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Physical activity and health assessment in children and adolescents: application and usefulness of Physical Activity Questionnaire (PAQ)

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AUTORIZA

La Presentación de la Tesis Doctoral, realizada por D. Javier Benítez Porres, con el título: " **Physical activity and health assessment in children and adolescents: application and usefulness of Physical Activity Questionnaire (PAQ)**, de la cual he sido Director, siendo proyectada, desarrollada y redactada bajo mi supervisión, para la obtención del Grado de Doctor Internacional por la Universidad de Málaga.

Y para que surtan los efectos oportunos, al interesado, firmo la presente en Málaga, a diez de diciembre de dos mil quince

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A mi familia y especialmente a mis padres Marisa y Antonio, por educarme, ayudarme y empujarme a ser quien soy apoyándome incondicionalmente.

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INDEX OF CONTENTS

ABBREVIATIONS

ACL	Accelerometer
ANOVA	Analysis of Variance
AUC	Area under the curve
BMI	Body mass index
C0	Change from on time to late maturation
C1	No change in maturation
C2	Change from late/on time to on time/early maturation
CI	Confidence interval
CPM	Counts per minute
DLW	Doubly labelled water
DXA	Dual-energy X-ray absorptiometry
EE	Standard error
FFQ	Food frequency questionnaire
FM	Fat mass
FMP	Fat mass percent
GT3X	Actigraph triaxial accelerometer
ICC	Intraclass correlation coefficient
ISAK	International society for the advancement of kinanthropometry
LR	Likelihood ratios
MET	Metabolic equivalent
MVPA	Moderate-to-vigorous physical activity
NW	Normal-weight
OW+O	Overweight plus obesity

PAQ	Physical activity questionnaire
PAQ-C	Physical activity questionnaire for children
PAQ-A	Physical activity questionnaire for adolescents
P	Significance level
PV	Predictive values
RHO	Spearman's rank correlation coefficients
ROC	Receiver operating characteristic
S1	September 2011
S2	September 2012
S3	September 2013
SD	Standard deviation
SPSS	Statistical package for the social sciences
VO_{2max}	Máximum oxygen uptake
WC	Waist circumference
WHO	World health organization

LIST OF TABLES AND FIGURES

TABLES

FIGURES

ABSTRACT

Physical activity (PA) has been identified as an important agent in the prevention of chronic diseases such as obesity, cardiovascular diseases, and metabolic syndrome. In order to know more precisely the levels of PA during childhood and adolescence, it is necessary to develop and validate instruments able to adequately and widely assess PA to identify the impact on health in primary and secondary school populations. Quantifying PA will be helpful in order to focus school and community interventions on those groups with unhealthy lifestyles. In this sense, longitudinal studies help move researchers closer to understanding determinants and mediators of PA patterns.

The Physical Activity Questionnaire (PAQ) is a self-report instrument developed specifically for Children (PAQ-C) and later adapted for Adolescents (PAQ-A), which has been widely used to assess PA in healthy school populations. However, there is a lack of uniformity and information about the meaning of final score, which would differentiate sedentary behaviors in youth.

The overall purpose of this dissertation research was, on the one hand, to validate PAQ psychometric characteristics in Spanish children and to determine cut-off points that would improve the utility of the PAQ-C and PAQ-A for future research applications; and, on the other hand, to study longitudinal changes of body composition and PA behaviors in adolescence using this tool.

The main variables of different studies included in this dissertation were evaluated as follows: PA level was evaluated using the Physical Activity Questionnaire (PAQ-C or PAQ-A) and/or accelerometers (Actigraph GT3X); body composition was assessed by

anthropometric measurements; sexual maturity was estimated by predicted percentage of adult stature; and dietary intake was assessed by a self-administered food-frequency questionnaire.

The most important results show:

a) In the first study, test-retest reliability showed an Intraclass Correlation Coefficient of 0.96 for the final score of PAQ-C, which obtained a consistency of Cronbach's α of 0.76. Moreover, few and low correlations (rho=0.228-0.278, all $P<0.05$) were observed between PAQ-C and triaxial accelerometry and the accuracy analysis performed with the concordance coefficient correlation reported a low accuracy of PAQ-C compared with accelerometry (r=0.192, P=0.092). To sum up, the results suggest that PAQ-C had a high reliability but a questionable validity for assessing PA in our sample of Spanish children.

b) The main finding of the second study was to determine a PAQ-C and PAQ-A score cut-off point of 2.75 to discriminate 60 minutes of MVPA, which is associated within a total volume of 10664 steps/day for children and 9701 steps/day for adolescents. However, area under the curve (AUC) values of PAQ-C score were no significant ($P>0.05$) and only weak ($AUC<0.7$) discriminators between “active” and “non-active” children. So, according with the ROC analysis, only the PAQ-A can be a useful tool to classify adolescents as active or inactive following international recommendations as criteria.

c) In the longitudinal study, significant differences for FMP were found among S1, S2 and S3 (23.41±8.24 vs. 21.89±7.82 vs. 22.05±8.06, $P<0.05$; respectively); a significant interaction with sex was observed ($P<0.05$), but not for maturation. Regarding PA, S2 was significantly higher than S3 (2.58±0.72 vs. 2.29±0.73, $P<0.001$). An interaction between PA and maturation was statically significant ($P<0.05$). Our results suggest that body composition changes observed during adolescence are not driven by changes in PA. Moreover, the interaction analysis suggests that sex affects PA behavior, but not maturation or nutritional variables.

These overall results suggest that the PAQ appears to be a more appropriate tool to measure PA in adolescents than in children, and it may discriminate active and inactive students in adolescence according to international guidelines.

In addition, assessments conducted longitudinally in this dissertation show the problems of progressive decline of PA among adolescents, which seems to be influenced by the gender, regardless of maturation.

CHAPTER I: INTRODUCTION

PHYSICAL ACTIVITY AND HEALTH IN YOUTH

Physical activity (PA) is recognized to have important benefits for all segments of the population [1-5]. The World Health Organization (WHO) has published official PA guidelines [6], which provide specific recommendations for the type and amount of PA needed for different segments of the population including children and adolescents, adults, the elderly, and those with special needs. A review by Janssen & Leblanc [3] summarized the various health benefits of regular PA. According to the review, PA has been shown to improve body composition, promote glucose homeostasis, enhance insulin sensitivity, reduce blood pressure, improve lipid lipoprotein profiles (e.g., through reduced triglyceride levels, increased high density lipoprotein HDL cholesterol levels and decreased low-density lipoprotein LDL), reduce systemic inflammation and blood coagulation, promote autonomic tone and enhance cardiac and endothelial function. In short, regular PA is absolutely critical for good health.

PA is important for all segments of the population but there is considerable interest in promoting PA in youth. This is due in large part to concerns over the increasing prevalence of obesity, but also to the growing consensus about the importance for good health. Childhood and adolescence are important periods of life because of dramatic changes in various physiological and psychological aspects, such as hormonal regulation, body composition, transient changes in insulin sensitivity [7]. More significantly, many lifestyle habits established during childhood and adolescence periods tend to track into adulthood [8]. Preventing obesity in early life is critical since evidence suggests that overweight youth have a five times greater risk of being overweight than normal weight

children of the same age [9]. In this sense, childhood and adolescent overweight and obesity show a high prevalence in Spain [10,11]. Longitudinal studies, both follow-up and intervention, help move researchers closer to understanding determinants and mediators of PA and adiposity [12]. An advantage of these designs is that they can address reverse causality.

The needs for children and adolescents warrant unique activity guidelines. The PA guidelines suggest that children and adolescents should accumulate 60 minutes or more of PA daily. The amount of PA recommended to youth is twice that of adults, not only because youth have more freedom and greater needs for PA, but also because forming a healthy lifestyle at an early age has an influence on lifestyle later on. The United States is not the only country that has adopted national PA guidelines for youth. A number of other countries including Australia, the United Kingdom, and Canada have published their own guidelines. Though there are minor discrepancies between them, all of the guidelines suggest that youth should engage in at least 60 minutes of MVPA on a daily basis.

The message of formalized youth PA guidelines has generated considerable interest in understanding and promoting levels of PA in children and adolescents. Schools have been targeted as one of the most promising settings for reaching and impacting youth. A variety of assessment tools are available but they differ in validity and feasibility. There are various options or methods for assessing PA. However, emphasis will be based on more practical methods that can be used in schools since there is specific interest in documenting levels of activity during the school day.

PHYSICAL ACTIVITY MEASUREMENTS FOR YOUTH

Following the postulates of Corder [13] and Sirard [14], this section will provide a brief overview of the most common methods to measure or estimate PA (not criterion standards such as DLW or indirect calorimetric) in youth, and additional strengths and weaknesses (table 1). We can classify these methods in two groups: subjective and objective methods.

The first category include questionnaires, interviews, activity diaries, and direct observation. These methods vary in the measured variables and therefore in their primary outcomes.

The second category involve the measurement of physiological or biomechanical parameters and use this information to estimate PA outcomes.

Table 1. Advantages and disadvantages of methods used to assess physical activity

	Advantages	Disadvantages
Heart rate monitoring	Suitable for all populations. Low respondent burden for short period. Physiological parameter. Provides information about intensity. Good association with energy expenditure. Easy and quick data collection. Relatively cheap.	Only useful for aerobic activities Conditions unrelated to PA can cause an increase in heart rate without a corresponding increase in VO^2
Multi-sensor systems	Suitable for all populations Low respondent burden Relative ease of data collection	Data analysis relatively complex. Monitors relatively expensive.
Pedometers	Suitable for all populations Low respondent burden Objective measure of common activity behaviour Easy data collection and analysis Cheap	Children may tamper or alter behaviour. Are specifically designed to assess walking only. Inability to record non-locomotor movements. Inability to examine the rate or intensity of movement.
Direct observation	Mostly used in paediatric studies No respondent burden provides excellent quantitative and qualitative information	Expensive as labour intensive. Observer presence may artificially alter normal PA patterns.

Accelerometers	Suitable for all populations. Low respondent burden. Objective indicator of body movement (acceleration). Provides information about intensity, frequency and duration. Relatively easy data collection.	Inaccurate assessment of a large range of activities. Financial cost may prohibit assessment of large numbers of participants.
Self-report	Suitable for all populations Low respondent burden captures quantitative and qualitative information Ease of data collection and analysis Cheap	Proxy reporters required for children and possibly elderly. Reliability and validity problems associated with recall of activity.

PA, physical activity; VO^2, oxygen uptake.
From Warren et al. 2010, partially modified.

▶ Heart rate monitors and multi-sensor systems (objective method)

Heart rate monitors are the most common direct physiological measure used in free-living settings [15]. There is a strong linear relationship between heart rate and energy expenditure across the moderate and more vigorous intensity PA, although this relationship is not as strong in the light intensity range [16,17]. Overall error rates relative to the criterion measure are typically <3%, although this accuracy may be higher for some individuals [18]. Agreement across heart rate monitor units is also very strong. Heart rate monitor are excellent options for activities that may not be measured well with an accelerometer including cycling, swimming, and other non-ambulatory activities [19]. Some of the existing limitations of heart rate monitors are the necessity to account for blood pressure attenuating medications, focus of relative over absolute intensity, and potential discomfort of wearing the unit for long periods of time.

Multi-sensor systems combine multiple physiological and mechanical sensors to provide more precise measures of PA and energy expenditure. Parameters may include accelerometry (at multiple placements), heart rate, galvanic skin response, respiration, skin and core temperature, bioimpedance, global positioning, among others. The

advantages of multi-sensor systems are the additional precision, especially among non-ambulatory activities, that may come from triangulating energy expenditure estimates from multiple sensors. However, the cost and potential inconvenience of more complex systems may make these advantages less important depending on the application [15].

There is no gold standard objective wearable monitor. The choice of objective wearable monitors is complex due to many factors including the specific PA component of interest, the rapid and evolving evolution of technology and algorithm development, and practical considerations include ease of use, cost, and logistics.

- **Pedometers (objective method)**

In recent years, with the advancement of computing technologies, and the desire to track and evaluate PA, pedometers have become increasingly complex. Early forms have used a hip-worn mechanical sensor to identify steps based on the force on the unit generated from a typical heel-strike during ambulation. In the past 10 years the technology underlying pedometers has transitioned primarily to microelectromechanical systems and algorithm-based processing of the microelectromechanical systems signal to identify steps. Accuracy of these pedometers has improved with the transition toward microelectromechanical systems [20] and are excellent in measuring steps at walking speeds > 2 mph [21]. Crouter et al. [22] evaluated the accuracy of 10 different hip worn pedometers and found 8 of the 10 devices had excellent test–retest reliability and accuracy was > 95% and increased as walking speed increased. Karabulut et al. [23] examined the accuracy of two models of Omron pedometers on a treadmill at varying walking speeds (2-4 mph) and found both monitors were within 1.5% of actual steps taken. While most pedometers

are designed to be hip-worn, the most accurate placement for detecting steps appears to be the ankle [23]. The accuracy of pedometers is more compromised at slower walking speeds (≤ 2 mph), at other monitor placements (e.g., wrist, pocket), and among older adults and those with gait impairments [15].

The appeal of the pedometer to objectively monitor PA is their ability to quantify ambulatory activity during walking, jogging, and running through a common and easily understood metric (i.e., steps). Pedometers are of relative low cost and can be an important means for providing behavioural feedback and motivation. Pedometers may also be capable of providing a valid estimate of PA intensity [24]. The primary disadvantages of the pedometer is their inability to measure non-ambulatory activities, posture, and energy expenditure, and their reliance on proprietary algorithms to determine steps [15].

