter compared with the self-reported total activity (MET minutes per day).

The criterion for inclusion was an accelerometer recording of at least 10 h per day, for 4 days, of which one had to be a weekend day. The minimum number of hours per day was set according to the global reliability and validity study of IPAQ,[8] and the minimum number of recorded days according to the suggestion by Trost *et al*.[15]

Procedure

On day 1, the adolescents were invited to the study centre and were instructed, verbally and in writing, on how to handle the accelerometer. They were asked to wear the monitor during the daytime, except while bathing or during other aquatic activities. Starting on day 2, the adolescents wore the accelerometer for 7 consecutive days. On day 8, the adolescents returned to the study centre and completed the IPAQ-A.

Statistical analysis

All statistical analyses were performed using the software Statistical Product and Service Solutions (version 15.0 SPSS Inc., Chicago, IL, USA).

Before analysis, the adolescents were divided into two age groups, one older and one younger (aged 15–17 years and 12–14 years, respectively). The outcomes from the accelerometer and the IPAQ-A were described by mean and s.d. in total and by age groups. The mean differences between the two instruments were tested using Student's paired *t*-test.

The data were analysed both for the whole group and by age groups. Non-parametric Spearman's rank correlation coefficients (Rs) were calculated to assess the relationship between minutes per day in each intensity level and total physical activity as MET minutes per day from the IPAQ-A data and similar data from the accelerometer. The significance of the correlation coefficients was judged according to Altman (1991). The Bland and Altman method[16,17] was used to provide an indication of the systematic random error and the heteroscedasticity of the data, and 95% limits of agreement were used for describing the total error between the two methods. The variables used for the Bland and Altman analysis were daily time spent on moderate and vigorous activities according to the IPAQ-A and the accelerometer.

Tertiles of total physical activity given as MET minutes per day from the IPAQ-A (Q1 = 0–362, Q2 = 363–708 and Q3 = 709–2214) and total physical activity measured by the accelerometer (Q1 = 51–113, Q2 = 114–162 and Q3 = 163–762) given as counts per minute were compared using Kendall's tau-b and presented as a figure.

The level of significance was set at $P<0.05$.

Results

A total number of 248 adolescents (51% boys) had eligible data, with 188 in the older age group and 60 in the younger age group. The number of adolescents from each centre was, Athens (Greece), 23; Dortmund (Germany), 22; Ghent (Belgium), 26; Lille (France), 41; Pécs (Hungary), 19; Rome (Italy), 28; Vienna (Austria), 16; Stockholm/Västerås (Sweden), 40 and Zaragoza (Spain), 33.

Table 1 shows descriptive data from the accelerometer and the IPAQ-A instruments, stratified by age groups and in total.

Table 1 Descriptive physical activity obtained by the Actigraph accelerometer and the IPAQ-A, respectively

	All (N = *248*)		*15–17 years* (N = *188*)		*12–14 years* (N = *60*)	
	Actigraph[a]	*IPAQ-A*	*Actigraph*[a]	*IPAQ-A*	*Actigraph*[a]	*IPAQ-A*
Total measured time (min day^{-1})[b]	739 (83)	160 (117)	722 (77)	154 (110)	792 (81)	179 (137)
Vigorous intensity PA (min day^{-1})	10 (9)	32 (42)	10 (7)	32 (42)	10 (6)	39 (47)
Moderate intensity PA (min day^{-1})	105 (40)	66 (53)	114 (39)	71 (55)	74 (25)	83 (59)
Walking (min day^{-1})		61 (58)		59 (58)		69 (60)
Low intensity PA (min day^{-1})	169 (36)		169 (36)		170 (40)	
	Counts min^{-1}	*MET min day*$^{-1}$	*Counts min*$^{-1}$	*MET min day*$^{-1}$	*Counts min*$^{-1}$	*MET min day*$^{-1}$
Total PA	182 (126)	616 (470)	142 (87)	592 (438)	309 (144)	709 (547)

Abbreviations: IPAQ-A, International Physical Activity Questionnaire for Adolescents; MET, metabolic equivalent; PA, physical activity. Mean (s.d.). [a]Student's paired *t*-test between the results of the accelerometer and the IPAQ. $P<0.001$; regarding the IPAQ-A, moderate walking and moderate PA were summed before comparison with the accelerometer. [b]Total measured time for the IPAQ-A is the time spent on vigorous, moderate and walking activities; the total measured time for the accelerometer is the wearing time including low and sedentary activities.

