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Original research

Comparison of the IPAQ-A and Actigraph in relation to VO_2max among European adolescents: The HELENA study

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Abstract

The purpose was to compare data obtained from a modified, long, self-administered version of the International Physical Activity Questionnaire (IPAQ-A) with objective data obtained in parallel from Actigraph accelerometers, and VO_2max in adolescents. The study comprised a total of 2018 adolescents (46% male) from ten European cities participating in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. Physical activity was assessed over seven consecutive days by accelerometry and expressed as min/day of moderate, vigorous, and moderate to vigorous (MVPA) physical activity (PA). PA was also assessed with the IPAQ-A. VO_2max was estimated from a 20-m shuttle run test. Poor to fair correlations between the two methodologies were found for the whole study sample and when stratified by age and gender ($r_s = 0.08$–0.26, $p < 0.01$). On average, the self-reported time spent in moderate PA was higher compared to the time measured with the accelerometer, while the differences between both instruments were less clear for vigorous intensity. Adolescents reporting high levels of PA (3rd tertile IPAQ-A) also showed higher levels of PA (accelerometers) in all the study variables (moderate, vigorous and MVPA), compared to adolescents reporting low PA (1st tertile IPAQ-A) (all $p < 0.001$). Both methods were moderately correlated with estimated VO_2max. Within the HELENA-study, the IPAQ-A showed the modest comparability with the accelerometer data for assessing PA in each intensity level and was the highest for vigorous intensity. Both instruments are able to detect the adolescents with the highest cardio respiratory fitness, which are the most active adolescents.

Keywords: Motor activity; Physical activity measurement; Youth; Measurement; Physical activity and exercise methodology

1. Introduction

Self-reported questionnaires are used to assess physical activity (PA) at population level.[1] A questionnaire extensively and broadly tested among adults is

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the International Physical Activity Questionnaire (IPAQ) (http://www.ipaq.ki.se/ipaq.htm). IPAQ was originally developed as a cross-national monitoring tool for PA and inactivity in adults (age range of 15–69 years). Long and short versions of the questionnaire are available. The long version provides separate domain specific scores for walking, moderate-intensity and vigorous-intensity activity within each of the work, transportation, domestic chores and gardening and leisure-time domains. Important drawbacks have been recognized when using questionnaires in youth.[2] The sporadic nature of children's PA[3] makes physical activities difficult to recall, quantify and categorize. Because leisure time activity is more difficult to quantify than occupational activity,[2] recall bias is a bigger problem when working with adolescents. Also, in comparison with objective measurements, adolescents tend to overestimate the recall of their vigorous PA and underestimate the recall of their moderate PA, which is more sporadic and less organized and therefore less memorable and quantifiable.[2]

Objective assessments of PA, such as accelerometry, are now widely being used for assessing PA in youth.[4] However, the most accurate and reliable methodology for PA assessment in youth still remains to be defined. Therefore both methods (accelerometry and self-reporting questionnaires) were used in the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) study. The aim of the present study was to examine how comparable these two methodologies are among European adolescents. Secondly, both methods were compared with an objective measure for cardio respiratory fitness, to investigate if they are able to identify adolescents with high PA intensity levels, using VO_2max as a surrogate marker for high PA intensity.[5]

2. Methods

The HELENA-study was conducted in 10 European cities (Athens in Greece, Dortmund in Germany, Ghent in Belgium, Heraklion in Crete, Lille in France, Pecs in Hungary, Rome in Italy, Stockholm in Sweden, Vienna in Austria, and Zaragoza in Spain) from 2006 to 2007. The main objective was to obtain reliable and comparable data of a sample of European adolescents (12.5–17 years) on a variety of nutrition and health related parameters, such as PA, via standardized procedures.[6] The study was approved by the Ethical Committee of each study centre involved.[7] A signed informed consent was obtained from both the adolescents and their parents. Details on sampling procedures and study design of the study have been reported before.[6]

