Physical activity assessed by accelerometer and self-reported questionnaire in an Italian sample of adolescents

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Background: The purpose of the present study was to examine and compare physical activity (PA) in an Italian sample of adolescents, measured by a self-reported questionnaire and accelerometer.

Methods: A total of 301 adolescents (aged 15–16) were investigated in this cross-sectional study from December 2011 to May 2012. They completed the questionnaire and wore an accelerometer for 7 days. Body weight, height and waist circumference (WC) were measured.

Results: Far fewer youths significantly met the international PA guidelines based on objective measures of moderate-vigorous physical activity (MVPA), compared to self-reported (4.0% *vs.* 43.9%), with significantly higher percentage of males than females (7.9% *vs.* 1.1%, P=0.003 by the accelerometer, and 52.0% *vs.* 37.9%, P=0.002 by the questionnaire). A low level of agreement was observed (r=0.319; P<0.000) between the questionnaire and the accelerometer data for MVPA. Bland-Altman plots illustrated the difference between the two methods (MVPA by accelerometer and by questionnaire) and showed that the mean difference was 39.2 and 95% limits of agreement were 117 and –38 min/day.

Conclusions: Very few adolescents met international PA recommendations, with boys being more active than girls, while nearly half of the participating adolescents were active according to questionnaire data. Considerable differences were observed between accelerometer and self-reported questionnaire when MVPA was measured. This suggests that the two methods were not equivalent for the measurement of PA in adolescents.

Keywords: Adolescents; accelerometer; moderate-vigorous physical activity (MVPA); physical activity (PA); self-reported

Introduction

Physical activity (PA) is defined as any body movement produced by skeletal muscle contraction that results in caloric expenditures (1) and includes competitive or recreational sports, exercise, active hobbies (including playing), walking, cycling and some daily life activities as household chores (2). PA benefits the physical, psychological, social and cognitive health of children and youths (3,4); it increases, in fact, cerebral blood flow and

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circulating levels of norepinephrine and endorphins, which affect positively mood, self-confidence and concentration, and at the meantime moderate anxiety, stress and anger. Cognitive development, skill acquisition and behavior are also positively affected (5). PA behaviors established in youth are likely to be kept also in adulthood (6).

Young people nevertheless spend much of their free time sedentarily and lots of them do not meet current public health recommendations in terms of PA (7). Guidelines commonly recommend 60 minutes of moderate-vigorous physical activity (MVPA) as a daily minimum (7 days a week) for school-age children and adolescents (8,9).

In the scientific literature, several methods or techniques are reported to assess PA in children and adolescents. Subjective measures such as self-reports are usually used in epidemiological studies, while accelerometers are often used in health-related research to assess objective PA in free-living conditions (10).

Accelerometers currently represent the most accurate, inexpensive and reliable method to measure objectively both the amount and intensity of PA, as well as the amount of sedentary behavior (11); however, GTM1 and AM7164 accelerometers cannot be worn in some situations such as when swimming, they do not manage to detect bike riding, and they cannot differentiate between going up stairs with or without carrying a load (12).

Various studies reported low-to-moderate correlation between self-reported and accelerometer-measured PA among youth people (13-16). This may be explained by differences in the methodologies used to reduce, process and analyze accelerometer data (17).

In Italy, the international cut-off point is used for children and adolescents that reach the recommended PA levels, as endorsed in the global recommendations of World Health Organization (WHO) on PA for health (8). The national data collected from 2010 to 2013 show that 43% of children and adolescents (6–17 years) meet the WHO recommended PA levels, with a higher percentage of boys (46%) being physically more active than girls (44%) (18).

According to estimates for 2010 year, reported in WHO global recommendations on PA for health, PA levels in Italian adolescents (defined as aged 11–17 years in relation to WHO data) differ widely from the national reported results, with only 8.2% meeting WHO recommendations for PA levels. However, the general trend of a greater number of boys being physically active than girls (9.0% and 7.4%, respectively) is consistent in the two datasets (8).

The purpose of the present study was to examine PA in an Italian sample of adolescents, as measured by two different methods: self-reported questionnaire and accelerometry.

We present the following article in accordance with the MDAR reporting checklist (available at https://pm.amegroups.com/article/view/10.21037/pm-20-91/rc).

Methods

Sample

This research falls within the framework of the cross-sectional ALIADO study, that aimed to analyze and examine in depth the prevalence of overweight and obesity in Italian adolescents in relation to their food habits and lifestyle (19,20).