Table 2 Spearman's rank correlation coefficient (Rs) of time spent on physical activity (min^{-1}) measured by the Actigraph accelerometer and the IPAQ-A, respectively ($N=248^a$)

	Actigraph								
	Moderate			Low			Average intensity		
	All	15–17 years	12–14 years	All	15–17 years	12–14 years	All	15–17 years	12–14 years
Actigraph									
Vigorous	0.32**	0.44**	0.29*	0.01	0.00	0.08	0.68**	0.81**	0.53*
Moderate				0.23**	0.23**	0.47**	0.07	0.64**	−0.07
Low							0.05	0.10	0.21
Average intensity									
IPAQ-A									
Vigorous									
Moderate									
Walking									

	IPAQ-A											
	Vigorous			Moderate			Walking			Total (MET)		
	All	15–17 years	12–14 years	All	15–17 years	12–14 years	All	15–17 years	12–14 years	All	15–17 years	12–14 years
Actigraph												
Vigorous	0.27**	0.30**	0.19	0.04	0.09	−0.22	0.01	0.00	0.02	0.18**	0.20**	0.11
Moderate	0.19**	0.26**	0.20	0.15*	0.25**	−0.07	0.04	0.16*	−0.11	0.18**	0.29**	0.03
Low	0.14*	0.16*	0.03	0.19*	0.27**	−0.01	0.06	0.08	0.02	0.20**	0.28**	−0.01
Average intensity	0.23*	0.30**	0.08	0.10	0.15*	−0.10	0.15*	0.12	0.15	0.20**	0.27**	0.08
IPAQ-A												
Vigorous				0.42**	0.37**	0.55**	0.27**	0.16*	0.55**	0.77**	0.75**	0.85**
Moderate							0.37**	0.32**	0.52**	0.74**	0.74**	0.74**
Walking										0.60**	0.54**	0.74**

Abbreviation: IPAQ-A, International Physical Activity Questionnaire for Adolescents. [a]Age 15–17 years, $N=188$; age 12–14 years, $N=60$. *$P<0.05$ and **$P<0.01$.

On average, the accelerometers were worn for a mean of 738 min per day, which equals 12 h. The average time spent on vigorous and moderate activities from the accelerometer was 10 and 105 min, respectively. The adolescents reported on average 61 min walking, 66 min moderate activity and 32 min vigorous activity per day on the IPAQ-A, which is, in all cases, significantly more than the average measured time using the accelerometer ($P<0.001$).

Table 2 shows the Spearman's rank order correlations of the physical activity measures using the accelerometer and measures the IPAQ-A in total and separated into age groups. Modest but significant correlations were observed for the older age group for vigorous, moderate, walking and total physical activities (Rs = 0.17–0.30, $P<0.05$). No significant correlations between the instruments were found for any of the variables studied in the younger age group. Correlation analysis was also performed by sex and study centre separately. The results were similar to those of the whole sample and are therefore not shown.

Figure 1 shows the Bland and Altman analyses of moderate activity from the IPAQ-A and the accelerometer for the older and younger age groups, respectively. The mean (s.d.) differences were −8 (89) min day^{-1}(NS) and −67 (108) min day^{-1}($P<0.001$), respectively. The 95% limits of agreement were large and the higher the values reported in the IPAQ-A, the larger the errors between the instruments ($R^2=0.48$ and 0.78, respectively).

Figure 2 shows the Bland and Altman analyses of vigorous intensity obtained by the IPAQ-A and the accelerometer for the older and younger age groups, respectively. The mean (s.d.) differences were −21 (40) min day^{-1} ($P<0.001$) and −28 (46) min day^{-1} ($P<0.001$), respectively. The 95% limits of agreement were large and the higher the values reported in the IPAQ-A, the larger the errors between the instruments ($R^2=0.81$ and 0.93, respectively).

Figure 3 describes the number of participants in tertiles of total physical activity with the IPAQ-A and the accelerometer. A significant but weak association was found between the instruments for the total sample (Kendall's tau-b, 0.18 and $P<0.001$) and for the older age group (Kendall's tau-b, 0.22 and $P<0.001$). The figure shows consistent associations between the two methods at low and high tertiles of physical activity. No significant correlations were found for the younger age group.