The Actigraph accelerometer model GT1M (Actigraph MTI, Manufacturing Technology Inc., Pensacola, FL, USA), was used to assess PA. This small uni-axial accelerometer measures accelerations (G) from 0.05 to 2.1 G in the vertical axis. Its acceleration is filtered, which discriminates human movements from vibrations. The data is stored at a sampling rate of 10 samples per second and summed over a selected time interval or epoch. The accelerometers were initialized as described by the manufacturer. For the present study, data was saved in 15 s epochs. Each adolescent was monitored for 7 consecutive days. The adolescents wore the accelerometers on the lower back, secured with an elastic belt, underneath clothing and only during the waking hours. They were also advised not to wear the monitor during aquatic activities. After the testing period, the accelerometers were collected by the researcher and data were uploaded onto a computer. The rough data of all participants were analyzed centrally to ensure standardization. Data with periods of zero values of more than 20 min were excluded from the analysis. A recording of more than 20,000 counts/min was seen as a potential malfunction of the accelerometer and was also excluded from the analyses. Data were considered as valid if the adolescents had accelerometer counts for at least 3 days with at least 8 h of recording time per day. Data were analyzed for min/day spent in moderate and vigorous intensity. The time engaged at moderate PA (3–6 metabolic equivalents) was calculated based on cut-off points of 2000–3999 counts/min. The lower cut-off of 2000 counts/min, is equivalent to walking at 4 km/h.[8] The time spent in vigorous PA (>6 metabolic equivalents) was calculated based on a cut-off of $\geq$4000 counts/min. Those cut-off points are similar to those used in previous studies.[9] The time engaged in at least moderate PA (MVPA, $\geq$2000 counts/min) was also calculated.

To assess PA of the last 7 days, IPAQ-A (International Physical Activity Questionnaire for Adolescents, see Appendix B supplementary material), an adapted version of the IPAQ, was used, which was filled at the end of the testing period. Questions about PA at work had been replaced by questions about PA at school (i.e. physical education, walking, moderate and vigorous PA at school). Furthermore, only one question (versus three in the original IPAQ) about PA in the garden or at home remained. Also, the order of PA intensities was changed, to avoid over reporting.[10] The time spent at walking was asked before the time spent at vigorous and moderate intensity (versus vigorous, moderate and walking in the original IPAQ). For each of the four domains (school, transport, housework and leisure time), total min/week were computed followed by min/week for walking, moderate and vigorous PA based on the guidelines for data processing and analyses of the IPAQ (http://www.ipaq.ki.se/ipaq.htm). The data were cleaned and truncated based on previous research.[11] As part of the HELENA-study, IPAQ-A was pretested for validity by comparing the IPAQ-A results with accelerometer data.[12] Significant, but the modest correlations (−0.07–0.30) and a higher validity in the older adolescents in comparison with the younger ones were found.

During the period of examinations, the adolescents also conducted a physical fitness test, which was developed to assess several health related physical fitness components

(flexibility, muscular strength, speed/agility and cardio respiratory capacity).[13] A 20-m shuttle run test was performed to measure aerobic fitness and was described earlier by Léger et al.[14] Maximal oxygen consumption (VO_2max) was estimated from the 20-m shuttle run test via the Ruiz and Léger equations.[14,15]

A total of 2018 adolescents (46% male) with valid data on IPAQ-A (86.2% of total sample) and 3-day accelerometer data (62.4% of total sample) were included in this study. A complete 7 day accelerometer registration was only obtained for 27.5% ($n = 970$) of the total HELENA-study sample ($n = 3528$). Comparison of gender distribution, age, weight, height, and BMI between the original HELENA-study sample ($n = 3528$) and the present study ($n = 2018$) revealed that only the male group of the present study had significantly lower weight and BMI values.