- **Accelerometers (objective method)**

Accelerometers are small wearable monitors that record accelerations in gravitational units on one or more planes at sampling rates >1 time/second (typically 40–100 hz). Captured accelerations are then processed to a lower resolution (i.e., epoch) and then calibrated to a known criterion measure (e.g., oxygen consumption or DLW). Most of the existing calibration studies rely on a unitless intensity metric or "counts" and then apply thresholds to summarized data to output the duration and frequency of PA into sedentary, light, moderate, and vigorous intensities. There is controversy over the appropriate pre- and post-processing methods (many of which are proprietary in nature) and thresholds for various populations and desired PA component [25]. More recently, pattern recognition

techniques have been explored that develop algorithms to detect PA types (e.g., running vs. walking) and EE that do not rely on proprietary processing and threshold methods [26,27]. These efforts have been modestly fruitful (although have limited validity in free-living settings) and are computationally resource-intensive and therefore not practical for most end users.

Most single-sensor accelerometer systems perform poorly compared to the gold standard of DLW [28]. Calibration studies have shown a wide range of correlations (r = 0.45 to 0.93) with measures of oxygen consumption and METs [29]. This wide range is due to a number of protocol-related variations including the monitor under study (i.e., some monitors and their associated algorithms are more accurate than others), monitor placement (i.e., hip, wrist, ankle, trunk), activities under investigation (e.g., ambulatory PAs are more accurate than non-ambulatory PAs such as cycling and household chores), and context (laboratory-based studies have greater accuracy than free-living studies). Accelerometers are typically worn on the hip, although increasingly are being fixed to the wrist or ankle. Hip-worn accelerometers are assumed to provide the most accurate assessments of normal ambulation, although recent comparative studies have shown only minimal differences in accuracy between the hip and wrist [30]. There is an increased interest in moving monitor placement from the hip to the wrist for practical reasons including increased wear time (i.e., fewer need to remove the device) and ability to accurately monitor sleep.

The appeal of the accelerometer for measuring PA (and sedentary behaviours) is the detailed and relatively precise manner, with minimal invasiveness, in which the frequency, duration, pattern, and intensity of activity can be monitored over days, weeks,

and even longer. However, accelerometers are not without considerable limitations. Some of these limitations include the proprietary nature of many algorithms to quantify PA, lack of sensitivity on sedentary and light-intensity range of the activity spectrum, and inability to detect non-ambulatory activities such as cycling and weight-lifting [16].

- **Self-reports (subjective method)**

Self-report instruments are the most widely used tools to assess PA and include self or interviewer-administered questionnaires, recalls, logs and activity diaries [15]. Self-report methods are the cheapest and easiest way to collect PA data from a large number of people in a short time. There are numerous limitations to self-reported methods, which include: difficulties in ascertaining the frequency, duration and intensity of PA, capturing all domains of PA, social desirability bias and the cognitive demands of recall [31]. The sequential cognitive processes underlying the storage of memories have been described along with models explaining their retrieval, illustrating the complexity of the task especially to report durations [14]. These issues along with problems with reliability, validity and sensitivity have been comprehensively summarized [32]. However, structured questionnaires provide an assessment of PA by domains, which is not obtained when using objective measurement of PA and may have the potential to provide valid estimates of PA and time spent at different intensity levels on group level.

A list of PA questionnaires designed to measure PA in young shown in table 2 (children), table 3 (adolescents) and table 4 (both):

Table 2. Self-report methods validated for assessing physical activity in children.

Self-report	Sample	Evaluation	Aim	Admin.	Criterion	Validity
2013. Youth Activity Profile (YAP) [33]	343 children	Past week	Habitual PA at school and out of school and sedentary behaviour	Self-administered	ACL SWA Armband	PA: r = 0.58 (P <0.001) Sedentary behaviour: r = 0.75 (P <0.001)
2011. Pre-PAQ [34]	67 children	Past 3 days	Habitual and sedentary activities in home environment	Parent reported	ACL Actigraph	r = -0.07 - 0.19 (P >0.05)
2010. BONES physical activity survey [35]	40 children	Past 2 days	Common activities and Total METs	Interview	ACL Actigraph	*rho* = 0.47-0.48 (P <0.01)
2010. MRPARQ [36]	86 children	Past week	All organised and non-organised PA	Interview	ACL Actigraph	r = 0.31 (P <0.05)
2006. The Multimedia Activity Recall for Children and Adolescents (MARCA) [37]	66 children	Past day	PA intensities and EE	Self-administered (computerized)	ACL Actigraph	*rho* = 0.45 (P <0.01)
2006. School Health Action, Planning and Evaluation System (SHAPES) [38]	67 children	Past 7 days	MVPA and sedentary behaviour	Self-administered (computerized)	ACL MTI	*rho* = 0.44 (P <0.01)
2004. Checklist to record outdoor playtime [39]	250 children	3 days	Outdoor playtime	Parent reported	ACL RT3 Triaxial	r = 0.33 (P <0.001)
2004. Children's Leisure Activities Study Survey (CLASS) [40]	280 children	Past week (weekdays and weekend)	Habitual PA	Parent Reported and self-administered	ACL Actigraph	*rho* = -0.04 (P >0.05).
2004. Recall of outdoor playtime [39]	250 children	Past month	Outdoor playtime	Parent reported	HR	r = 0.20 (P <0.01)
2003. GEMS Activity Questionnaire (GAQ) [41]	68 girls	Past day	Habitual PA	Self-administered	ACL CSA	Previous day: r = 0.27 (P <0.03) Habitual: r = 0.28 (P <0.02)
2001. Assessment of Young Children's Activity Using Video Technology [42]	47 children	Past day	Habitual and MVPA	Computerized	ACL Caltrac and HR	Caltrac: r = 0.40 (P <0.001) Minutes over 50% maximum HR: r = 0.50 (P< 0.001)
2001. Physical activity recall (PAR) [43]	46 girls	Past day	Estimation of EE	Interview administered	ACL Caltrac and HR	HR: r = 0.50 (P< 0.01) Caltrac: r = 0.2 (P <0.01)

2001. Computer delivered physical activity questionnaire (CDPAQ) [44]	30 children	Past day	MVPA and Total METs	Self-administered (computerized)	ACL Caltrac and FR	HR: r = 0.66 (P< 0.01) Caltrac: r = 0.41 (P <0.05)
2000. Habitual Activity Questionnaire (HAQ) [45]	683 children	Past year	Mode and frequency of sport and PA outside school	Interview administered	ACL Caltrac	r = 0.09 for both years (P < 0.02)
1998. Computerized Activity Recall (CAR) [46]	45 children	Past day	Total activity and TEE	Self-administered (computerized)	ACL Tritrac	r = 0.51 (P <0.001) significantly overestimated EE
1997. Physical activity questionnaire [47]	62 children	1 day	MVPA	Parent or teacher reported	ACL RT3 Triaxial	HR: r = 0.40-0.45 (P <0.01-0.001) Accelerometer: r = 0.53 (P <0.001)
1997. Physical Activity Questionnaire for older Children (PAQ-C) [48]	97 children	Past 7 days	Total activity (frequency)	Self-administered	ACL Caltrac	r = 0.39 (P <0.05)
2003 Activity diary [41]	68 girls	Past 3 days	Mode, intensity and duration of activity or rest	Self-administered	ACL CSA and pedometer	CSA: r = 0.37 (P < 0.002) Pedometer: r = 0.47 (P < 0.001)
2000. Activity diary [49]	69 children	3 days	Short-term PA	Self-administered	ACL Caltrac	r = 0.2 to 0.25 (P < 0.001)

ACL, accelerometer; EE, energy expenditure; MET, metabolic equivalent task; TEE, total EE; HR, heart rate; PA, physical activity; MVPA, moderate-to-vigorous PA.

Table 3. Self-report methods validated for assessing physical activity in adolescents.

Self-report	Sample	Evaluation	Aim	Admin.	Criterion	Validity
2010. Recess Physical Activity Recall (RPAR) [50]	125 adolescents	Past day (recess)	MVPA and Total METs	Self-administered	ACLs Yamax, Biotrainer and ActiGraph	Yamax: *r* = 0.35 (*P* <0.05) Biotrainer: (*r* = 0.54 (*P* <0.01) ActiGraph: *r* = 0.42 (*P* <0.05)
2008. The International Physical Activity Questionnaire (IPAQ-A) [51]	248 adolescents	Past 7 days	PA intensities and Total METs	Self-administered	ACL Actigraph	*rho* = 0.17-0.30 (*P* <0.05)
2006. Flemish physical activity computer questionnaire (FPACQ) [52]	33 adolescents	Past week	Sedentary, leisure, occupation, Transportation . Total METs	Self-administered (computerized)	ACL CSA	*r* = 0.56 (*P* <0.01)
2005. Physical Activity Questionnaire for Adolescents (PAQA) [53]	33 adolescents	Habitual week	PA during school, transport and leisure during habitual week	Interview administered	DLW	*r* = 0.62, (*P* <0.001)
2003. 3-Day Physical Activity Recall (3DPAR) [54]	70 adolescents	Past 3 days	Overall, MVPA and Vigorous PA	Self-administered	ACL CSA	Over 7 days: *r* = 0.35-0.51, (*P* < 0.01) Over 3-days: *r* = 0.27-0.46 (*P* < 0.05)
2003. Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ) [55]	35 adolescents	Past year	Leisure time physical activity TEE estimated	Interview administered	DLW	*r* = 0.49 (*P* <0.01) to *r* = 0.73 (*P* <0.01)
2001. Physical Activity Screening Measure [56]	57 adolescents	Past 7 days	MVPA and vigorous PA	Self-administered	ACL CSA	*r* = 0.40 (*P* <0..001)
1997. Physical Activity Questionnaire for Adolescents (PAQ-A) [57]	85 adolescents	Past 7 days	Total activity (frequency)	Self-administered	ACL CSA	*r* = 0.33 (*P* <0.05)
1999. Activity diary [58]	30 adolescents	3 days	TEE and time spent at different intensity levels	Self-administered	ACL Caltrac	Mean difference -3.4±14.4 (not significant)
1997. Activity diary [59]	50 adolescents	7 days	TEE and PA level	Self-administered after tuition and followed by discussion	DLW	No group-level significant difference

ACL, accelerometer; DLW, doubly labeled water; MET, metabolic equivalent task; TEE, total energy expenditure; HR, heart rate; PA, physical activity; MVPA, moderate-to-vigorous PA.

Table 4. Self-report methods validated for assessing physical activity in children and adolescents.

Self-report	Sample	Evaluation	Aim	Admin.	Criterion	Validity
2007. Youth Media Campaign (YMCLS) [60]	192 children and adolescents	Past day and past 7 days	Bouts and minutes of MVPA	Interview by phone	ACL Actigraph	*r* = 0.53 and 0.37 for time and bouts of MVPA (previous day). *r* = 0.24 for total weekly PA
2005. Fels physical activity questionnaire (FPAQ) [61]	229 children and adolescents	Past day, month, or year	Leisure, occupation and sports/exercise	Self-administered	ACL Actiwatch	*r* = 0.34 (*P* <0.01)
2002. Activity questionnaire [62]	20 children and adolescents	Past day	Estimated TEE	Parent and child reported, any discrepancies resolved with staff member	HR	HR: *rho* = 0.72
1999. Previous Day Physical Activity Recall (PDPAR) [63]	48 children and adolescents	Past day	PA behaviour, intensities and METs	Self-administered	ACL Caltrac and pedometer	Caltrac: *r* = 0.77 (*P* <0.01) Pedometer: *r* = 0.88 (*P*< 0.01)
2007. Activity diary [60]	192 children and adolescents	Past 7 days	Bouts of MVPA	Self-reported	ACL Actigraph	*r* = 0.31 for bouts of weekly PA
2003 Activity diary [41]	68 girls	Past 3 days	Mode, intensity and duration of activity or rest	Self-administered	ACL CSA and pedometer	CSA: *r* = 0.37 (*P* < 0.002) Pedometer: *r* = 0.47 (*P* < 0.001)

ACL, accelerometer; MET, metabolic equivalent task; TEE, total energy expenditure; HR, heart rate; MVPA, moderate-to-vigorous PA.

Three key concepts must be understood when considering the accuracy and precision of any measurement technique, that is, reliability, validity and responsiveness [64].

One aspect of reliability is the reproducibility of a method, that is, the same results are obtained when the method is used by different independent assessors. Reliability is a prerequisite to validity. Validity refers to the ability of a measure to measure what it is supposed to measure. Criterion validity is when a method is validated against an objective method or gold standard method; the relationship is frequently reported as a correlation

coefficient. Absolute validity is when the absolute outcome, for example, time spent in activity, is compared with the same result obtained by an objective instrument. Relative validity is when an instrument is validated against a similar instrument.

Ideally, validity should be reported as the degree of agreement between methods [65,66], because correlation coefficients may be misleading [67]. A reliable questionnaire that overestimates PA to a large extent may correlate highly with an objective PA; these two measurements correlate but disagree. This questionnaire is considered valid to rank individuals (validity at the population level) but is not valid to measure PA with an absolute score (lack of validity at the individual level).

Responsiveness (sometimes called sensitivity) refers to the ability of an instrument to detect change over time. Reliability and validity are requirements for responsiveness. A commonly used index of responsiveness is the effect size for paired differences.

The development of more accurate and precise methods of assessing PA behaviour is an important public health research priority. Subjective (survey-based) tools are inexpensive and easy to use but these suffer from questionable validity. Objective measures are often used to validate less accurate measures such as subjective instruments but this does not directly improve the accuracy or precision of the self-report instrument.

PHYSICAL ACTIVITY QUESTIONNAIRE (PAQ)

The Physical Activity Questionnaire is a self-report instrument developed specifically for Children (PAQ-C) and later adapted for Adolescents (PAQ-A). The PAQ-C and PAQ-A are self-administered 7-day (previous week) recall questionnaires composed of 9 and 8 items, respectively, that assess overall level of MVPA during school time, after-school, evening, week and weekend (the PAQ-A is identical to the PAQ-C; however, it only has 8 items since it does not include a recess item) [68]. The PAQ-C was designed to be administered during the regular school year, and not intended to estimate activity variables or energy expenditure [69]. These questionnaires are limited in their ability to explain important dimensions of PA such as frequency, time and intensity and were developed to provide an overall indicator of PA levels (MVPA).