The study was carried out on a representative sample of adolescents (15–16 years of age), living in the Lazio region (Central Italy) and attending the second class of randomly selected public and private High Schools, present in a list provided by the Education Office of the Lazio Region. Twenty-one secondary school classes were recruited (i.e., a total number of 11 high schools and a number of 10 technical/professional training schools). Cluster sampling was performed according to WHO cluster survey methodology (21), with classes taken as sampling unit, as reported in a previous study (22). A total of 367 students were enrolled and wore the accelerometer. A number of 66 participants were excluded from analysis because they reported a non-valid number of days with PA measured by accelerometer. Overall, 301 adolescents (127 males and 174 females) were investigated in the study.

Data collection was performed from December 2011 to May 2012. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved the Ethical Committee of the National Research Institute on Food and Nutrition (CRA-ex INRAN prot.0003288/01.11 Rome 04/07/2013) and informed consent was taken from parent or legal guardian of the participants.

Anthropometric measurement

Weight and height measurements were made by trained and standardized staff, according to WHO recommendations (23). Height was measured to the nearest 0.1 cm by a stadiometer SECA 214 (Hamburg, Germany), with the subject without shoes and standing up, with weight equally distributed on

feet, head in the Frankfurt plane and the back of the head, buttocks and heels (if possible) in contact with the vertical board. Weight was measured to the nearest 50 g by an electronic scale SECA 872™ (Hamburg, Germany), with the subject in fasting condition (or after a light breakfast) and after emptying the bladder. Waist circumference (WC) was measured to the nearest 0.1 cm in triplicate by a metric tape (SECA 201). The average of three measurements was used.

Body mass index (BMI) was calculated as weight in kilograms divided by the square of the person's height in meters (kg/m²). In order to categorize adolescents ponderal status, BMI values were compared to those reported in the international reference tables, recommended by the International Obesity Task Force (IOTF), which are specific for age and sex (24).

PA measured by accelerometer

Adolescent PA was measured by an ActiGraph accelerometer, positioned on the right side fastened to the waist by an expandable belt. The tool detects movements made according to the vertical axis and determined by the combined function of movement frequency and intensity. The data were recorded in one time interval, known as the epoch length, and are expressed in "counts". Each count represents the quantity and the amplitude of the accelerations collected in each time interval. In this study, two ActiGraph uniaxial accelerometer models were used: GTM1 and AM7164, as both provide similar results for the classification of subjects in various levels of PA when the 1minute recording time interval is applied (25). We used uniaxial accelerometers, because previous research observed no differences in measurement of PA by uniaxial or triaxial accelerometers in population studies, and hence both of them are suitable for being used in such studies (26,27).

For a reliable assessment data were collected for 7 consecutive days, 5 weekdays and 2 days on weekends (28), except during water sports and bathing because the ActiGraph is not waterproof. A valid day was defined as a day with 10 or more hours of wear time; a valid participant was defined as a person with at least 4 valid days (29), so the inclusion criterion of at least 4 valid weekdays and 1 weekend day of 10 valid hours of combined data, was chosen to maximize data retention for analysis and to enhance the reliability of the presented results. The data files obtained through the accelerometers were retrieved by the MAHUffe program (ActiLife software versions 3.7) and allowed to evaluate, for each subject, the time (in minutes per day) spent in the different categories of PA intensity, as an average over the 7-day measurement period. In this study, the average was calculated as average of valid monitored days (average of possible 4 to 7 monitored valid days per participant).

Participants took notes of the duration and schedule time of all MVPAs which did not allow wearing an accelerometer (such as swimming, or other sport activities which could damage the tool), on the dedicated diary, received together with the accelerometer. Duration time (in minutes) were added to the MVPA minutes recorded by the accelerometer.

Light physical activity (LPA) has been defined for the range of 100–1,951 counts per minute, moderate activity by intensity between 1,952 and 5,725 counts per minute, and vigorous activity for more than 5,725 counts per minute (30). Because the time spent performing vigorous activities was very short, it was considered a unique variable, including both minutes of moderate and vigorous PA. Total physical activity (TPA) is the sum of MVPA and LPA. Participants were classified as active above 60 minutes/day of time spent in MVPA, according to the recommendations for PA (8).