All statistical analyses were performed for the total population and stratified by gender and age (younger: 12.5–14.99 years; older: 15–17.5 years), using the software Statistical Package for the Social Sciences (version 15.0 SPSS Inc., Chicago, IL, USA). The outcome of the IPAQ-A and the Actigraph are described in total time spent per day (min/day) in three different intensity levels, namely moderate, vigorous and MVPA. The median and the inter quartile range (IQR) of the PA scores derived from both instruments are reported (Table 1). The differences between the two instruments were tested using the Wilcoxon Signed Ranks Test. To balance between type I and type II errors, an alpha level of $p < 0.05$ was used to decide upon statistical significance. To determine the relation between min/day in each intensity level from the IPAQ-A and the Actigraph, non-parametric Spearman's rank correlation coefficients (r_s) were calculated. Agreement between the IPAQ-A and the Actigraph was assessed using the Bland and Altman method.[16] The Bland and Altman plots give an indication of the systematic and random error and the heteroscedasticity of the IPAQ-A measures of PA. For describing the total error between the two methods, 95% limits of agreement were used. Individual results for time spent in a certain PA level, calculated by the IPAQ-A and accelerometer, were classified into tertiles. This was done to assess the ability of the IPAQ-A for classifying individuals in the same tertile of time spent at a certain PA level as the accelerometer. To determine the measurement error of the IPAQ-A, 'actual values for surrogate categories' were calculated as follows: adolescents were assigned to tertiles according to the IPAQ-A PA scores. Then within these tertiles the mean PA score, as measured with the accelerometer, was calculated and compared with a Kruskal–Wallis test across IPAQ-A tertiles. The Pearson's chi-square test was used to examine the differences between the IPAQ-A and Actigraph when classifying the adolescents in reaching the PA recommendation for youth, which states that adolescents should accumulate at least 60 min/day of MVPA.[17] Spearman rank correlations were used to examine the relationship between both methods and VO_2max.

Table 1
Median time spent at different intensities of physical activity according to subjective methodology, questionnaire (IPAQ-A), and objective methodology, accelerometer (the Actigraph), in the total sample and stratified by gender and age category.

	Male				Female				Total			
	N	IPAQ-A (IQR)	Acceler. (IQR)	Diff. (%)	*N*	IPAQ-A (IQR)	Acceler. (IQR)	Diff. (%)	*N*	IPAQ-A (IQR)	Acceler. (IQR)	Diff. (%)
12.5–14.99 year												
Moderate PA (min/day)		68 (34–118)	43 (34–54)	37*		63 (33–111)	36 (28–44)	43*		64 (34–116)	38 (31–48)	41*
Vigorous PA (min/day)	518	34 (9–75)	22 (13–32)	35*	634	13 (0–34)	11 (6–18)	15*	1152	19 (3–51)	15 (9–25)	21*
MVPA (min/day)		109 (59–183)	65 (50–85)	40*		81 (43–139)	48 (37–61)	41*		93 (50–162)	55 (42–72)	41*
15–17.5 year												
Moderate PA (min/day)		49 (24–94)	37 (29–47)	24*		43 (20–86)	35 (28–44)	19*		46 (21–90)	36 (28–45)	22*
Vigorous PA (min/day)	416	26 (6–54)	23 (15–34)	12*	450	6 (0–26)	14 (7–22)	−133	866	14 (0–41)	18 (10–28)	−29
MVPA (min/day)		86 (42–143)	62 (47–76)	28*		58 (26–110)	50 (38–65)	14*		70 (33–129)	55 (42–71)	21*
Total												
Moderate PA (min/day)		60 (29–109)	40 (32–50)	33*		51 (26–99)	36 (28–44)	29*		56 (29–47)	37 (27–104)	34*
Vigorous PA (min/day)	934	30 (9–64)	22 (14–33)	27*	1084	9 (0–33)	12 (6–19)	−33*	2018	17 (9–26)	16 (0–50)	6*
MVPA (min/day)		97 (51–169)	64 (49–81)	34*		71 (36–129)	49 (37–62)	31*		81 (42–71)	55 (82–230)	32*

Data are median (IQR); IQR, inter quartile range (25th percentile to 75th percentile); PA, physical activity.
* $p < 0.05$ for difference between instruments used (IPAQ-A versus Actigraph), based on Wilcoxon Signed Ranks Test.