Nevertheless, there is evidence supporting the psychometric properties of these instruments [48,57,69-73] and different review papers have indicated the PAQ as having the better validity and reliability indicators when compared with existent self-report measures for youth [74,75]. Biddle and colleagues, in a review of self-report instruments for youth, identified the PAQ as being one of the most promising self-report tools available in the field [76]. The PAQ has shown great potential to assess PA, however, its scoring system is based on ordinal scales with no true meaning may add limited information when studying PA in the context of dose-response [77,78]. One of the possible reasons for such limitation is the inherent floor and ceiling effects associated with restricted scales. This limitation poses some concerns when assuming linear relationships between outcome (such as the PAQ score) and independent variables [79]. Continuous scores (e.g., MET.min or minutes

in MVPA) offer clear advantages in this context since they can add valuable insights about future PA recommendations targeting different health outcomes [77,80].

However, a limitation is that the outcome score is not readily interpretable [76].The lack of a meaningful outcome measure and possible floor or ceiling effects associated with the PAQ limit its utility [76]. One possible technique that can be used to overcome this limitation is to calibrate the raw outcome measure into a more meaningful unit. Calibration allows different scales (e.g., activity monitor estimates of MVPA and PAQ scores) to be similar in magnitude and variability, meaning they assume the same unit of measurement [81,82]. With this approach, raw data from a self-report measure can be calibrated to match output from a more objective activity monitoring device.

As shown, it is a weakness of the PAQ that there is a lack of uniformity and information about the meaning of final score, which would provide a useful outcome measure such as total minutes of PA or differentiate youth active and non-active based on international PA guidelines. One key challenge when calibrating self-report tools is the lack of an error-free criterion measure of PA. While there are advanced techniques that can minimize the impact of this limitation [80,83] a simple calibration design would most likely improve the utility of self-report instruments such as the PAQ. This particular instrument has been widely used in different areas of research and field settings [84-92] and therefore the proposed clarification work of score would greatly enhance its utility in the field. This work provides good evidence that the utility of self-report tools (PAQ-C and PAQ-A) can be improved.

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CHAPTER II: AIMS AND HYPOTHESIS

The overall purpose of this dissertation research was, on the one hand, to evaluate the reliability and validity of the PAQ in Spanish children and to determine cut-off points that would improve the utility of the PAQ for future research applications; on the other hand, to study longitudinal changes of body composition and PA behaviors in adolescence.

Two separate studies were conducted as part of the evaluation of the PAQ. Study 1 evaluated the validity and measurement properties of the original version of the PAQ-C using recommended approaches. Study 2 was aimed to evaluate different calibration approaches to classify youth as active or inactive following international recommendations as criteria. Finally, a follow-up study (Study 3) is focused on an important concern, since that is a longitudinal follow-up, where we will look the behavior of PA and body composition changes, during a two academic year on Spanish adolescents.

Thus, the specific objectives of this PhD dissertation are described below:

- ☑ To evaluate the reliability and validity of the PAQ-C questionnaire in Spanish children using triaxial accelerometry as criterion. (Study I).

- ☑ To determine PAQ-C and PAQ-A score cut-off values using PA thresholds objectively measured as reference criteria based on international PA recommendations (Study II).

☑ To explore PA changes assessed by PAQ-A in Spanish students during adolescence. Additionally, to analyze PA changes explain changes in adiposity independently of sex, nutrition and maturation. (Study III).

Based on the previous literature in children and adolescents, we hypothesized that:

- The PAQ-C questionnaire have an adequate reliability and a reasonable validity for assessing PA in Spanish children (Study I).

- The PAQ score can relate to with the established international PA recommendations to categorize youth according to their self-reported PA (Study II).

- Boys are more physically active than girls during adolescence, where PA level declines for both sexes (Study III).

- Sex and maturation play an independent role in body composition and PA pattern (Study III).

CHAPTER III: MATERIAL AND METHODS

SAMPLE AND RECRUITMENT

Participants were students of compulsory education (Primary and secondary education) attending to schools in different provinces in Spain (Andalucía and Galicia). A probabilistic method was used to select the sample, the next criteria were used: easy access to the sample, select a representative sample of primary and secondary schools, select a significant percent of the population of both schools.

One of the physical education teacher in the school carried out the recruitment process. Briefly, an informative document and proposal of the study was present to the administrative committee of the school. After obtaining the administrative waiver, full information of procedures and assessments were shown or sent to students and their parents or guardians respectively. Then, an informative meeting, where all doubts and questions were answered, a written informed consent was handed in.

Participants were accepted to participate in the studies always they met the next inclusion criteria (see Appendix III):

- ✓ Signed written informed consent.
- ✓ Not suffer any acute or chronic disease by the time of the study.
- ✓ Not be under medications that could interfere with body composition and perceptive capacity.
- ✓ Agree to complete all assessments.

During the four year of the GEOS project (2011-2014), 527 children and adolescents, enrolled in different educational institutions of Spain, were evaluated: 80 adolescents (I.E.S. Nuestra Señora de la Victoria "Martiricos", Málaga), 126 children and adolescents (I.E.S. Fernando de los Rios, Ronda-Málaga), 138 adolescents (I.E.S. Miguel Romero Esteo, Málaga), 21 children, (C.E.I.P. Julio Gurriarán Canalejas, Galicia), 54 children (C.E.I.P. de Maceda, Galicia), 48 children (C.E.I.P. Divina Pastora, Galicia), 41 children (C.E.I.P. San Sebastian, Málaga), 19 children (C.E.I.P. Cándido Nogales , Jaén).

The final sample included in this PhD dissertation is shown in Table 5.

BODY COMPOSITION SPECIFICATIONS

Body composition was assessed using the anthropometric method. All procedures followed the next protocol: All students were in fasting conditions, although water was permitted until one-hour before doing the measurements (except for body weight). Participants refrained from taking tea, coffee, chocolate or any other kind of stimulants; also, they did not perform any intense exercises or efforts during the previous 24 hours before the tests.

Anthropometry. The height and weight were measured to the nearest 0.1 cm 0.1 kg respectively with a stadiometer (Tanita® Leicester) and scale (Tanita®, model UM-060). An inextensible tape (Rosscraft, Canada) was used to obtain waist (WC), arm, thigh and calf circumferences to the nearest 0.1 cm. Skinfolds (triceps, thigh and calf) were measured with a calibrated caliper (Holtain Ltd, Crosswell, UK) with a precision of 0.2 mm, on the right side of the body. All measurements were carried out according to the

standardized procedures described in the literature and in accordance with guidelines of the International Society for the Advancement of Kinanthropometry*.

Body Compostion Models. Based on the previous measurements body composition components were calculated as follow. BMI was calculated using the formula (weight (kg) / squared height (m^2)). Fat mass percent (FMP, equations 1 and 2), and fat free mass (FFM, equation 3) were calculated using the two compartments (2C) model described by Slaughter:

$$\text{FMP } ♀ = 0.610 \cdot (\sum \text{triceps skinfold + calf skinfold}) + 5.1 \qquad \textit{Equation 1}$$

$$\text{FMP } ♂ = 0.735 \cdot (\sum \text{triceps skinfold + calf skinfold}) + 1.0 \qquad \textit{Equation 2}$$

$$\text{FFM (kg)} = \text{Weight} - (\%\text{FM}/100 \cdot \text{Weight}) \qquad \textit{Equation 3}$$

The rest of Material and Methods section, as well as Results and Discussion section, is displayed as papers have been previously summited or accepted. However, the Material and Methods section is summarized in the next table (table 5), which includes the most relevant methodological information of the studies from this PhD dissertation.

* Marfell-Jones M, Olds T, Stewart AD, Carter L. International Standards for Anthropometric Assessment. Potchefstroom (South Africa): International Society for Advancement in Kinanthropometry (ISAK); 2006.

Table 5. Summary of the methodology used in the current dissertation

	Study design	Participants	Main variables studied	Material	Statistical analysis
Study I. Reliability and validity of the PAQ-C questionnaire to assess physical activity in children.	Cross-sectional	83 children (46 boys, 37 girls)	Age, height, weight, BMI, FMP, subcutaneous skinfold thickness and PA.	Stadiometer SECA, Tanita UM-050 digital, anthropometric equipment, PAQ-C, Actigraph GT3X and SPSS.	Kolmogorov-Smirnov test. Spearman rank correlation coefficient. Intraclass Correlation Coefficient. Cronbach's α Coefficient. Bland and Altman method.
Study II. The physical activity questionnaire score cut offs to classify physical activity level in children and adolescents.	Cross-sectional	146 children (83 boys, 63 girls) and 234 adolescents (115 boys, 119 girls)	Age, height, weight, BMI, FMP, subcutaneous skinfold thickness and PA.	Stadiometer SECA, Tanita UM-050 digital, anthropometric equipment, PAQ-C, PAQ-A, Actigraph GT3X, SPSS and MedCalc.	Kolmogorov-Smirnov test. Spearman rank correlation coefficient. ROC curves.
Study III. The influence of 2-year changes in physical activity, maturation, and nutrition on adiposity in adolescent youth.	Longitudinal	80 adolescents (38 boys, 42 girls)	Age, height, weight, BMI, FMP, subcutaneous skinfold thickness, maturation level, nutrition and PA.	Stadiometer SECA, Tanita UM-050 digital, anthropometric equipment, PAQ-A, FFQ and SPSS.	Kolmogorov-Smirnov test. Spearman rank correlation coefficient. Khamis-Roche method. Repeated measures. General linear model.

BMI: Body Mass Index, FFQ: Food-frequency questionnaire, FMP: Fat mass percent, PA: Physical activity, PAQ-A: Physical activity questionnaire for adolescents, PAQ-C: Physical activity questionnaire for children, ROC: Receiver operating characteristic, SPSS: Statistical package for the social sciences.

CHAPTER IV: RESULTS AND DISCUSSION

I

RELIABILITY AND VALIDITY OF THE PAQ-C QUESTIONNAIRE TO ASSESS PHYSICAL ACTIVITY IN CHILDREN

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INTRODUCTION

Physical activity (PA) has been identified as an important agent in the prevention of chronic diseases such as obesity, cardiovascular diseases, and metabolic syndrome [1-3]. Therefore, in order to know more precisely the levels of PA during childhood and to identify the impact on health, it is necessary to develop and validate instruments able to adequately and widely assess PA in school populations.

Survey instruments continue to provide useful information in population-based studies of children's PA. The most accurate method for measuring energy expenditure during PA, such as doubly labelled water or indirect calorimetry are complex, time-consuming, and are expensive and impractical procedures when evaluating large populations [4]. Over the last decade a rise in the technology of accelerometers has allowed us to obtain reliable measurements of the duration of PA, and has provided an indirect, yet reasonably accurate measure of PA in this area. However, this continues to be an expensive method for application in certain settings such as primary schools. Self-report instruments provide a convenient way to assess activity patterns in large populations, however, there are few questionnaires designed to estimate PA in children.

One of the most widely used questionnaires for this age group is the Physical Activity Questionnaire for Children (PAQ-C) [5], though it has never been validated with Spanish children. The PAQ-C is a simple questionnaire that assesses the PA a child has performed over the last 7 days. The overall result of the test is a score of 1-5 points that allows for a graded level of PA performed by each subject. PA measured by PAQ-C has been associated with indicators of adiposity, bone mineral content, heart rate variability

and certain psychological indicators (sports competition, body satisfaction, anxiety) [6-8]. The PAQ-C have acceptable reliability and convergent validity [9]. The mean of all items is used to indicate level of PA. A high score indicates higher levels of PA. Moreover, attempts to obtain cut-off points from PAQ-C final score have been reported for English children [10]. In addition, this questionnaire has adequate validity and reliability in other countries [9], although the validity and reliability assessed varies by ethnicity and requires additional development to be a useful measure of physical activity in American and European children from diverse ethnic populations [11]. However, not enough is known about the capacity of PAQ-C to estimate PA measured objectively. Moreover, discrepancies and high variability in children's PA measured by accelerometers around the world have been reported, which may introduce a bias in validation studies [12,13]. So transcultural validation of PA questionnaires will allow us to compare results among countries and a more reliable and valid assessment of PA in each country.

Considering the need for adequate and viable methods of measuring PA in school settings, the aim of this study was to evaluate the reliability and validity of the PAQ-C when applied to Spanish children using as a reference criterion the objective measurement of PA by triaxial accelerometry.

METHODS

Participants

An invitation to participate in the study was sent to all parents who had their children in fourth, fifth or sixth grade in two different primary schools (Málaga and

Orense, Spain). Eighty-three potentially eligible subjects responded, and gave their written informed consent after receiving detailed information about the aims and procedures of the study. Subjects with incomplete PA (n=0) data or technical errors in the instrument (n=5) were excluded. A final sample of 83 children (46 boys, 37 girls) participated in the reliability study and 78 children (42 boys, 36 girls) cover the criteria for the validity study. There were no differences on age and body mass index (BMI) between the excluded participants and the final sample.

This study is part of two larger studies where the sample size was randomized from all eligible students of each primary school who met the inclusion criteria. Briefly, in the Orense school we had only thirty possible candidates (budget limitation) to participate in a doubly labeled water follow-up study during four weeks within one year. One hundred-fifty informed consents were distributed among children who were interested in the study. Of those, twenty-five met the inclusion criteria and only nineteen completed the final protocol.