Discussion

This validation study is unusual, as data have been collected on adolescents from randomly chosen schools in nine European countries. The results showed that the IPAQ-A data were significantly correlated with the accelerometer data in the older age group of adolescents but not in the younger age group.

The IPAQ was carefully adapted for adolescents based on interviews and experiences from the study centres. Never-

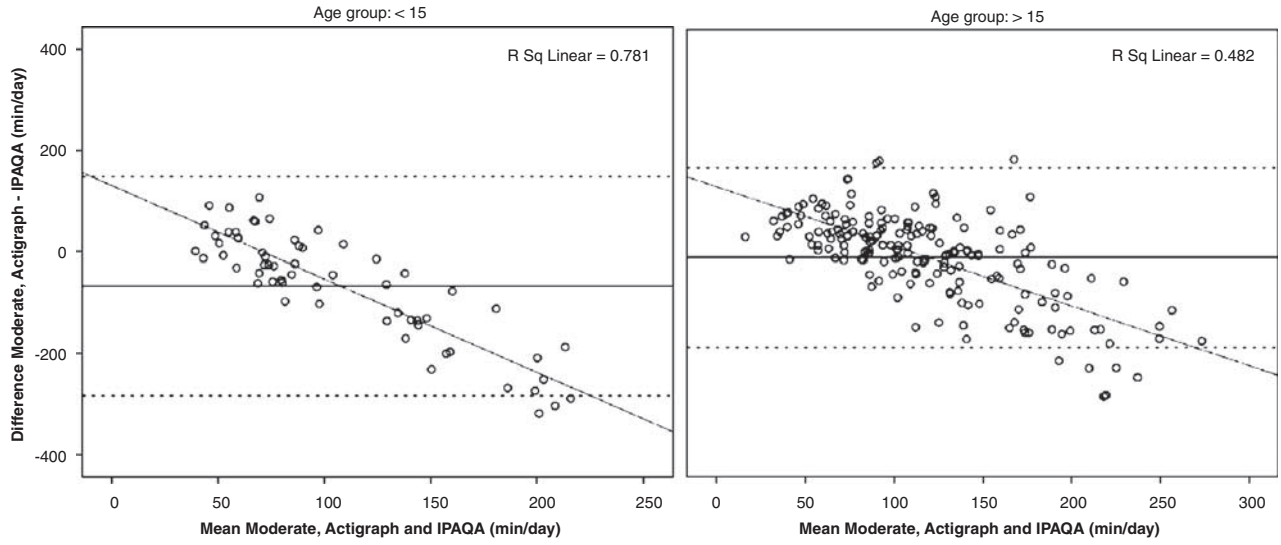

Figure 1 Bland–Altman plot for time spent in all moderate intensity activity (minutes per day) for adolescents aged 12–14 years and 15–17 years, respectively. Mean difference −67 min day^{-1} ± 2 s.d.; −283 to 149 min day^{-1} ($P<0.001$) and −8 min day^{-1} ± 2 s.d. and −186 to 170 min day^{-1} ($P=0.214$), respectively.