Table 2
Spearman's rank correlations coefficient for time spent on physical activity (min/day) from IPAQ-A and Actigraph.

IPAQ-A versus Actigraph (min/day)	Total ($N = 2018$)	By age		By gender	
		Youngest 12.5–14.99 ($N = 1152$)	Oldest 15–17.5 ($N = 866$)	Male ($N = 934$)	Female ($N = 1084$)
Moderate	0.15*	0.13*	0.14*	0.21*	0.08*
Vigorous	0.25*	0.26*	0.26*	0.15*	0.17*
Moderate + vigorous	0.21*	0.20*	0.22*	0.21*	0.13*

* Correlation is significant at the 0.01 level (2-tailed).

3. Results

Table 1 presents descriptive data from both instruments by gender, by age category, and for the whole study sample. The median values for the reported time of moderate PA on the IPAQ-A were significantly higher than those registered with the accelerometer. Significant yet small differences were observed in vigorous PA between both instruments. Likewise, significant differences between methods in MVPA were found. When stratified by gender and age category the same trend could be seen.

The Spearman rank correlations for the PA assessments using the IPAQ-A and the accelerometer are shown in Table 2. For the whole study sample low to fair correlations were found for the different PA intensities.

In Fig. 1 the Bland and Altman plots for moderate and vigorous PA show the differences between the IPAQ-A and the accelerometer. For both intensities, differences (i.e. error) between the IPAQ-A and the accelerometer scores increased as the min/day reported in the IPAQ-A were higher. In other words, the higher the time spent in a certain level of PA assessed by the accelerometer, the higher the difference between both methods.

In Table 3, actual values for surrogate IPAQ-A tertiles showed a progressive increase in PA, for all intensities, between the 1st and the 3rd tertile, with significant differences in mean PA time between the different tertiles.

Percentage of adolescents complying with the PA recommendations is shown in Fig. 2. According to the findings obtained with the IPAQ-A, more adolescents reached the PA recommendations compared to the results of the accelerometer. Except for the male adolescents in the younger age group, the differences between both instruments were significant.

Table 4 reports Spearman rank correlations for the time spent on PA, measured with the IPAQ-A and the accelerometer, and the estimated VO_2max. Because the results were similar for the VO_2max estimated via the Ruiz and Léger equations, only those from the Ruiz equation were reported. For the whole study sample low to moderate correlations were found for both instruments for the different PA intensities. The correlation coefficients were the highest for vigorous PA when compared with moderate PA and MVPA. For the different intensities, the Actigraph reported higher correlation coefficients than the IPAQ-A. When stratifying by age and gender, correlations were still significant, but clearly higher for vigorous PA and MVPA than moderate PA. Higher correlations were found for the IPAQ-A among the oldest adolescents, but lower correlations for the Actigraph when compared with the youngest. This was the case for all inten-