Regarding the Malaga school, all students were called to participate in a randomized control trial study, and one hundred informed consents were distributed to the fourth, fifth and sixth grades of the school. Among those children/parents who signed the consent, a randomization was performed to select sixty who had availability to perform two separate physical and body composition assessments in our laboratory. Sixty-four students participated in the study, although only forty-one finished the intervention. In summary, data for this analysis comes from a randomized sample from two primary schools in Spain, where physical activity assessment by questionnaires was one of the variables in those longitudinal studies.

The research protocol was reviewed and approved by the Ethics Committee of the Sports Medicine School, at Faculty of Medicine (Málaga, Spain). The study was developed following the ethical guidelines of the Declaration of Helsinki-Seoul, last modified in 2008.

Instrumentation

Initial measurements

Anthropometric measurements (waist and hip circumferences, sagittal abdominal diameter and skinfolds), including height and body mass, were performed according to the International Society for the Advancement of Kinanthropometry (ISAK) standards for anthropometric assessment. Height was assessed with socks while shoes were taken off, using a stadiometer (SECA Leicester, Birmingham, UK). A Tanita UM-050 digital weighing scale (Tanita UK Ltd,Yiewsley, Middlesex, UK) was used to assess body mass. Fat mass percent (FMP) was calculated using Slaughter´s equation [14] from anthropometric measures.

BMI were calculated using the classical equation and were categorized into 3 levels: normal-weight, overweight and obesity, according Cole´s cut-off points [15].

Physical Activity Questionnaire for Children (PAQ-C)

PA was assessed using the PAQ-C [5]. The PAQ-C is a nine item, 7-day PA recall designed for use with elementary and middle school children in a field-based setting. A

tenth item not used in the calculation of the activity score asks children if they were sick or otherwise prevented from engaging in regular PA. The PAQ-C was administered twice and children were asked to recall their participation in activities over the last 7 days to compute an activity score. Once a value from 1 to 5 for each of the 9 items (items 1 to 9) used in the PA composite score is obtained, the mean of these 9 items is taken, which results in the final PAQ-C activity summary score.

Cultural adaptation of the Spanish PAQ-C was performed following the basic steps of standardized questionnaires cultural adaptation process [16]. The research team members made the original Spanish translation. Subsequently, two bilingual researchers outside the group performed the reverse translation. The differences between the original version and the translations were reviewed and discussed by the research group and external researchers. Typically, the questionnaire was completed at school in a quiet room, and researchers were available to help children and confirm that all items were answered. The entire process lasted approximately 10-15 minutes.

Accelerometry

The Actigraph GT3X monitor device (Actigraph, Pensacola, FL, USA), was used to assess PA. The accelerometer is lightweight (27 g), compact (3.8×3.7×1.8 cm) and has a rechargeable lithium polymer battery. It uses a solid-state tri-axial accelerometer to collect motion data on 3 axes: vertical (Y), horizontal right-left (X) and horizontal front-back axis (Z). The GT3X measures accelerations in the range of 0.05g to 2g, which is digitized by a 12-bit analog-to-digital converter at a rate of 30 Hz. Once digitized, the data are filtered using a band-limited frequency of 0.25 to 2.5 Hz. The Actigraph

accelerometer has been shown to be a reliable and valid tool for the assessment of different types of physical activities [17,18].

Researchers distributed pre-initialized accelerometers face-to-face at schools. Participants wore the accelerometers on the right side of the hip, secured with an adjustable elastic belt, underneath clothing, near to the center of gravity. Participants received a demonstration from a trained researcher on how to wear the accelerometer. They were asked to only remove the device when sleeping and engaging in water-based activities. Additionally, children received a brochure about accelerometer use including the instructions. Accelerometers were set to register 1-second epoch cycles, and were programmed to start the record at midnight of the following day they received the monitor and to record activity for the following 7 days.

The version 6.11.1 of Actilife Software (Actigraph, Pensacola, FL, USA) was used to process the accelerometer data. Periods of ≥60 minutes of zero values, allowing for 2 minutes of non-zero interruptions, were defined as accelerometer "non-wear" time and were removed from the analyses. The first day of recording was not included in the analysis. Only participants with ≥4 complete days, including one weekend day, were included [19]. A day was considered valid if it contained ≥10 hours of wear time for weekdays and ≥8 hours for weekend days considering different sleep patterns over weekends [20].

We selected the cut points from Evenson et al. [21] to determine the time spent on different intensity levels of PA: ≤100 cpm for sedentary behavior, <2296 cpm for light, <4012 cpm for moderate, and ≥4012 cpm for vigorous physical activity.

A recording of more than 15,000 counts per minute was considered as a potential malfunction of the accelerometer and the value was excluded from the analyses, based on the recommendations from Esliger et.al. [22].

Procedure

Following agreement to participate in the study, participants were assessed (initial measurements) and received an accelerometer and later (8 days) completed PAQ-C twice, with a gap of 6 hours between the two questionnaires. After the trial period, the material and questionnaires were collected by the researcher, and the data was stored in a spreadsheet using Microsoft Excel for further analysis.

Data Analysis

The characteristics of subjects were described with frequency distribution and mean, standard deviation (SD). The reliability (within-subject variability) was calculated by applying the PAQ-C during the same day twice and Intraclass Correlation Coefficient (ICC) was used to confirm the reproducibility. Additionally, agreement analysis was performed between first and second measurements of total score, also systematic and proportional bias were calculated by independent sample T-test and Kendall´s tau rank correlation. Individual item reliability was also carried out by the same procedure. The internal-consistency of the questionnaire was analyzed using Cronbach's α coefficient. Removing every item in order to confirm or exclude redundancy of the individual items was performed also by Cronbach's α. Additionally, we carried out an inter-item raw

correlation coefficient to complete reliability analysis as suggested by Clark and Watson [23].

The relationship between the PAQ-C and the accelerometer scores was performed using Spearman's rank correlation coefficients (Rs). Agreement between the PAQ-C (Total score values) and the accelerometer (MVPA minutes per day) was assessed using the Bland and Altman method [24]; after Z Score transformation for PAQ-C and accelerometer values. The Bland and Altman plots give an indication of random error and bias (see previous paragraph). The first PAQ-C was selected always as reference, and the second one was used to carry out the intra-day and/or intra-subject reliability.

In respect to statistical power analysis, if we assume an 80% of power and alpha value of 0.001, it will permit us to detect coefficients of correlation as low as 0.3 with a sample size of 66 students, which is below of our sample size, so we could confirm our correlation analysis for validity will not be biased by the sample size (type II error). The analyses were done using SPSS 21.0 (SPSS Inc. Chicago, Illinois) and the level of significance was set at $P<0.05$.

RESULTS

Characteristics of the participants are reported as mean and standard deviations in table 6. No significant gender differences were found in the variables shown.

Table 6. Characteristics of study participants by sex.

	All (n=83)	Boys (n=46)	Girls (n=37)
Age (years)	10.98±1.17	11.09±1.18	10.85±1.16
Weight (Kg)	42.06±11.32	41.70±10.58	42.51±10.30
Height (cm)	145.85±10.05	145.43±10.11	146.38±10.09
BMI (Kg/m2)	19.49±3.51	19.44±3.17	19.54±3.94
Normal-weight (n=49; 26♂, 23♀)	17.05±1.75	17.15±1.64	16.93±1.90
Overweight (n=28; 17♂, 11♀)	22.29±1.43	21.84±1.26	22.98±1.45
Obesity (n=6; 3♂, 3♀)	26.33±1.88	25.70±2.17	26.95±1.73
Fat Mass Percent (%)	23.26±7.63	21.62±6.92	25.30±8.06
PA Total Score (PAQ-C)	3.24±0.64	3.22±0.70	3.26±0.56
MVPA (min/day)*	63.22±14.40	63.43±15.23	62.98±13.57
Steps/day*	10,690.55±1,934.87	10,852.04±2,130.52	10,502.15±1,688.50

Values are presented as mean ± SD.
PA: physical activity; MVPA: moderate-vigorous physical activity.
PA Total Score (PAQ-C) is the average of the nine items (items 1 to 9).
* n=78; 42♂, 36♀

Table 7. Reliability analyses of Physical Activity Questionnaire for Children (PAQ-C) by Intraclass Correlation Coefficient (n=83).

	All	Boys (n=46)	Girls (n=37)	NW (n=49)	OW+O (n=34)
Total Score	0.96	0.96	0.97	0.97	0.95
Item 1: activity checklist	0.96	0.94	0.98	0.97	0.94
Item 2: physical education	0.95	0.95	0.99	0.97	0.92
Item 3: recess	0.79	0.66	0.92	0.77	0.83
Item 4: lunch	0.87	0.87	0.89	0.84	0.90
Item 5: after school (14-18 h)	0.82	0.80	0.86	0.79	0.84
Item 6: afternoon (18-22 h)	0.77	0.69	0.88	0.71	0.87
Item 7: weekend	0.63	0.45	0.85	0.60	0.65
Item 8: intensity last week	0.90	0.91	0.89	0.89	0.92
Item 9: week summary	0.95	0.95	0.94	0.94	0.95

NW: normal-weight; OW+O: overweight plus obesity.
The reliability was calculated by intraclass correlation coefficient from two repeated measures by applying twice the PAQ-C during the same day. The first PAQ-C was selected always as reference.

Table 7 shows results for PAQ-C within-subject reliability. Low differences between the first and second questionnaire administration were observed (Difference between 1st and 2nd time Scores = 0.0248 ±0.2568). Also, the highest reliability values for the total score were obtained from girls and normal-weight children (ICC=0.97 for both). Regarding individual item analyses, item 7, which informs about PA during the weekend, showed an ICC of 0.63, which was the lowest value. Moreover, compared to girls, the

results reported by boys had an even lower ICC value (0.45 vs. 0.85) in this particular item, so boy's answers biased the reliability in this item. Conversely, item 1 had the best reliability (ICC=0.96) without differences between genders.

The internal-consistency coefficients of the questionnaire can be seen in the table 8. The PAQ-C questionnaire obtained a consistency of Cronbach's α = 0.76. The internal consistency was reduced after removing every single item (table 8), which may indicate no redundant items are included in the questionnaire. Removing third and eighth items had the lowest values in the internal consistency, showing a high contribution to final test score, except for the group of overweight and obese children, who reported higher values in these items. The inter-item correlation coefficients were between 0.581 (item 1 and 9) and 0.177 (item 1 and 3), and the average inter-item correlation coefficient rho = 0.442.

Table 8. The internal-consistency of the Physical Activity Questionnaire for Children (PAQ-C) by Cronbach's α coefficient (n=83).

	All	Boys (n=46)	Girls (n=37)	NW (n=49)	OW+O (n=34)
Total Score	0.76	0.78	0.75	0.77	0.86
Item 1: activity checklist	0.58	0.55	0.65	0.55	0.58
Item 2: physical education	0.40	0.45	0.31	0.43	0.71
Item 3: recess	0.34	0.38	0.36	0.40	0.58
Item 4: lunch	0.44	0.60	0.16	0.46	0.48
Item 5: after school (14-18 h)	0.52	0.45	0.65	0.51	0.46
Item 6: afternoon (18-22 h)	0.59	0.53	0.69	0.51	0.67
Item 7: weekend	0.41	0.32	0.58	0.65	0.55
Item 8: intensity last week	0.38	0.53	0.13	0.25	0.72
Item 9: week summary	0.68	0.65	0.75	0.63	0.71

NW: normal-weight; OW+O: overweight plus obesity.
Internal consistency was calculated by Cronbach`s coefficient alpha, which is based on the average correlation among the items in the questionnaire and the variance of the total score of PAQ-C.
Cronbach's α coefficient by item indicates the α when that item is removed from the questionnaire.

Spearman rank correlations between the PAQ-C and the accelerometer for the total PA were significant, although they remain weak (Rs = 0.23-0.28, all $P<0.05$). Items six, eight and nine showed significant correlations with the total activity, MVPA and steps

measured by accelerometry. The highest correlation was observed for item nine (Rs = 0.31, *P*<0.01).

The accuracy analysis performed with the concordance coefficient correlation reported a low accuracy compared with accelerometry (r=0.192, P=0.092), which was graphically confirmed by the scatter plot between PAQ-C and accelerometry where regression line Z values of both instruments (R^2=0.07, P<0.05) were compared with the identity line (Figure 1).

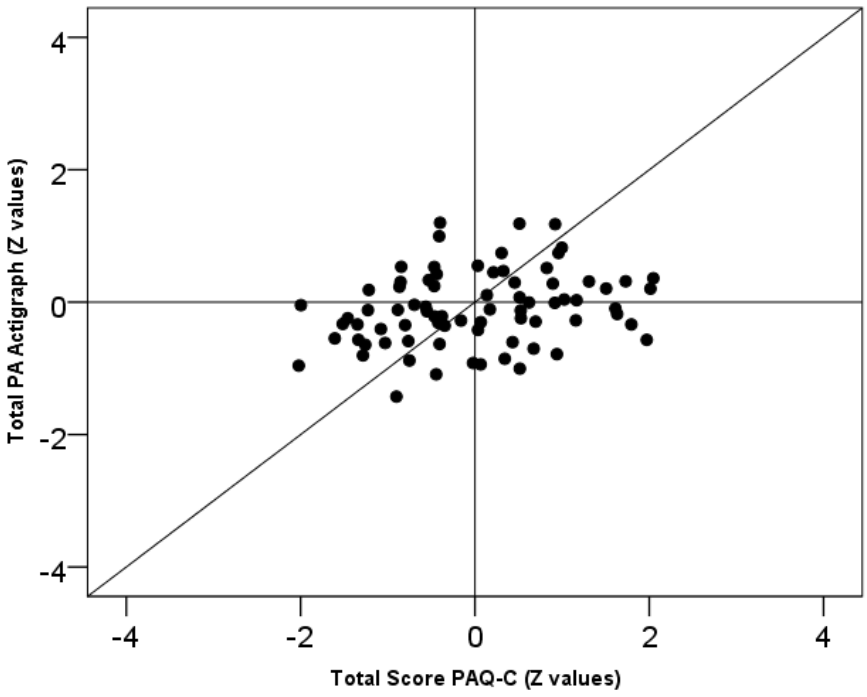

Figure 1. Scatter plot between Z values of Physical Activity Questionnaire for Children (PAQ-C) and total PA by Actigraph.
Z value = (Individual score - mean score)/SD.