PA measured by questionnaire

A self-administered questionnaire (see lifestyle questionnaire ALIADO file; https://cdn.amegroups.cn/static/public/pm-20-91-1.doc) was completed by adolescents in classroom at school. The participants were asked to provide estimates of the time they spent in structured PA such as doing sport (Physical Education classes included), and in unstructured PA, such as cycling, playing football, jogging, dancing, etc. Information was retrieved about how many times a week, how long each time and if the PA was amateur or competitive sport. The reported values by domain were summed to get TPA from the questionnaire. Average daily values were calculated for each domain of PA, so that they were comparable to the MVPA accelerometer data.

Statistical analysis

The descriptive analyses were presented as means ± standard deviations for quantitative variables, and as percentages for categorical variables. One-way analysis of variance (ANOVA) with the Student-Newman-Keuls post hoc test for quantitative variables and Chi-square test for categorical variables were conducted to investigate the association between gender, weight status and type school. Comparison between the two methods (self-report and

Table 1 Study sample characteristics (means ± standard deviation and %)

Variables	Males (n=127)	Females (n=174)	Overall (n=301)	P
Age (years)	15.8±0.5	15.7±0.5	15.7±0.5	0.012[§]
Weight (kg)	67.6±15.4	57.8±10.1	61.9±13.5	<0.001[§]
Height (cm)	173.5±6.4	162.1±6.6	166.9±8.6	<0.001[§]
BMI (kg/m^2)	22.4±4.6	22.0±3.5	22.1±4.0	0.376[§]
WC (cm)	76.9±10.7	70.1±7.5	73.0±9.6	<0.001[§]
WtHR (cm)	0.44±0.06	0.43±0.05	0.44±0.05	0.094[§]
Weight status (%)				
Obese	10.2	4.0	6.6	0.037[§§]
Overweight	18.9	13.8	15.9	
Normal weight	62.2	76.5	70.5	
Underweight	8.7	5.7	7.0	
Type of school (%)				
High school	61.4	73.6	68.4	0.025[§§]
Technical/professional training	38.6	26.4	31.6	
School municipality (%)				
Metropolitan	56.7	60.3	58.8	0.526[§§]
Non metropolitan	43.4	39.7	41.2	

[§], comparison between males and females based on one-way ANOVA; [§§], comparison between males and females based on Chi-square test; statistical significance is expressed as P<0.05. BMI, body mass index; WC, waist circumference; WtHR, waist-to-height ratio; ANOVA, analysis of variance.

accelerometer) were done using Sperman's rank correlation coefficients (rho).

Bland-Altman analysis (31) was used to visualize the agreement with 95% limits between the questionnaire and accelerometer.

For all the tests, P values <0.05 were considered to be statistically significant. All statistical analyses were performed using MedCalc Software version 19.4.0 for Windows.

Results

Study sample details are reported in *Table 1*. The percentage of females in the sample exceeded that of males (57.8% *vs*. 42.2%). Participants were 15.7±0.5 years of age and had weight 61.9±13.5 kg, height 166.9±8.6 cm, BMI 22.1± 4.0 kg/m^2, WC 73.0±9.6 cm and waist-to-height ratio (WtHR) 0.44±0.05. The prevalence of overweight/obesity was 22.5% with higher and significative values in males than

females (29.1% *vs*. 17.8%; P=0.037).

The percentages of students who attended high school was higher than those who attended technical and professional training institutes (68.4% *vs*. 31.6%) with significant differences between females and males (respectively, 73.6% *vs*. 61.4%; P=0.025). Also, there were no substantial differences between gender in the variable school municipality.

In the *Table 2*, PA measures from objective and self-reported variables for gender, weight status and type of school are presented. When TPA, LPA and MVPA were measured by accelerometer, significant differences emerged between genders, with values higher for males than females (305.1 *vs*. 278.5 min/day, P=0.001 for TPA; 275.1 *vs*. 257.3 min/day, P=0.013 for LPA and 30.0 *vs*. 21.2 min/day, P=0.001 for MVPA). Significant differences in LPA were measured by accelerometer for weight status, with means higher in overweight/obese participants than in under/normal weight (279.1 *vs*. 260.6 min/day; P=0.030), and for type of

Table 2 Descriptive PA data (means ± standard deviation) from objective measures and self-reported variables for gender, weight status and type of school