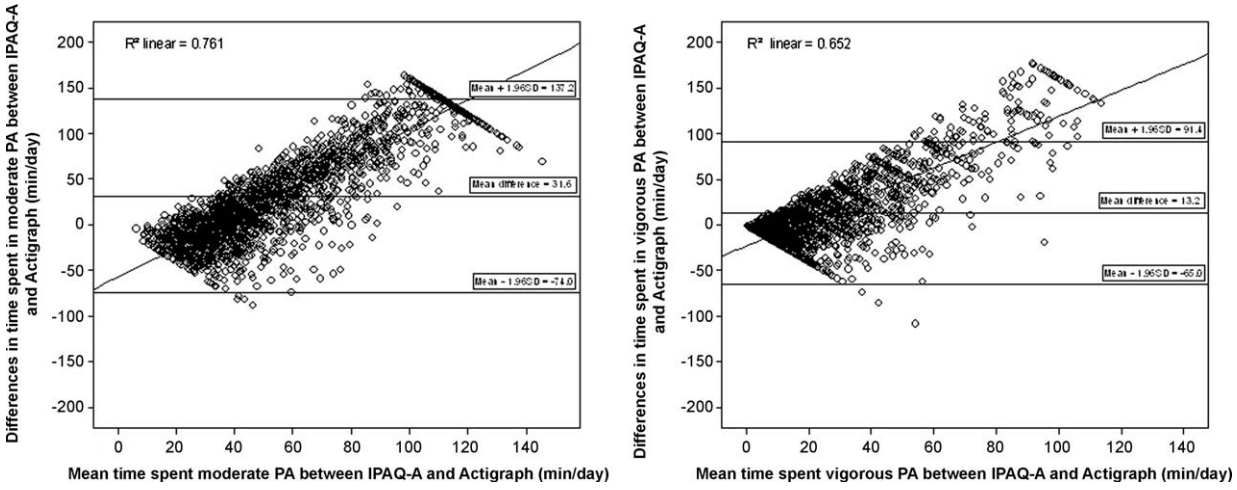

Fig. 1. Bland and Altman plots with differences in mean time spent in moderate and vigorous physical activity (PA) for the IPAQ-A and the Actigraph.

Table 3
Use of actual values for tertile categories to compare physical activity (min/day) of the IPAQ-A with the Actigraph (mean values and standard deviations).

	Time spent in PA (min/day)[a] IPAQ-A tertiles				
	T1 mean (SD)	T2 mean (SD)	T3 mean (SD)	χ^2	$p^{\dagger}$
Moderate PA					
IPAQ-A	18 (9.7)	56 (14.4)	137 (34.6)		
Actigraph	37 (14.2)	38 (13.7)	42 (14.6)	44.3	<0.001
Vigorous PA					
IPAQ-A	1 (1.4)	17 (7.8)	75 (39.8)		
Actigraph	16 (12.9)	18 (12.1)	23 (14.3)	113.1	<0.001
MVPA					
IPAQ-A	28 (15.1)	83 (18.2)	198 (61.0)		
Actigraph	54 (21.7)	58 (22.9)	64 (24.5)	70.6	<0.001

PA, physical activity.
[a] 'Mean values' based on the accelerometer data were assigned to the categories defined by the surrogate method (IPAQ-A).
[†] Kruskal–Wallis test was used to investigate differences between Actigraph values for IPAQ-A tertiles.

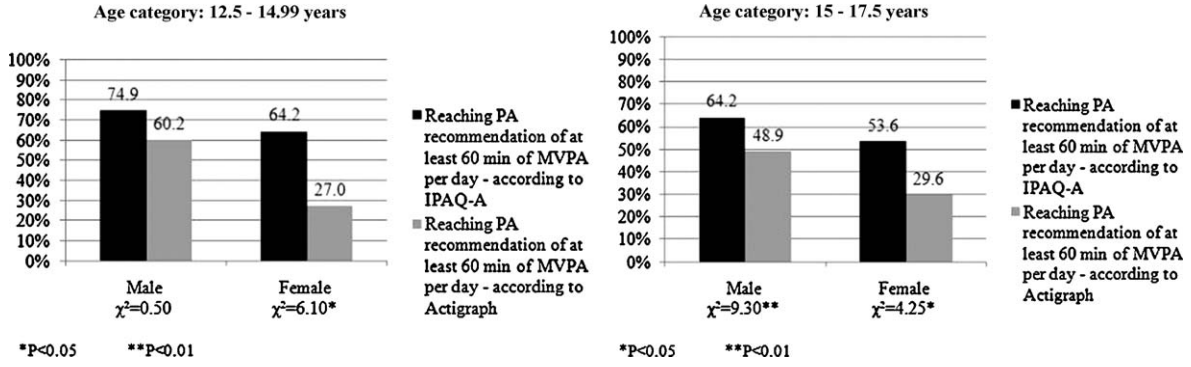

Fig. 2. Percentage of adolescents reaching the PA recommendation of 60 min of MVPA per day according to IPAQ-A and Actigraph measurements (by age category and for the total sample, separated by gender).