In Figure 2 the Bland and Altman plot for Z values of the total PA estimated by PAQ-C and accelerometry showed significant differences between the PAQ-C and the accelerometer. Additionally, differences between the PAQ-C and the accelerometer

scores increased as Z values, so higher Z mean, higher Z difference (Kendall´s Tau=0.189, *P*<0.05).

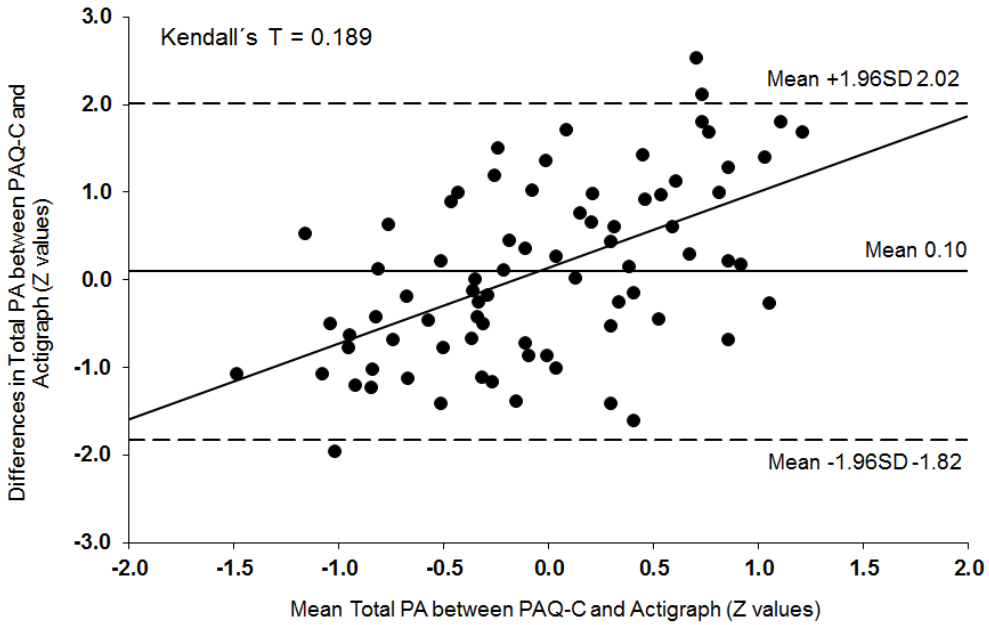

Figure 2. Bland and Altman Plots with differences in mean total PA for the Physical Activity Questionnaire for Children (PAQ-C) and the Actigraph. Dashed lines are agreement limits; thin solid line represents mean difference between Z-scores of physical activity measured by PAQ-C and accelerometers; thick solid line indicates trend from Kendall's Tau correlation.
Z value = (Individual score - mean score)/SD.

DISCUSSION

The present study evaluated the reliability and validity of the Spanish version of the PAQ-C questionnaire to assess physical activity in schoolchildren. One of the strengths of this study was to evaluate the reliability and validity of the PAQ-C using a triaxial accelerometer as criterion (setup: 1-second epoch). Also, it is the first time that this has been conducted with Spanish children. The results show high test-retest reliability (ICC = 0.96) for the Spanish adaptation of the PAQ-C. The reliability of the PAQ-C was good in other studies conducted in other countries [5,9,25] and with children of different races [11].

An estimate of Cronbach`s coefficient alpha > 0.70 is usually considered indicative of a reliable questionnaire [26]. Our results confirm the satisfactory internal consistency of the questionnaire (α = 0.76), which is in accordance with other studies reporting similar results, so Crocker et al. reported 0.79 to 0.89 for two time PAQ-C measurements [5]; Janz et al. reported 0.72 to 0.76 after three repeated measures [25]; and Moore et al. found an alpha of 0.75 for European American children [11].

However, the individual item analysis revealed that reliability was not uniform along the questionnaire, so the seventh item revealed a low ICC, which appears to be sex-dependent since boys had significantly lower consistency than girls. This item asks for PA during the weekend, and it should be more variable and irregular than weekdays (usually children have a schedule during weekdays), so it could be more difficult for children to reproduce the same answer. Regarding the difference between boys and girls being more difficult to interpret, we can speculate that maturity and behavior differences could be plausible causes, however this hypothesis would need to be investigated (i.e. girls may have more consistent activities during the weekends than boys or the representativeness weekend activities is more important for girls than for boys, which may help girls to give more consistent answers). Additionally, it was important to observe that internal consistency was lower than 0.70 after removing items (table 8), which may confirm all items were important for the internal consistency of final score (no redundancy). These results of reliability were confirmed by the inter-item coefficient correlation of 0.442, which is in the range of values suggested in the literature [23].

The PAQ-C questionnaire was compared with an objective measure of PA to determine the concurrent validity of the PAQ-C using triaxial accelerometry. The

Spearman correlation coefficients between the PAQ-C and accelerometer scores ranged from 0.047 to 0.295 (Rs 0.28 for Total PA Score; $P<0.05$), indicating a low correlation between both instruments. These correlations for total activity were slightly lower than those obtained in the study reported by Janz et al. [25]. This result does not concur with a validation study of the Physical Activity Questionnaire for Adolescents (PAQ-A) conducted on Spanish adolescents [27], which showed reasonable validity of the PAQ-A for this age range (Rs = 0.39; $P<0.001$). These data confirm a line of evidence that suggests PA questionnaires for adolescents correlated better with accelerometer scores than PA questionnaires for children [6]. Nonetheless, it could be argued that a small sample size did not permit us to detect high correlation coefficients. However, our *post hoc* statistical power analysis informed our results must not be influenced by the sample size. Therefore, our sample of eighty-three participants permitted us to detect correlation coefficients lower than 0.3.

Accelerometers have been suggested as one of the best criterion measures for validation of self-report instruments of PA [28,29]. However, this practice has been criticized due to the fact that accelerometers and self-report instruments measure different things [30] and both instruments produce considerably different results in PA intensity in this population [31]. Accelerometry measures body movement, while questionnaires often ask respondents to rate the activities related to the effort or frequency. Moreover, the activities reported in the first item of the PAQ-C, skateboarding and cycling, are impossible to capture with the accelerometer because these instruments only capture locomotive activities where center of gravity has oscillation. Further, PAQ-C asks for frequency spent in physical activities, which is a subjective rating of exercise load and different measurement unit compare to accelerometer. We tried overcoming this limitation to

compare both instruments with Z value transformation, nevertheless, the results were similar, and significant differences and low correlations were confirmed; therefore, the observed agreement between the PAQ-C (a measure of self-report) and accelerometer (an objective measure) should be interpreted in this light.

The output from accelerometers is a dimensionless unit commonly referred to as accelerometer counts. Researchers have attempted to calibrate these counts with energy expenditure in order to get a biological meaning to the output [32]. This has resulted in the publication of count thresholds relating to various categories of energy expenditure that allow researchers to summarize time spent in a given intensity of activity [33]. The availability of multiple cut points or equations has led to much confusion in the accelerometer literature [34]. We used the Evenson et al. [21] cut points, recommended in Trost et al. [35] comparative study to estimate time spent in sedentary, light-, moderate-, and vigorous-intensity activity in children and adolescents. Other cut points would have yielded different results. Nonetheless, the associations and differences with total PA will continue to be the same since this variable must not be highly dependent of cut-off values.

The Bland-Altman plots showed that PAQ-C gave higher values of total PA than the accelerometer. Subjects are likely to overestimate the frequency of activities and this is not reflected in real movement data. In other words, higher the time spent in a certain level of PA assessed by the accelerometer, higher the difference between both methods.

Finally, another source of error must be related with the adiposity level. In adolescents, an overestimation of PA has been reported when assessed by self-reported tools [36]. In our sample an interaction between reliability and BMI groups was not plausible

since similar coefficients of correlations were found among normal, overweight and obese children. Also, non-significant correlations were observed between BMI or FMP and differences in total PA for the PAQ-C and accelerometry. However, it could be speculated that such results could be influenced by a low rate of overweight and obese children, but in this study the prevalence of overweight and obesity (40.9%, table 6) was similar to the Spanish prevalence (34.9%) [37]. In summary, we can conclude that the overestimation of PA founded in overweight and obese adolescents was not confirmed in children.

Bearing in mind the use of the cut-off points for PA intensities Yngve et al. [38] reported, when establishing cut-off values the results are affected by the types of activities performed and the setting. Age-specific equations must be used to ensure the correct use of accelerometer in children. However, the PAQ-C questionnaire only assessed the frequency of PA and not intensity, so the total PA must be more valuable to compare both instruments. Meanwhile, a recent study have reported that the PAQ-C can be calibrated to provide accurate group-level estimates of MVPA, which can be used to improve the usability of the questionnaire [39].

Limitations

We could speculate the low correlations observed in this study might be due to sample size as well as the level of maturity associated with the age of the children. However, the sample size was similar to the original validation studies [9,40] and the statistical power analysis informs our simple size is enough to detect even stronger correlations. Other limitations could explain these low associations, so there must be inherent subjectivity when individuals are asked to respond to questions about their

behavior. Some issues as recalling errors, deliberate misrepresentations, social desirability and other biases have been pointed out to be particularly important when dealing with children [41]. All these previous limitations may be hard to overcome with the current protocol of the questionnaire, which assume a self-report procedure. So, only an enhanced protocol, which includes additional control items or provides more help to children to fill the PAQ-C (in example by showing actual references such as PA-related videos of children), would improve the validity of the questionnaire. However, we could not implement any of these strategies since we followed the published procedure thoroughly.

Conclusions

In summary, this was the first study that analyzes validity and reliability of PAQ-C in Spanish children, which may help to understand the meaning and applicability of the questionnaire. The results suggest that PAQ-C had a high reliability but questionable validity for assessing PA in our sample of Spanish children. These findings would suggest that the PAQ-C requires additional development to be a useful measure of PA in Spanish children. Therefore, PA measurement in children should not be limited to self-report measures solely and whenever possible an ACL or other capture-movement device should be used. This approach will allow us to obtain a better interpretation of the actual results of PA in which children are involved. In view of the known benefits of PA in this population [42-44], there is a need to develop new self-report measures or validate other existing PA questionnaires.

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II

THE PHYSICAL ACTIVITY QUESTIONNAIRE SCORE CUT OFFS TO CLASSIFY PHYSICAL ACTIVITY LEVEL IN CHILDREN AND ADOLESCENTS

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INTRODUCTION

Physical activity (PA) is a powerful predictor of cardiovascular [1], skeletal [2-4], and mental health [5], in children and adolescents. Moreover, PA has been identified as an important agent in the prevention of chronic diseases such as obesity, cardiovascular diseases, and metabolic syndrome [1,6,7]. However, current youth, and especially girls, are often not enough active [8-12].

PA assessment by questionnaires is a cornerstone in the field of sport epidemiology studies. Survey instruments continue to provide useful information in population-based studies of young's PA and they enable a convenient way to assess activity patterns on large populations [13]. The Physical Activity Questionnaire for children and adolescents (PAQ-C & PAQ-A) are a cost-effective tools to assess PA patterns during childhood and adolescence [14] and it has been widely used in research and field settings. However, a limitation is that the outcome score is not readily interpretable [15]. The PAQ asks for frequency spent in physical activities, which is a subjective rating of intensity, moreover their items are scored using ordinal scales (1-5 scale) and the outcome measure is computed as a simple mean of the individual items. This makes it difficult to relate the PAQ score with the established international PA recommendations [16].

Meanwhile, objective measures are often used to validate less accurate measures, such as subjective instruments, but this does not directly improve the accuracy or precision of the self-report instrument. Equivalent estimates of PA could be generate in a more efficient and cost- effective way if we use handle self-report instruments. In this line, the utility in youth can be greatly enhanced by calibrating self-report output against

objectively measured PA data. Therefore, although objective instruments are now widely used, there is a considerable need to improve the utility and accuracy of self-report measures.

Triaxial accelerometers provide an objective indicator of free-living PA that can be temporally linked to data from a self-report tool [17,18], so it is an appropriate method to establish cut-offs points as PA recommended. The most accurate method to measure energy expenditure of PA, such as doubly labelled water or indirect calorimetry are expensive [18] and impractical procedures to achieve this goal. Accelerometry-derived measures of youth PA are usually expressed as daily min of light, moderate and vigorous physical activity to allow classification of PA according to whether health-related PA guidelines are met. Thus, it would be possible to carry out the meaningful interpretation of PA measurements into active and non-active, because this classification is linked with clinically relevant health outcomes.

In previous studies, various arbitrary PAQ-score cut-off points have been proposed to categorize youth according to their self-reported PA. Ogunleye et al. [19] divided youth as "active" or "low-active" based on an age–sex-specific median split of PAQ scores. Bailey et al. [20,21] grouped youth into "active," "average" and "inactive" based on age–sex specific PAQ-score quartiles (top, middle two, and bottom quartiles, respectively). Chen et al. [22] assigned PAQ scores ≤2 as "low activity," >2 and ≤3 as "moderate activity," and >3 as "high activity".

As shown, it is a weakness of the PAQ that there is a lack of uniformity and information about the meaning of final score which would differentiate youth active and

non-active based on international PA guidelines and related studies [16,23-31]. Therefore, the aim of this study was to determine PAQ-C and PAQ-A score cut-off values using PA thresholds objectively measured as reference criteria based on international recommendations.