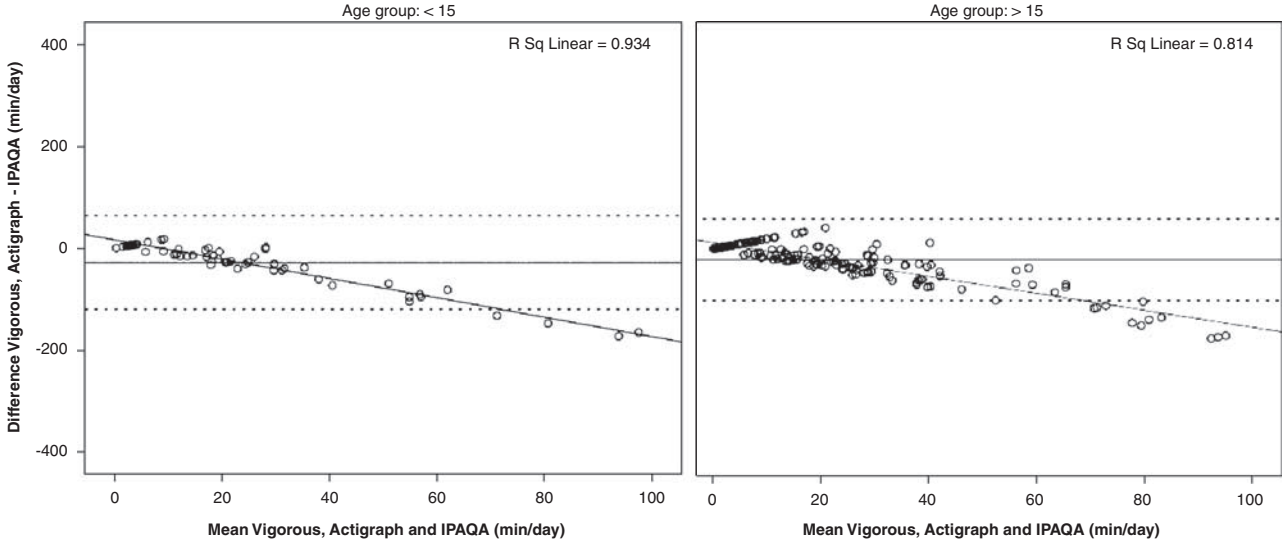

Figure 2 Bland–Altman plot for time spent in vigorous intensity activity (min day^{-1}) for adolescents aged 12–14 years and 15–17 years, respectively. Mean difference −28 min day^{-1} ± 2 s.d.; −120 to 64 min day^{-1} ($P<0.001$) and −21 min day^{-1} ± 2 s.d.; −101 to 59 min day^{-1} ($P<0.001$), respectively.

theless, interindividual variation in the understanding of the concepts under investigation here is likely to exist. Furthermore, when calculating the total physical activity as MET minutes per day from the IPAQ-A, estimates from a published compendium on energy costs were used.[11,12] One limitation of this is that a single estimate of the energy costs of a specific activity is applied to all adolescents.[11,12,18] This does not allow for interindividual variation in energy expenditure for a given intensity or for variations in mechanical and metabolic efficiency.[19–21] In addition, the compendium is derived from studies on adults. However, these published estimates of energy costs of different physical activities are the only ones for which data are available.

An accelerometer (Actigraph, MTI) was considered a criterion measure for concurrent validity. Uniaxial accelerometers, such as the Actigraph, can provide information about acceleration in the vertical plane. They are precise in assessing ambulatory activities, which are likely to make up a large part of the physical activity performed by adolescents. However, accelerometers are known to underestimate physical activity at specific activities, and this may lead to an underestimation of total energy expenditure.[22–24] As accelerometers can only provide information about acceleration,

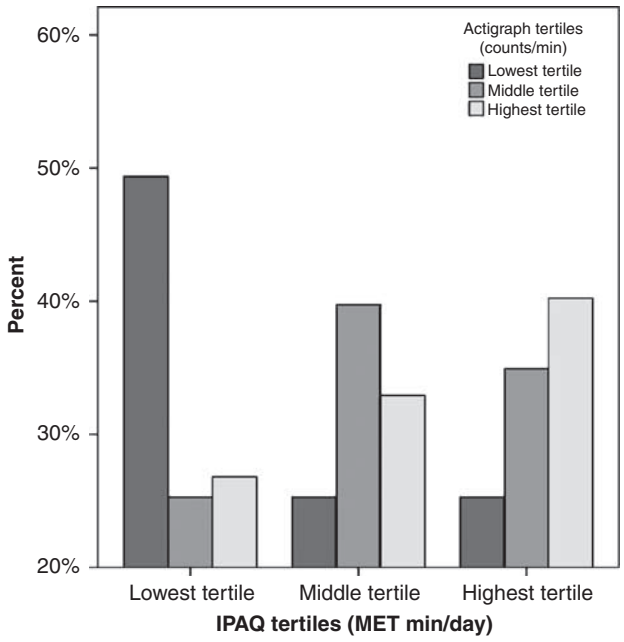

Figure 3 IPAQ-A total physical activity tertiles by total physical activity using the Actigraph.

they do not yield correct information about the intensity of activities such as carrying heavy loads, walking on stairs, skating or riding a bike. They are also not suitable for use during water activities.

For the accelerometer output, cutoff values of vigorous and moderate physical activities from an experimental study were used.[14] The use of these cutoff points in field studies has been criticized.[23,25,26] It seems that when establishing cutoff points, the results are affected by the types of activities and the settings in which the calibration between activity counts and energy expenditure estimates is performed.[27] In this study, it is mostly ambulatory activity that is captured by the cut points used, meaning that the results have to be interpreted carefully.