Table 4
Spearman's rank correlation coefficients for time spent on physical activity (min/day) from IPAQ-A & Actigraph and VO_2max (estimated via Ruiz equation).

PA (min/day)	VO_2max				
	Total (N = 1696)	By age		By gender	
		Youngest 12.5–14.99 (N = 993)	Oldest 15–17.5 (N = 703)	Male (N = 792)	Female (N = 904)
Moderate PA					
Actigraph	0.20**	0.28**	0.08*	0.10**	0.12**
IPAQ-A	0.08**	0.08*	0.12**	0.08*	0.07*
Vigorous PA					
Actigraph	0.47**	0.52**	0.40**	0.25**	0.30**
IPAQ-A	0.35**	0.33**	0.41**	0.26**	0.19**
MVPA					
Actigraph	0.37**	0.43**	0.28**	0.19**	0.23**
IPAQ-A	0.21**	0.20**	0.26**	0.17**	0.13**

PA, physical activity; MVPA, moderate to vigorous physical activity.
[*] Correlation is significant at the 0.05 level (2-tailed).
[**] Correlation is significant at the 0.01 level (2-tailed).

sities. Correlation coefficients were comparable between the male and female adolescents.

4. Discussion

The HELENA pilot study[12] showed that the IPAQ-A data were moderately correlated with the data from accelerometry. For the whole study population the correlation coefficients found in the present study for moderate and vigorous PA intensity (0.15 and 0.25, respectively) are similar to those found in the validation study (0.15 and 0.27, respectively). When stratifying by age, Hagstromer et al.[12] only reported significant correlations in the older age category, while the findings in the current full-scale study showed similar correlation coefficients for the older and younger adolescents for all

PA intensities. However, the present results indicated a larger median difference between both methods used to assess total time spent in PA in the younger age category compared to the older adolescents. Since the Bland–Altman plots showed a worse agreement at higher levels of PA, the well-known higher activity levels of younger people[2,18] could explain the higher inter-method variability observed in them. Also variations in the understanding of the questions of the IPAQ-A between the younger and older adolescents should be considered as a possible reason for the larger differences found between both instruments in the younger age group. This assumption is supported by the finding that adolescents in the younger age category showed higher correlations between the Actigraph and the VO_2max compared to the IPAQ-A. The opposite was found in the older adolescents, which could suggest that older adolescents show less compliance in wearing the accelerometer, compared to younger ones. However, these findings should be further investigated/confirmed in future studies. Our finding that female adolescents, especially those in the oldest age category, spent less time in (organized) sports of vigorous intensity, concur with others.[18] Because the time spent in high intensity activities in this subgroup of adolescents is so low, a significant difference between both instruments could not be found. Rounding up of time spent in several PA can also be a reason for the higher values found with the IPAQ-A. On the other hand, it is known that accelerometers underestimate PA at specific activities.[19] In addition, the accelerometer was removed during some activities (e.g. swimming and contact sports).

Modest correlations between PA questionnaires and objective measurements like the accelerometer have been found in earlier studies with adolescents.[20] The higher correlations for vigorous PA intensity found in the present study, were also seen in a previous validation study in Vietnamese adolescents.[21] Hagstromer et al.[22] also found a higher validity for vigorous activity levels in adults. Results from the Nord-Trondelag Health Study (HUNT 1 and 2) also reported acceptable validity for self-reported questionnaires for adults when assessing vigorous PA.[23,24] The higher correlation found between the IPAQ and the accelerometers for the more vigorous PA intensities can be explained by the fact that more intensive activities are easier to recall.[25] In a study, with adolescents, of Rangul et al.[26] the IPAQ was measured against VO_{2peak}, where low correlations were found except for the questions concerning the vigorous physical intensities. Our results also show higher correlations coefficients for both instruments and VO_2max for vigorous PA than moderate and MVPA.