METHODS

Sample

An invitation to participate in the study was sent to all parents who had their children and adolescents in different schools of primary and secondary education (Málaga, Jaen and Galicia, Spain). Four-hundred and forty potentially eligible subjects responded, and gave their written informed consent after receiving detailed information about the aims and procedures of the study. Subjects with incomplete PA data (n=18) or technical errors in the instrument (n=42) were excluded. A final sample of 146 children (n=83 boys, n=63 girls) and 234 adolescents (n=115 boys, n=119 girls) participated in this study. There were no differences on age and body mass index (BMI) between the excluded participants with the final sample.

The research protocol was reviewed and approved by the Ethics Committee of the Sports Medicine School, at the Faculty of Medicine (Málaga, Spain). The study was developed following the ethical guidelines of the Declaration of Helsinki-Seoul, last modified in 2008.

Measures

Body Composition.

Participant´s heights were measured with socks and shoes removed using a stadiometer (SECA Leicester, Birmingham, UK). A Tanita UM-050 digital weighing scale (Tanita UK Ltd, Yiewsley, Middle-sex, UK) was used to measure body mass. Body mass index (BMI; weight/height; kg/m^2) was then calculated.

Anthropometric measurements, including skinfolds, height and body mass, were performed by a level 3 certified anthropometrist according to standards for anthropometric assessment of International Society for the Advancement of Kinanthropometry. Fat mass percent (FMP) was calculated using Slaughter´s equation [32].

Physical Activity Questionnaire

PA was assessed using the PAQ-C and PAQ-A [33]. The PAQ have acceptable reliability and convergent validity [34,35] and the administration and scoring are described elsewhere [36]. In brief, the self-administered, 7-day recall questionnaire comprises nine or eight items (PAQ-C includes an additional item on recess), respectively, and collects information on participation in different types of activities and sports (activity checklist), effort during physical education classes, and activity during lunch, after school, evening and at the weekend during the past 7 days. Each item is scored between 1 (low PA) and 5 (very high PA) and the average score denotes the PAQ score. A high score indicates higher levels of PA. The ninth (PAQ-A) and tenth (PAQ-C) item are not used in

calculation of the activity score, asks children and adolescents if they were sick or otherwise prevented from engaging in regular PA. Once a value from 1 to 5 for each of the 8-9 items used in the PA composite score is obtained, the mean of these 8-9 items is taken, which results in the final PAQ activity summary score.

Cultural adaptation of the Spanish PAQ was performed following the basic steps of standardized questionnaires cultural adaptation process [37]. The original Spanish translation was made by the research team members. Subsequently, two bilingual researchers outside the group performed the reverse translation. The differences between the original version and the translations were reviewed and discussed by the research group and external researchers.

Triaxial accelerometry.

The Actigraph GT3X monitor device (Actigraph, Pensacola, FL, USA), was used to assess PA objectively. The accelerometer is lightweight (27 g), compact (3.8×3.7×1.8 cm) and has a rechargeable lithium polymer battery. It uses a solid-state tri-axial accelerometer to collect motion data on three axes: vertical (Y), horizontal right-left (X) and horizontal front-back axis (Z). The GT3X measures accelerations in the range of 0.05g to 2g, which is digitized by a 12-bit analog-to-digital converter at a rate of 30 Hz. Once digitized, the data are filtered using a band-limited frequency of 0.25 to 2.5 Hz. The Actigraph accelerometer has been shown to be a reliable and valid tool for the assessment of different types of physical activities [38,39].

Researchers distributed pre-initialized accelerometers face-to-face at schools. Participants wore the accelerometers on the right side of the hip, secured with an adjustable elastic belt, underneath clothing, near to the center of gravity. Participants received a demonstration from a trained researcher on how to wear the accelerometer. They were asked to only remove the device when sleeping and engaging in water-based activities. Additionally, children received a brochure about accelerometer use including the instructions. Accelerometers were set to register 1-second epoch cycles, and were programmed to start recording at 12 midnight of the day following they receive the monitor and to record activity for the following 7 days.

The version 6.11.1 of Actilife Software (Actigraph, Pensacola, FL, USA) was used to process the accelerometer data. Periods of ≥60 minutes of zero values, allowing for 2 minutes of non-zero interruptions, were defined as accelerometer "non-wear" time and were removed from the analyses. The first day of recording was not included in the analysis. Only participants with ≥4 complete days, including one weekend day, were included [40]. A day was considered valid if it contained ≥10 hours of wear time for weekdays and ≥8 hours for weekend days considering different sleep patterns at weekends [41].

We selected the cut points for children from Evenson et al. [42] to determine the time spent on different intensity levels of PA for children: ≤100 cpm for sedentary behavior, <2296 cpm for light, <4012 cpm for moderate, and ≥4012 cpm for vigorous PA. These cut-offs values were subsequently validated for adolescents [43].

A recording of more than 15,000 counts per minute was considered as a potential malfunction of the accelerometer and the value was excluded from the analyses, based on the recommendations from Esliger et.al. [44].

Procedure

The subjects each received an information sheet and consent form for parents, and were asked to return the forms to their school. Children and adolescents with completed consent forms subsequently were assessed (initial measurements) and received an accelerometer and later (8 days) completed PAQ-C and/or PAQ-A questionnaire. A considerable time was taken to fully explain the questionnaire and examples were provided. After the trial period, the material and questionnaires were collected by the researcher, the data is stored in a database for further analysis.

Statistical Analysis

The characteristics of participants were described as mean and standard deviation (SD). A descriptive statistical analysis was performed for all quantitative variables and an analysis of the normal distribution was carried out using the Kolmogorov-Smirnov test. The relationship between the PAQ and the accelerometer scores was performed using Spearman's rank correlation coefficients (rho).

Based on international recommendations [16,23-31] three factors of two levels were created as participants met or not the PA recommendations and discriminate between "active" and "non-active" youth (MVPA >60 min/day, vigorous PA >30min/day, and

light PA >116 min/day; respectively). Receiver operating characteristic (ROC) curves [45] were carried out to identify PAQ-C and PAQ-A score cut-off point for each factor. Classification accuracy for each set of cut-points was evaluated by calculating weighted statistics, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC). An area of 1 represents perfect classification, whereas an area of 0.5 represents an absence of classification accuracy. ROC–AUC values of >0.90 are considered excellent, 0.80–0.89 good, 0.70–0.79 fair, and <0.70 poor [46].

The analyses were performed using SPSS 22.0 (Chicago, Illinois) and MedCalc 14.12.0 (Mariakerke, Belgium) for ROC curves. The level of significance was set at $P<0.05$.

RESULTS

Characteristics of the participants (children and adolescents) for both sex combined and separately are presented in table 9. All values are reported as mean and standard deviations (SD). Significant differences between boys and girls were found in adolescents for weight, height, FMP, PAQ-A score, all PA intensities and number of steps, with higher values for boys, except for FMP. No differences between sexes were found in children. 53.4% of children met the 60 minutes of MVPA recommended; while 41.9% of adolescents met this recommendation. PAQ score was positively associated with vigorous PA, MVPA and number of steps (rho=0.19, rho=0.17, rho=0.16, respectively; all $P<0.05$) for children. In adolescents, PAQ score was positively associated with all intensities (light, moderate, vigorous and MVPA) and number of steps supplied by the accelerometer (rho=0.33, rho=0.21, rho=0.39, rho=0.36 rho=0.41, respectively; $P<0.001$).

Table 9. Characteristics of study participants by age and sex (n=480).

	Children			Adolescents		
	All (n=146)	Girls (n=63)	Boys (n=83)	All (n=234)	Girls (n=119)	Boys (n=115)
Age (years)	10.8±1.3	10.7±1.3	10.9±1.2	15.3±1.4	15.2±1.4	15.4±1.3
Weight (Kg)	41.5±11.7	40.0±12.7	42.7±10.8	59.5±13.3	57.5±1.7	61.5±13.7*
Height (cm)	144.6±10.5	143.2±10.9	145.6±10.1	163.9±8.2	160.2±6.0	167.6±8.4***
BMI (Kg/m2)	19.5±3.7	19.1±4.0	19.9±3.4	22.1±4.4	22.4±4.6	21.8±4.2
FMP (%)	22.9±9.2	22.9±6.6	22.9±10.9	18.9±8.0	21.2±7.7	16.6±7.6***
PA Score (PAQ-C)	3.09±0.64	3.11±0.60	3.07±0.66	-	-	-
PA Score (PAQ-A)	-	-	-	2.51±0.72	2.29±0.68	2.73±0.70***
Sedentary time (min/day)	603.5±60.9	609.0±61.2	599.3±60.7	642.9±75.7	642.7±83.4	643.1±67.2
Light PA (min/day)	120.3±33.8	121.7±46.2	119.3±20.3	92.7±28.4	88.0±27.4	97.6±28.7*
Moderate PA (min/day)	33.7±6.8	33.6±6.2	33.8±7.3	33.8±12.8	31.5±11.9	36.2±13.4**
Vigorous PA (min/day)	29.1±8.9	27.8±8.3	30.1±9.2	23.0±14.9	16.6±10.4	29.7±15.8***
MVPA (min/day)	62.8±13.9	61.3±12.7	63.9±14.7	56.9±22.9	48.1±18.9	65.9±23.3***
Steps/day	10668±1938	10556±1594	10752±2170	9320±3561	8434±3682	10264±3180***

BMI: body mass index; FMP: fat mass percent; PA: physical activity;
* P<0.05; ** P<0.01. *** P<0.001; independent sample t test between boys and girls.

Physical activity questionnaire for children (PAQ-C)

Details for AUC, as well as PAQ-C scores and number of steps equivalent to the coordinates with the greatest sum of sensitivity and specificity are shown in Table 10 and 11.

Table 10. Area under the ROC curve of PAQ-C score and steps/day, based on PA recommendations.

PA Recommendations	60 MVPA		30 Vigorous PA		116 Light PA	
	Score	Steps	Score	Steps	Score	Steps
AUC	0.551	0.896	0.545	0.879	0.527	0.756
EE	0.0483	0.0259	0.0488	0.0278	0.0482	0.0408
95% CI	0.467 to 0.634	0.835 to 0.940	0.460 to 0.627	0.815 to 0.927	0.443 to 0.610	0.678 to 0.823
P	0.2896	<0.0001	0.3579	<0.0001	0.5728	<0.0001
Youden index	0.1572	0.6497	0.1659	0.6575	0.1269	0.439

PA: physical activity; MVPA: moderate to vigorous physical activity; AUC: area under the curve; EE: standard error; CI: confidence interval; P: significance level.

Table 11. PAQ-C score and steps/day cut-off points and sensitivity, specificity, likelihood ratios and predictive values, based on PA recommendations.

PA Recommendations		Cut Point	Sens	95% CI	Spec	95% CI	+LR	95% CI	-LR	95% CI	+PV	95% CI	-PV	95% CI
60 MVPA	PAQ score	>2.75	73.08	61.8 - 82.5	42.65	30.7 - 55.2	1.27	1.0 - 1.6	0.63	0.4 - 1.0	59.4	48.9 - 69.3	58	43.2 - 71.8
	Steps/day	>10664	78.21	67.4 - 86.8	86.76	76.4 - 93.8	5.91	3.2 - 11.0	0.25	0.2 - 0.4	87.1	77.0 - 93.9	77.6	66.6 - 86.4
30 Vigorous PA	PAQ score	>2.75	75.41	62.7 - 85.5	41.18	30.6 - 52.4	1.28	1.0 - 1.6	0.6	0.4 - 1.0	47.9	37.6 - 58.4	70	55.4 - 82.1
	Steps/day	>11038	78.69	66.3 - 88.1	87.06	78.0 - 93.4	6.08	3.5 - 10.7	0.24	0.2 - 0.4	81.4	69.1 - 90.3	85.1	75.8 - 91.8
116 Light PA	PAQ score	>2.78	68.75	57.4 - 78.7	43.94	31.7 - 56.7	1.23	0.9 - 1.6	0.71	0.5 - 1.1	59.8	49.0 - 69.9	53.7	39.6 - 67.4
	Steps/day	>10190	78.75	68.2 - 87.1	65.15	52.4 - 76.5	2.26	1.6 - 3.2	0.33	0.2 - 0.5	73.3	62.6 - 82.2	71.7	58.6 - 82.5

PA: physical activity; MVPA: moderate to vigorous physical activity; Sens: sensitivity; CI: confidence interval; Spec: specificity; LR: likelihood ratios positives (+) and negatives (-); PV: predictive values positives (+) and negatives (-).

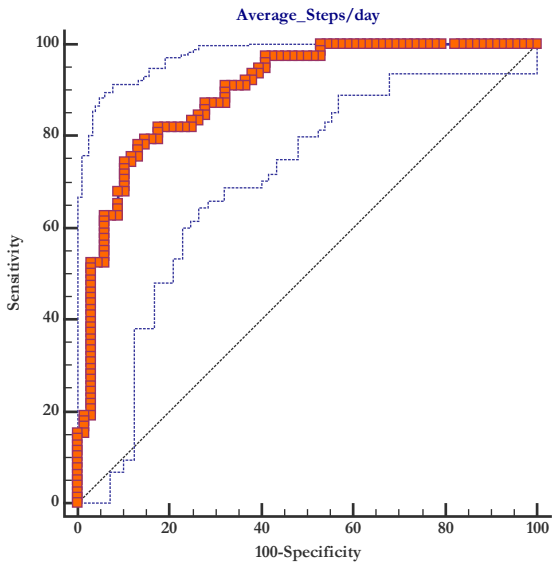
Table 13. PAQ-A score and steps/day cut-off points and sensitivity, specificity, likelihood ratios and predictive values, based on PA recommendations.