Variables	Gender				Weight status			Type of school		
	Males (n=127)	Females (n=174)	Overall (n=301)	P	Normal weight (n=233)	Overweight obese (n=68)	P	High school (n=206)	Technical/professional training (n=95)	P
Objective (accelerometer)										
TPA, minute/day	305.1±75.8	278.5±55.7	289.7±66.2	0.001*	286.2±64.3	301.8±71.4	0.087	283.5±58.2	303.2±79.5	0.016*
LPA, minute/day	275.1±72.9	257.3±51.6	264.8±70.0	0.013*	260.6±59.1	279.1±69.7	0.030*	257.6±53.9	280.4±74.6	0.003*
MVPA, minute/day	30.0±17.7	21.2±12.8	24.9±15.6	<0.001*	25.5±15.4	22.7±16.5	0.188	25.9±15.4	22.8±16.1	0.114
Self-report (questionnaire)										
PA, minute/day	72.2±42.2	58.1±40.0	64.0±41.4	0.004*	66.3±41.3	56.3±41.2	0.0078	65.2±39.2 [37]	61.6±46.0	0.490

P from one-way ANOVA; *, statistical significance is expressed as P<0.05. PA, physical activity; TPA, total physical activity; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity; ANOVA, analysis of variance.

Table 3 MVPA according to recommended by guidelines (≥60 min/day)

Measurement	Males (%)	Females (%)	Overall (%)	P
Objective (accelerometer)	7.9	1.1	4.0	0.003*
Self-report (questionnaire)	52.0	37.9	43.9	0.015*

P from Chi-square test; *, statistical significance is expressed as P<0.05. MVPA, moderate-to-vigorous physical activity.

school with values higher in students attending technical and professional training institutes than students attending high School (respectively, 303.2 *vs.* 283.5 min/day, P=0.016 for TPA and 280.4 *vs.* 257.6 min/day, P=0.003 for LPA). No significant differences were observed in MVPA and TPA. Concerning PA, as reported in the answers to the questionnaire, there were significant differences only for gender, with means higher in males than females (72.2 *vs.* 58.1 min/day, P=0.004).

Table 3 shows the attainment of the recommended MVPA guidelines (≥60 min/day). Far fewer adolescents met the international PA guidelines based on objective measures of MVPA compared with self-reported (4.0% *vs.* 43.9%), with significantly higher percentage of males than females (7.9% *vs.* 1.1%, P=0.003 by the accelerometer and 52.0% *vs.* 37.9%, P=0.015 by questionnaire).

In addition, when MVPA of two methods were compared a low level of agreement was observed (r=0.319; P<0.000) between the questionnaire and the accelerometer. Sub-group analysis by sex, weight status and type of school showed similar low correlations with high coefficient for students attending high school (r=0.353; P<0.000) and very low coefficient for student attending technical/professional training (r=0.186; P=0.071) (*Table 4*).

Results for the Bland-Altman plots illustrated the difference between the two methods (MVPA by accelerometer and by questionnaire) and showed that the mean difference was 39.2, and 95% limits of agreement were 117 and –38 min/day (*Figure 1*).

Discussion

This study examined PA in an Italian sample of adolescents measured by two different methods: accelerometry and self-reported questionnaire. Insufficient daily MVPA (30.0 min/day) was found in adolescents, and only 4% of them could be considered active with respect to the guideline recommendations for PA (8). The values obtained

Table 4 MVPA: Sperman's rho coefficient correlation for the questionnaire *vs.* accelerometer

Sample	N	Variables	Sperman's rho coefficient	95% CI	P
Overall sample	301	Questionnaire *vs.* accelerometer MVPA (min/day)	0.319	0.2–0.4	<0.000
Males	127		0.275	0.1–0.4	0.002
Females	174		0.299	0.2–0.4	0.000
Under/normalweight	233		0.288	0.2–0.4	<0.000
Overweight/obese	68		0.332	0.1–0.5	0.006
High school	206		0.353	0.2–0.5	<0.000
Technical/professional training	95		0.186	–0.02–0.4	0.071