Important strengths of this comparability study are the large sample size and the geographical spread of the study sample all over Europe. In addition the highly standardized procedures and the central handling and analysis of the accelerometer data used within the HELENA-study are an important strength of this study. This study has also some limitations. As mentioned before, accelerometers are known to underestimate total time spent in PA.[19] Nevertheless the IPAQ-A and the Actigraph show poor agreement in the present study, a combination of a self-report questionnaire, and an objective instrument, like the accelerometer, whether or not combined with an activity diary, might be most optimal in large study populations.[27] Also because the measurement errors of both instruments are highly independent, this is a suitable combination. Another point of concern is the use of the cut-off points for PA intensities. They were based on previous research and the validation study of the HELENA-study,[12] but they may also create measurement errors. Yngve et al.[28] reported that when establishing cut-off values, the results are affected by the types of activities performed and the setting. Also the inclusion criteria for the accelerometer data used in the present study (3 days, with at least 8 h of monitoring), can be seen as a limitation. Evidence based guidelines recommended 4–9 days of monitoring including 2 weekend days, with at least 10 h of recording time, to achieve reliable results.[1] However, in the current study, a compromise had to be made between the number of individuals and the number of monitoring days since the compliance of adolescents to a 7-day monitoring protocol was sometimes poor. Therefore the most optimal cut-offs for inclusion of accelerometer data in the HELENA-study were derived via post hoc power calculations performed by statistical experts in this field. Furthermore, like in every large scale survey, a lack of compliance to the study protocol might influence the data collection. For instance, the monitoring periods of the IPAQ-A and accelerometer do not always correspond exactly for all adolescents even though this was requested in the study protocol. However, for all adolescents included in the study sample, there was always an overlap between the two monitoring periods. The use of the same questionnaire for all age categories can also be seen as a limitation. This can lead to variations in understanding of questions between the oldest and youngest age categories. A last remark is related to the estimated VO_2max. Both equations used in the present study might underestimate the directly measured VO_2max.[29] Second, VO_2max is partly genetically programmed and influenced by PA levels of the past months/years, and might therefore not always corresponds with the measured PA of the past week (IPAQ-A and Actigraph).[30]

5. Conclusion

In conclusion, the results showed a poor to fair comparability between the IPAQ-A and the accelerometers among adolescents, which is also in accordance with previous research. The comparability between both assessments was the highest for vigorous intensity. Also, adolescents reporting high levels of PA (3rd tertile IPAQ-A) showed higher levels of PA (accelerometers) in all the study variables (moderate, vigorous and MVPA), compared to adolescents reporting low or medium PA (1st and 2nd tertiles IPAQ-A). Because VO_2max is an indication of the cardio respiratory fitness and exercise has a positive, longitudinal influence on physical fitness, it

can also be concluded that the performance of both instruments is in line with the expectations to identify the most physically active adolescents in a large population.

Although accelerometry has the advantage of being an objective method, PA questionnaires could give us more information about the context of the activity and about the non-registered and missed activity time when using the accelerometer. Therefore, it should be further investigated whether the use of multiple methods, like the accelerometers, PA questionnaires and PA diaries, should be recommended to measure PA among adolescents.

Practical implications

- There is a modest yet significant comparability between the IPAQ-A and the accelerometers among adolescents and was highest for vigorous intensity.
- The accelerometer and IPAQ-A used in the present study are able to detect the most physically active adolescents in a large population.
- Multiple methods can be recommended to measure physical activity among adolescents.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2011.02.008.

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