The accelerometer measurements were performed for the same time period as that which the questionnaire referred to. There is, therefore, no reason to believe that the respondents did not refer to the same week when answering the questionnaire as that measured by the accelerometer.

The low correlations found especially among the younger age group may be explained by several factors. First, the concepts used might not be as easily understood and interpreted by the younger adolescents. As well as providing less accurate information, the younger adolescents may also be involved in different types of activities that could be responsible for the low validity scores. The older adolescents are more likely to either participate in structured activity (sports) or be sedentary, whereas the younger adolescents and children are more often engaged in spontaneous activities. These types of activities are more difficult to assess with a questionnaire. The IPAQ instrument was developed for use in adults from the age of approximately 18 years and above, and hence, it is not illogical that the IPAQ-A was more valid in the older adolescents than in younger group.

It has been reported before that children and younger adolescents may have difficulties in reporting their physical activities.[28] Weak but significant associations between questionnaires and accelerometer data have been found in other studies with adolescents,[29–31] particularly in young adolescents.[30] Good measurements of low and moderate physical activities, using self-reported means, have been shown to be the most difficult to obtain for both adults and adolescents.[20,21,28] These activities are being accumulated throughout the day and the number as well as diversity of these activities is great, resulting in poor recall.

In contrast, high intensity physical activities, such as different types of exercise, are more structured and stable over time and are easier to recall. The stronger correlations found in this study regarding the vigorous intensity of physical activity compared with moderate intensity illustrate this point and agree with earlier findings.[19]

In the older age group, no significant differences between the instruments for moderate intensity were found. However, the Bland–Altman plots showed that the higher the reported time, the larger the error between the instruments. This can partly be explained by the detailed design of the instrument. The more possibilities that can be filled in, the larger the error will be. If each domain is overestimated by, for example, 10 min per day, this will yield an overestimation of 40–60 min per day if a participant is active in all domains.

When data were analysed by tertiles of total physical activity, low but significant correlations were found between the instruments for older age group, indicating that the IPAQ-A can satisfactorily detect not only the least active but also the highly active participants.

If the aim is to measure total physical activity of different intensities, objective physical activity methods, such as accelerometers, should be prioritized in future epidemiological studies in children and adolescents, as children are less able than adults to recall their physical activity. However, from a public health perspective, it is also important to know the context in which physical activity occurs in adolescents. Heart rate monitors or accelerometers do not provide information on those contexts (school-related activity, active transportation, housework, leisure time activity and sports), which are crucial to develop future interventions. Our results suggest that more work is needed to look into the specific problems of the IPAQ-A for younger adolescents. Additional changes in the questionnaire will be required to tailor it more to their environments and experiences, and to help them to fill it in more accurately.

In conclusion, the results from this study show that the IPAQ-A has reasonable validity properties for assessing intensities and total physical activity in healthy European adolescents aged 15–17 years. For adolescents aged 14 years and younger, the correlations were unsatisfactorily low and

objective methodology, such as accelerometry, may be the appropriate alternative.

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Conflict of interest

The authors state no conflict of interest.