PA Recommendations		Cut Point	Sens	95% CI	Spec	95% CI	+LR	95% CI	-LR	95% CI	+PV	95% CI	-PV	95% CI
60 MVPA	PAQ score	>2.75	51.02	40.7 - 61.3	77.94	70.0 - 84.6	2.31	1.6 - 3.4	0.63	0.5 - 0.8	62.5	51.0 - 73.1	68.8	60.9 - 76.0
	Steps/day	>9701	86.6	78.2 - 92.7	93.08	87.3 - 96.8	12.51	6.6 - 23.6	0.14	0.09 - 0.2	90.3	82.4 - 95.5	90.3	84.0 - 94.7
30 Vigorous PA	PAQ score	>2.77	57.38	44.1 - 70.0	75.14	68.0 - 81.4	2.31	1.6 - 3.2	0.57	0.4 - 0.8	44.9	33.6 - 56.6	83.3	76.5 - 88.8
	Steps/day	>9806	86.89	75.8 - 94.2	77.11	70.0 - 83.3	3.8	2.8 - 5.1	0.17	0.09 - 0.3	58.2	47.4 - 68.5	94.1	88.7 - 97.4
116 Light PA	PAQ score	>2.73	53.33	37.9 - 68.3	68.78	61.7 - 75.3	1.71	1.2 - 2.4	0.68	0.5 - 0.9	28.9	19.5 - 39.9	86.1	79.5 - 91.2
	Steps/day	>12511	46.51	31.2 - 62.3	91.85	86.9 - 95.4	5.71	3.2 - 10.2	0.58	0.4 - 0.8	57.1	39.4 - 73.7	88	82.6 - 92.3

PA: physical activity; MVPA: moderate to vigorous physical activity; Sens: sensitivity; CI: confidence interval; Spec: specificity; LR: likelihood ratios positives (+) and negatives (-); PV: predictive values positives (+) and negatives (-).

AUC of PAQ-C score for MVPA >60 min/day, vigorous PA >30min/day, and light PA >116 min/day were no significant (P>0.05) and only weak (AUC<0.7) discriminators between “active” and “non-active” individuals. However, AUC of number of steps for all intensities were significant (P<0.001) and good (AUC>0.8 for 60 minutes of MVPA) discriminators.

ROC analysis showed PAQ-C score cut-off points >2.75 to discriminate active children. 60 minutes of MVPA in children appears to be achieved, on average, within a total volume of 10664 steps/day; 30 minutes of vigorous PA within a total volume of 11038 steps/day; and 116 minutes of light PA within a total volume of 10190 steps/day. The sensitivity associated with the different factors were moderate for PAQ-C score and steps/day. However, the specificity associated were low for PAQ-C score (42.7%, 41.2% and 43.9%, respectively) and high for steps/day (86.8%, 87.1% and 65.2%, respectively). This shows the low capacity of the PAQ-C to identify inactive children. A sample ROC curves is illustrated in Figure 3.



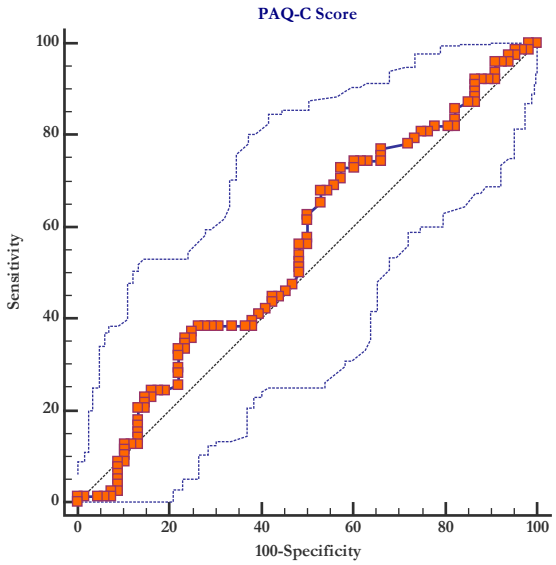


Figure 3. Examples receiver-operator curves for number of steps and the Physical Activity Questionnaire for Children (PAQ-C)'s ability to identify 60 minutes of moderate to vigorous physical activity (MVPA) (n=146).

Physical activity questionnaire for adolescents (PAQ-A)

Details coordinates with the greatest sum of sensitivity and specificity are shown for AUC, as well as PAQ-A scores and number of steps equivalent to the in Table 12 and 13.

Table 12. Area under the ROC curve of PAQ-A score and steps/day, based on PA recommendations.

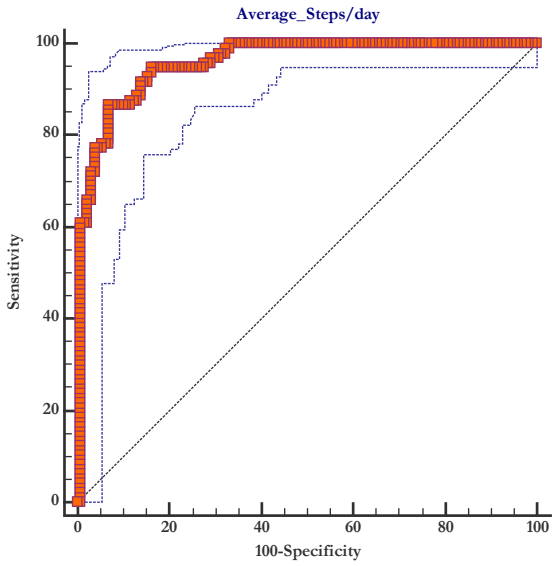
PA Recommendations	60 MVPA		30 Vigorous PA		116 Light PA	
	Score	Steps	Score	Steps	Score	Steps
AUC	0.677	0.957	0.658	0.879	0.631	0.724
EE	0.0356	0.0124	0.0408	0.0223	0.0476	0.0464
95% CI	0.613 to 0.736	0.921 to 0.979	0.594 to 0.719	0.829 to 0.918	0.565 to 0.693	0.661 to 0.781
P	<0.0001	<0.0001	0.0001	<0.0001	0.0061	<0.0001
Youden index	0.2896	0.7967	0.3252	0.6399	0.2212	0.3836

PA: physical activity; MVPA: moderate to vigorous physical activity; AUC: area under the curve; EE: standard error; CI: confidence interval; P: significance level.

AUC of PAQ-A score for all factors were significant (P<0.01) but only weak (AUC<0.7) discriminators between "active" and "non-active" youth. AUC of number of

steps for all intensities were significant too (P<0.001) and excellent (AUC>0.9 for 60 minutes of MVPA) discriminators.

ROC analysis showed PAQ-A score cut-off points >2.73 to discriminate active adolescents. 60 minutes of MVPA in children appears to be achieved, on average, within a total volume of 9701 steps/day; 30 minutes of vigorous PA within a total volume of 9806 steps/day; and 116 minutes of light PA within a total volume of 12511 steps/day. The sensitivity associated with the different factors were low for PAQ-A score and high for steps/day (except for 116 minutes of light PA). The capacity of the PAQ-A to identify inactive adolescent (specificity) was moderate (77.9%, 75.1% and 68.8%, respectively) and moderate-high for steps/day (93.1%, 77.1% and 68.8%, respectively). A sample ROC curves is illustrated in Figure 4.



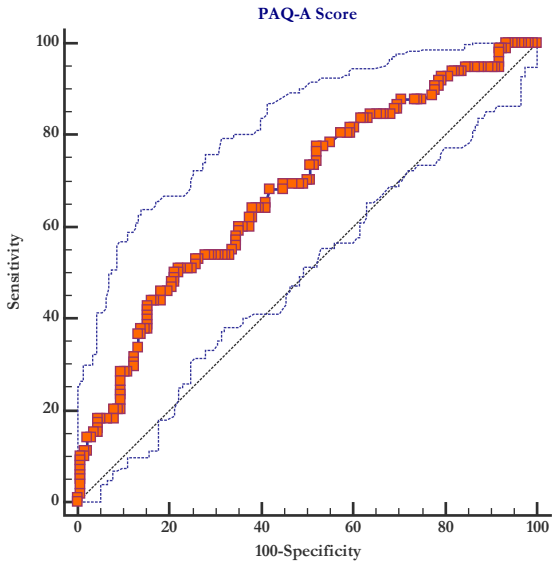


Figure 4. Examples receiver-operator curve for number of steps and the Physical Activity Questionnaire for Adolescents (PAQ-A)'s ability to identify 60 minutes of moderate to vigorous physical activity (MVPA) (n=234).

The capacity of number of steps to determine "active" or "inactive" youth is greater than the capacity of the questionnaire score, giving higher likelihood ratios positives values and lower likelihood ratios negatives values in all factors. The same applies to positives and negatives predictive values, as well as with sensitivity and specificity values (except for sensitivity of PAQ-A for 116 minutes of light PA).

DISCUSSION

The present study evaluated the capacity of PAQ-C and PAQ-A to differentiate active and non-active youth based on international PA guidelines. The main finding of this cross-sectional study was to determine a PAQ-C and PAQ-A score cut-off point of 2.75 to discriminate 60 minutes of MVPA, which is associated within a total volume of 10664 steps/day for children and 9701 steps/day for adolescents.

To our knowledge, this is the first study to define PAQ-C and PAQ-A cut-points values by accelerometry based on PA recommendations. Details to assess the PAQ-A score as cardiorespiratory fitness parameter have been published for English children. Our results are similar to obtained in the study of Voss et al. [47], in which a cut-off points of 2.9 for boys and 2.7 for girls were established, using cardiorespiratory fitness as the criterion-referenced standard. However, the ROC analysis reported differences between the two questionnaires and these results should be interpreted cautiously.

The sensitivity and the specificity analysis revealed that the PAQ-C cut-points were no able to distinguish the true negatives, but not the true positives. Furthermore, the AUC value indicates that the PAQ-C is unable to discriminate inactive children. In case of PAQ-A cut-off points, which proved sufficiently specificity to discriminate the true negatives but moderately the true positives, manifest an AUC value near to 0.7 ($P<0.001$). A diagnostic test that yields an AUC of <0.7, as observed here, may be deemed unacceptable for clinical use, given the potentially severe repercussions of misclassifying presence or absence of disease. However, the PAQ is not a clinical diagnostic test and comparatively low AUC are often published in a public health context. This could be related to the PAQ validity in Spanish youth. While the PAQ-A shown reasonable validity for this age range (rho=0.39; $P<0.001$) [48]; the PAQ-C shown a questionable validity (rho=0.28, $P<0.05$) for assessing total PA and MVPA in Spanish children. Our correlation results between both instruments also concur with the line of evidence that suggests PA questionnaires for adolescents correlated better with accelerometer scores than PA questionnaires for children [13].

Moreover, discrepancies and high variability in children's PA measured by accelerometers around the world have been reported, which may introduce a bias in this study [49,50]. The output from accelerometers is a dimensionless unit commonly referred to as accelerometer counts. Researchers have attempted to calibrate these counts with energy expenditure in order to get a biological meaning to the output [51]. This has resulted in the publication of count thresholds relating to various categories of energy expenditure, that allow researchers to summarize time spent in a given intensity of activity [52]. The availability of multiple cut points or equations has led to much confusion in the accelerometer literature [53]. We used the Evenson et al. [42] cut points, recommended in Trost et al. [43] comparative study to estimate time spent in sedentary, light-, moderate-, and vigorous-intensity activity in children and adolescents. Other cut points would have yielded different results. Nonetheless, the associations and differences with total PA will continue to be same since this variable must not be highly dependent of cut-off values.

The discriminative power of steps/day was, however, excellent, as evidenced by the high AUC values (near of 0.9 for PAQ-C and >0.9 for PAQ-A). The AUC provides an estimate of the "goodness" of a diagnostic test, whereby a theoretical perfect test with 100% specificity and 100% sensitivity yields an AUC of 1, and a non-discriminating test an AUC of 0.5. Sensitivity and specificity obtained were 78.2% (95% CI 67.4 to 86.8), 86.8% (95% CI 76.4 to 93.8) for 60 minutes of MVPA in children; and 86.6% (95% CI 78.2 to 92.7), 93.1% (95% CI 87.3 – 96.8) for 60 minutes of MVPA in adolescents. The cut-off points associated were 10664 steps/day for children and 9701 steps/day for adolescents. These values are similar to those reviewed by Tudor-Locke [23]. These aspects are of interest for public health since they corroborate the insights into PA needs and recommendations for children and adolescents that may use to evaluate scholar

population and implement intervention strategies by healthcare workers and physical education teachers. In addition, quantifying PA, with a low-cost way, will be helpful in order to focus school and community interventions on youth with unhealthy lifestyles.

The specific criteria used to categorize individuals as meeting or not meeting PA recommendations were selected based on WHO guidelines [16] and other studies that propose new data. Recent studies indicate the need to increase the recommendation of MVPA. Thus, Jimenez-Pavón et al. [27] recommend around 60 and 85 min/day of MVPA, including 20 min/day of vigorous PA. On the other hand, data from the European Youth Heart Study with objectively measured PA suggest 90 minutes of MVPA based on metabolic health and the metabolic syndrome [26]. Similarly, the criteria applied in this study (MVPA >60 min/day, vigorous PA >30min/day, and light PA >116 min/day) are in agreement with the proposed guidelines, but our approach support the hypothesis that 60 min or more of MVPA could be enough, if enough vigorous PA is accumulated during such period (at least 30 minutes).

Limitations

This study has several limitations that should be considered. First, subjectivity and limited recall ability are known limitations of self-reported PA, particularly in young people [54]. Limitations of self-reports items include the tendency for people to report socially desirable responses. Moreover, although objective measures of PA, such as triaxial accelerometry or heart rate monitors are ideal, even these methods have their limitations, and this practice has been criticized due to the fact that accelerometers and self-report instruments measure different things [55]. Other limitations could explain the

low capacity of discrimination. For example, our sample size was relatively small but relevant for the purpose of study. However, these results should be verified in larger samples.