MVPA, moderate-to-vigorous physical activity.
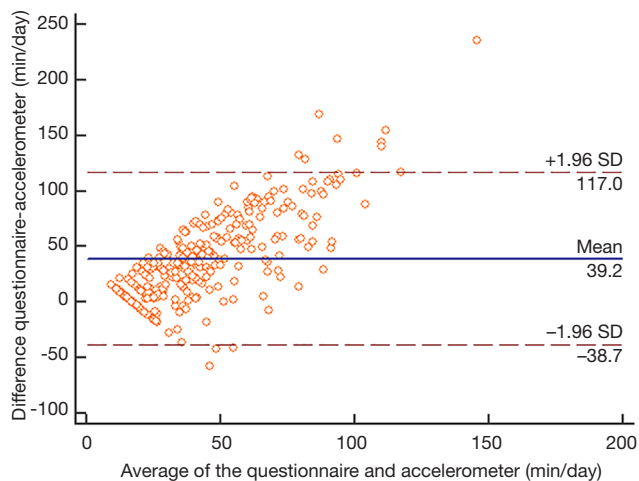
Figure 1 Bland-Altman plot of the difference versus the average of questionnaire and accelerometer.

from self-reported questionnaires were higher (72.2 min/day and about 44% of participants resulted active according to recommendation). The study of Leblanc and Janssen (3) also examined the relationship between accelerometer and self-reported measures of MVPA in a large and representative sample of American youths, and observed that MVPA was over-reported for at least 5 min/d by two-thirds of the participants. These results were confirmed and synthesized in a systematic review, where low-to-modest correlations were found between self-reported and accelerometer measured PA and self-reported measures overestimating activity in children and youths (14).

In addition, we observed that boys are more active in TPA, MVPA and LPA by accelerometer, and in PA by questionnaire than girls. The higher activity levels in the boys under analysis in our study is consistent with previous studies (32-34). The results regarding gender might be partly explained by biological factors, as the strength per gram of muscle becomes greater in boys during adolescence because of variance in the biochemical nature and structure of muscle cells upon male sex hormones (35). Aspects related to the socio-cultural environment might be one more aspect affecting results. Participation of girls in PA is, in fact, influenced by social subjective norms according to which boys are more likely to meet screen time recommendations (e.g., TV time <2 h/day) as parents prefer their male children do physical activities and do not encourage girls to do so (36,37).

In our study, under/normal weight participants were more active in MVPA than their overweight/obese peers, but less active in LPA and TPA according to the accelerometer, and more active in PA according to the questionnaire. These results are similar to previous studies that observed how overweight/obese adolescents spent less time in MVPA compared to under/normal weight peers (38-40).

This study found a low level of agreement and considerable differences between accelerometer and self-reported questionnaire to measures PA in line with previous studies (13-16). Potential misreporting in the questionnaire might derive from the fact that most daily activities are irregular and significant breaks or rest periods might occur. This may contribute to inaccurate recall and significant overestimation of the real amount of time spent on daily activities (41). In addition, PA recall is a complex process, influenced by (I) social desirability bias (e.g., greater PA is recalled because it may be viewed more favorably by others), (II) recall bias (e.g., the respondent is unable to accurately recall PA levels), and (III) a misunderstanding of movement intensities (13,42). In addition, adolescents

practice many unstructured PA such as spontaneous play, which is difficult to recall and quantify accurately (43). Colley *et al.* also suggested that some items of questionnaire may not be suitable to capture PA that is correspondent in intensity to accelerometer-measured-MVPA exclusively and may include PA which can be classified as LPA by the accelerometer (44).

This study has nevertheless some limitations. First, current research is a cross-sectional observational study which prevents causal inference accelerometers. Second, GT1M and AM 7164 ActiGraph cannot detect some activities, such as cycling, swimming, rowing, and upper body resistance training, but although the amount of minutes reported in the diary (as specified above) were added to the MVPA recorded by the accelerometer, they may have underestimated PA in the participants involved in this research. Third, the questionnaire used in this study was rather simple, was borrowed from a previous project and was not specifically designed for our study. For a more detailed questionnaire, other measures describing PA behavior, such as measures for assessing specific types of PA, should be used.

The strengths of our study lie in the sample representativeness of the studied population of 15–16 years old adolescents. Moreover, anthropometric variables were measured and not self-reported by the participants.

Conclusions

In conclusion, this study found that according to data recorded by accelerometry, very few adolescents met international PA recommendation, with boys being more active than girls; while according to the questionnaire data nearly half of the adolescents were active. In addition, within the framework of analysing how MVPA minutes can be recorded by the two different methods (i.e., accelerometry and self-reported questionnaire), the current survey shows considerable differences and disagreement in time spent on MVPA. This outcome suggests that these two methods were not equivalent for the measurement of PA in adolescents.

Acknowledgments

Footnote

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