References

1 CDC. *Physical Activity and Health. A Report from the Surgeon General*. CDC: Pittsburg, 1996.
2 Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scand J Med Sci Sports* 2006; **16** (Suppl 1): 3–63.
3 Brown W, Bauman A, Chey T, Trost S, Mummery K. Comparison of surveys used to measure physical activity. *Aust N Z J Public Health* 2004; **28**: 128–134.
4 WHA. World Health Assembly 57.17. Global Strategy on diet, physical activity and health, 2004, pp 1–4.
5 Moreno LA, González-Gross M, Kersting M, Molnár D, de Henauw S, Beghin L *et al*. Assessing, understanding and modifying nutritional status, eating habits and physical activity in European adolescents. The HELENA study. *Public Health Nutr* 2008; **6**: 288–299.
6 Aarnio M, Winter T, Kujala U, Kaprio J. Associations of health related behaviour, social relationships, and health status with persistent physical activity and inactivity: a study of Finnish adolescent twins. *Br J Sports Med* 2002; **36**: 360–364.
7 IPAQ. *The International Physical Activity Questionnaire*, http://www.ipaq.ki.se/.
8 Craig C, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE *et al*. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc* 2003; **35**: 1381–1395.
9 Barnett J, Nigg CR, De Bourdeaudhuij I, Maglione C, Maddock J. The effect of item order on physical activity estimates using the IPAQ. *Californian J Health Promot* 2007; **5**: 23–29.
10 ACSM. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc* 1998; **30**: 975–991.
11 Ainsworth BE, Haskell WL, Leon AS, Jacobs Jr DR, Montoye HJ, Sallis JF *et al*. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc* 1993; **25**: 71–80.
12 Ainsworth BE, Haskell WL, Whitt MC, Irwin ML, Swartz AM, Strath SJ *et al*. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc* 2000; **32**: S498–S504.
13 Computer Science Application. *Activity Monitor Operator's Manual*. In: Shallimar FL (ed). Model 7164 version AM7164;2-2, 1995, pp 3–24.
14 Trost SG, Ward DS, Moorehead SM, Watson PD, Riner W, Burke JR. Validity of the computer science and applications (CSA) activity monitor in children. *Med Sci Sports Exerc* 1998; **30**: 629–633.
15 Trost SG, Pate RR, Freedson PS, Sallis JF, Taylor WC. Using objective physical activity measures with youth: how many days of monitoring are needed? *Med Sci Sports Exerc* 2000; **32**: 426–431.
16 Altman D. *Practical Statistics for Medical Research*. Chapman & Hall: London, 1991.
17 Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med* 1998; **26**: 217–238.
18 Sirard JR, Pate RR. Physical activity assessment in children and adolescents. *Sports Med* 2001; **31**: 439–454.
19 Welk G. *Physical Assessment in Health-Related Research*. Human Kinetics: Leeds, UK, 2002.
20 Washburn RA, Heath GW, Jackson AW. Reliability and validity issues concerning large-scale surveillance of physical activity. *Res Q Exerc Sport* 2000; **71**: S104–S113.
21 Bassett Jr DR. Validity and reliability issues in objective monitoring of physical activity. *Res Q Exerc Sport* 2000; **71**: S30–S36.
22 Sirard JR, Melanson EL, Li L, Freedson PS. Field evaluation of the Computer Science and Applications, Inc. physical activity monitor. *Med Sci Sports Exerc* 2000; **32**: 695–700.
23 Hendelman D, Miller K, Baggett C, Debold E, Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med Sci Sports Exerc* 2000; **32**: S442–S449.
24 Ekelund U, Yngve A, Sjostrom M, Westerterp K. Field evaluation of the Computer Science and Application's Inc. Activity monitor during running and skating training in adolescent athletes. *Int J Sports Med* 2000; **21**: 586–592.
25 Ainsworth BE, Bassett Jr DR, Strath SJ, Swartz AM, O'Brien WL, Thompson RW *et al*. Comparison of three methods for measuring the time spent in physical activity. *Med Sci Sports Exerc* 2000; **32**: S457–S464.
26 Nichols JF, Morgan CG, Chabot LE, Sallis JF, Calfas KJ. Assessment of physical activity with the Computer Science and Applications, Inc. accelerometer: laboratory versus field validation. *Res Q Exerc Sport* 2000; **71**: 36–43.
27 Yngve A, Nilsson A, Sjostrom M, Ekelund U. Effect of monitor placement and of activity setting on the MTI accelerometer output. *Med Sci Sports Exerc* 2003; **35**: 320–326.
28 Caspersen CJ, Nixon PA, DuRant RH. Physical activity epidemiology applied to children and adolescents. *Exerc Sport Sci Rev* 1998; **26**: 341–403.
29 Crocker PR, Bailey DA, Faulkner RA, Kowalski KC, McGrath R. Measuring general levels of physical activity: preliminary evidence for the Physical Activity Questionnaire for Older Children. *Med Sci Sports Exerc* 1997; **29**: 1344–1349.
30 Wong SL, Leatherdale ST, Manske SR. Reliability and validity of a school-based physical activity questionnaire. *Med Sci Sports Exerc* 2006; **38**: 1593–1600.
31 McMurray RG, Ring KB, Treuth MS, Welk GJ, Pate RR, Schmitz KH *et al*. Comparison of two approaches to structured physical activity surveys for adolescents. *Med Sci Sports Exerc* 2004; **36**: 2135–2143.