Conclusions

In summary, our findings provide normative PAQ scores for children and adolescents. According with the ROC analysis, our results suggest that PAQ-A can be a useful tool to classify adolescents as active or inactive following international recommendations as criteria. It seems, that a 2.75 score can be used to detect adolescents performing enough PA. However, this does not apply to the PAQ-C, which might not be an adequate tool to classify children as active or inactive.

These cut-off points can be useful and a cost-economic way to evaluate children and adolescents and implement intervention strategies. However, as far as possible, we suggest, in accordance with recent studies [56], the use of a combination of objective and subjective assessment methods.

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III

THE INFLUENCE OF 2-YEAR CHANGES IN PHYSICAL ACTIVITY, MATURATION, AND NUTRITION ON ADIPOSITY IN ADOLESCENT YOUTH

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INTRODUCTION

Adolescence obesity has increased dramatically in several countries in recent decades [1,2]; however, the contribution of physical activity (PA) to adiposity levels during adolescence is unknown, as adiposity is influenced by several factors (e.g., age, maturation, sex, diet) in a complex manner, which requires clarification. PA during adolescence can exert both direct and indirect positive effects on adult health [3], and track from adolescence to adulthood [4], which suggests that PA promotion must start early in life [5]. However, little is known about how maturational differences between boys and girls of similar chronological age predict PA changes over youth.

Longitudinal studies, both follow-up and intervention, help move researchers closer to understanding determinants of PA and mediators of adiposity [6]. An advantage of prospective longitudinal designs is that they can address reverse causality. The interaction between PA and maturation has been studied in many context, namely: childhood-adolescence [7], adolescence [8-11] and childhood-adulthood [4], most of them including body composition variables [12,13]. However, the tracking of PA and body composition, while considering the influence of nutrition and maturational status during adolescence has been rarely reported utilizing a longitudinal approach. A longitudinal approach that considers a broader set of biological and behavioral variables will be useful in guiding future public health PA policies and interventions for youth.

It is presumed that PA level declines during the lifespan, particularly in adolescence [14-20]. The literature supports the contention that boys are more active than girls at all ages during the circumpubertal years when PA is measured using a variety of

self-report [21] and objective measures [22]. Several factors can influence the habits of PA in youth: social, family, biological, and environmental factors behavioral exert an important role in the PA change among youngsters and they move into adolescence [23].

Preliminary research suggests that the adolescent decline in PA may be more closely associated with biological age than chronological age [15,24,25]. However, the results are inconsistent across studies [26]. While Cumming et al. [25] concluded that sex-related differences in biological maturity contribute to sex-related differences in PA behavior during adolescence; Fawkner et al., in a longitudinal study, reported that neither maturation nor absolute changes in physical size appear to directly influence changes in PA in adolescent girls [9]. Therefore, the influence of sex, age, and maturation on changes in PA remains to be determined during adolescence.

In light of the inconclusive evidence, it is important to further explore the relationship between PA, adiposity, nutrition, and maturation during adolescence period, which has not been extensively studied. The aim of this study was to longitudinally explore PA and adiposity changes in Spanish students during adolescence to evaluate the effects of sex, maturation, and nutrition on changes in PA and body composition.

METHODS

Sample

An invitation to participate in the study was sent to all parents who had adolescent youth enrolled in schools of secondary education in Málaga and Ronda (Spain) during

the beginning of the academic year in 2011. The subjects each received an information sheet and written informed consent form for parents, and were asked to return the forms to their school. Parents of one hundred and twenty-three potentially eligible participants who received detailed information about the aims and procedures of the study provided written informed consent. A final analytical sample of 80 healthy adolescents provided longitudinal data (42 girls and 38 boys) after excluding those youth (n=43) with incomplete data at one of the three observational periods. There were no differences in age or body mass index (BMI) between the excluded participants and those in the final analytical sample.

The research protocol was reviewed and approved by the Ethics Committee of the Sports Medicine School, at the Faculty of Medicine (Málaga, Spain). The study was developed following the ethical guidelines of the Declaration of Helsinki-Seoul, last modified in 2008.

Measures

Body Composition.

Participant´s heights were assessed with socks and shoes removed using a stadiometer (SECA Leicester, Birmingham, UK). A Tanita UM-050 digital weighing scale (Tanita UK Ltd, Yiewsley, Middle-sex, UK) was used to assess body mass. Body mass index (BMI; weight/height; kg/m^2) was then calculated.

Anthropometric measurements, including skinfolds (triceps, subscapular, abdominal, thigh and calf), height and body mass, were performed from the certified personnel by International Society for the Advancement of Kinanthropometry (ISAK), according to the ISAK standards for anthropometric assessment [27]. Fat mass percent (FMP) was calculated using Slaughter´s equation [28].

PA Assessment (PAQ-A).

PA was assessed using the PAQ-A [29]. The PAQ-A is a nine-item, 7-day PA recall designed for use with older adolescents in a field-based setting. A ninth item not used in calculation of the activity score, asks adolescents if they were sick or otherwise prevented from engaging in regular PA.

The PAQ-A is designed to be administered once and asks adolescents to recall their participation in activities over the last 7 days to compute an activity score, but it is not intended to estimate metabolic-equivalent expenditure. The PAQ-A has previously acceptable reliability and convergent validity [30], and is an appropriate instrument for measuring PA in Spanish adolescents [31]. The mean of all items is used to indicate the level of PA. A high score indicates higher levels of PA.

Sexual maturity status.

Sexual maturity was assessed using the criterion of predicted percentage of maturity (adult stature). Briefly, the percentage of predicted mature (adult) height attained during measurement was used as an objective indicator of biological maturation. The method

assumes that among adolescents of the same chronological age, the child that is closer to his or her predicted mature height is more advanced in biological maturity [32].

The Khamis-Roche method [33] was used to predict the mature height from current age, height, and weight of the participant and mid-parent height (average height of biological parents). The median error bound (median absolute deviation) between actual and predicted mature height at 18 years of age is 2.2 cm in males and 1.7 cm in females. Biological parents of the students reported their heights. Percentages of predicted mature height were expressed as z-scores relative to age-specific means and standard deviations for percentage of mature height attained. Z-scores were used to estimate maturity status: on time, z-score between -1.0 and +1.0; late, z-score below -1.0; early, z-score greater than +1.0. Relative skeletal age, the difference between skeletal age and chronological age, was used as the criterion. On time was defined as a skeletal age within 1.0 year of chronological age. Late maturing was defined as a skeletal age behind chronological age by more than 1.0 year. Early maturing was defined as a skeletal age in advance of chronological age by more than 1.0 year [32].

Food-frequency questionnaire (FFQ).

Dietary intake was assessed by a self-administered, semi-quantitative food-frequency questionnaire (FFQ). The FFQ was an electronic version based on a questionnaire designed to be used in Spain [34]. The questionnaire consisted of 290 specific foods or food groups (including 15 fruit items and 28 vegetable and legume items) with nine response options ranging from “never” to “6 or more times per day” for the frequency of consumption of specified serving sizes. Questions on cooking methods, specific types

of fats, oils, margarines, breakfast cereals, takeaway foods, and self-prescribed nutritional supplements were also included on the questionnaire. Subjects were asked to recall their frequency of consumption for common serving sizes of food per month, week or day over the preceding six months. Afterwards, a specific Excel-based macro was used to calculate Calories and macronutrients composition from each food multiplies by number of serving sizes and extrapolated for day. Dietary intake assessment was only performed at S1 and S3.

Procedure

All procedures were performed during one day for each adolescent and identically along the three assessment time points. An assessment day was as follow: Adolescents, whom completed consent forms, attend to sport facility of the school at usual opening times (8:30 a.m.) in fasting conditions. Firstly, a general overview about the organization was explained by the leader of research team, in summary the evaluations follow the next order: Weight and height were measured, subsequently they started to complete the PAQ-A and FFQ questionnaires, and considerable time was taken to fully explain the questionnaires and examples were provided. Students who finished PAQ-A were asked to go to body composition assessment, which was carried out by research assistants using standard protocols and taken in same-sex pairs into a private room to complete anthropometric measurements. Two researchers were always with them in the room. Three assessments were performed: September 2011, 2012 and 2013 (S1, S2, and S3, respectively). Approximately 12 months and 24 months later, data were collected using the same procedures described above.

Statistical Analysis

The characteristics of participants were described as mean and standard deviation (SD). Spearman rank correlation coefficient was used to explore associations between variables. A repeated measures ANOVA (two-factor mixed model 2x3x3) were carried out among three time points for PA, BMI and FMP, and compared by maturation level and sex.

Differences between baseline and second year were calculated for FMP, PA, and nutrition and maturation level. A general linear model was used to estimate predictors of FMP changes, where PA, nutrition, sex and change in maturation level (as change of early (C0) or late state (C2) to on time and no change (C1)) were selected as independent variables. Interactions among sex, PA, nutrition and maturation level were explored.

Regarding statistical power analysis, if we assume an alpha value of 0.05 for a multiple linear regression with 4 predictors (PA, nutrition, maturation and sex), our final sample size of 80 adolescents will permit us confirm our statistical analysis with 78.5% of power.

The analyses were performed using SPSS 22.0 (SPSS Inc. Chicago, Illinois) and the level of significance was set at $P<0.05$.

RESULTS

Descriptive statistics at baseline and years 1 and 2 for chronological age, all indices of body composition, biological maturity, PA, and nutrition are summarized, by sex, in Table 14. Characteristics of the participants are reported as mean and standard deviations. Significant differences between boys and girls were found for weight, height, FMP, predicted adult stature and PAQ-A score.

Table 14. Comparison of characteristics of participants at baseline and years 1 and 2 by sex (n=80).

	S1		S2		S3		S1-S2	S2-S3
	Girls	Boys	Girls	Boys	Girls	Boys	*sig.*	*sig.*
Age (years)	14.5±1.8	14.6±2.6	14.8±1.7	15.1±2.4	16.2±1.6	16.1±2.3	†††	†††
Weight (Kg)	52.1±12.7	55.4±12.2	52.4±12.1*	59.6±12.8	54±11.3**	60.8±10.1	†††	
Height (cm)	157.5±7.1	162.4±13.7	159.5±7.0**	166.2±11.7	161.1±6.1***	168.7±10.7	†††	††† §§
BMI (Kg/m2)	20.9±4.5	20.8±3.0	20.4±3.7	21.4±3.1	20.8±4.0	21.3±2.5	†††	
FMP (%)	25.6±7.0*	21.0±8.9	24.6±6.8**	19.5±8.0	25.5±6.8***	18.2±7.6		§§
Predicted adult stature (cm)	162.5±5.0***	172.9±6.9	164.3±4.5***	173.8±5.6	163.9±5.2***	173.5±5.4		
Predicted adult stature (%)	97.1±4.4*	93.5±9,3	97.2±4.1	95.5±8.4	98.6±2.3	97±6.8	††† §§§	††† §§§
PA Total Score (PAQ-A)	2.3±0.9**	2.8±0.7	2.2±0.6***	3.0±0.6	2.1±0.7**	2.6±0.6		††† §§§
FFQ								
Carbohydrate (%)	44.7±6.8	46.6±5.8	-	-	45.8±7.2	46.5±6.7		
Protein (%)	15.4±3.1	14.3±2.4	-	-	15.7±4.2	15.1±3.9		
Fat (%)	39.7±6.7	39±5.6	-	-	38.4±5.3	38.1±6.0		
Energy (kcal/day)	3186±1540	3427±1757	-	-	2197±998	2565±1501	‡‡‡	

S1, S2, S3 (September 2011, 2012 and 2013 respectively); BMI, Body mass index; FMP, Fat Mass Percent; PA, Physical activity; FFQ, Food frequency questionnaire.
* P<0.05; ** P<0.01, *** P<0.001; independent sample t test between boys and girls.
††† P<0.001; repeated measures among three moments (time factor).
§§ P<0.01; §§§ P<0.001; interaction between time and sex.
‡‡‡ P<0.001; repeated measures between S1 and S3.

Correlations by three assessments group are variable: In S1, FMP was positively associated with protein intake, predicted adult height (cm), and BMI (Rho = 0.24, P<0.05; Rho = 0.27, P<0.05; Rho = 0.69, P<0.001; respectively), and inversely with predicted adult stature (%) (Rho= -0.39, P<0.01). Meanwhile, there were significant associations between PA Total Score (PAQ-A) and age and predicted adult stature (%) (Rho= -0.39; Rho= -0.38; all P<0.001, respectively). These associations were stronger in girls, in which maturation level was positively associated with FMP (Rho= 0.50; P<0.001) and negatively with PA (Rho= -0.44; P<0.05).

These correlations are maintained partially in S3 but not in S2, where there were significant associations between PA Total Score (PAQ-A) and age (Rho= -0.34, P<0.05) and FMP with predicted adult stature (Rho= -0.35; P<0.05). In contrast, in this case these associations were stronger in boys.

Figures 5 and 6 shows changes in FMP and PA at years 1 and 2 compared with baseline. Significant differences for FMP were found among S1, S2 and S3 (23.41±8.24 vs. 21.89±7.82 vs. 22.05±8.06, P<0.05; respectively); a significant interaction with sex was observed for change at S2 and S3 (F = 4.387, P<0.05), so boys reduced significantly more FMP than girls (table 1 and figure 1); none interaction was found for maturation. Regarding PA, S2 was significantly higher than S3 (2.58±0.72 vs. 2.29±0.73, P<0.001). An interaction between PA and sex was statically significant (F = 4.889, P<0.05), which indicated boys increased PAQ-A score at S2 more than girls, but reduced significantly more PAQ-A score at S3 than girls (table 14 and figure 6). There were not significant differences for nutritional variables between S1 and S3.

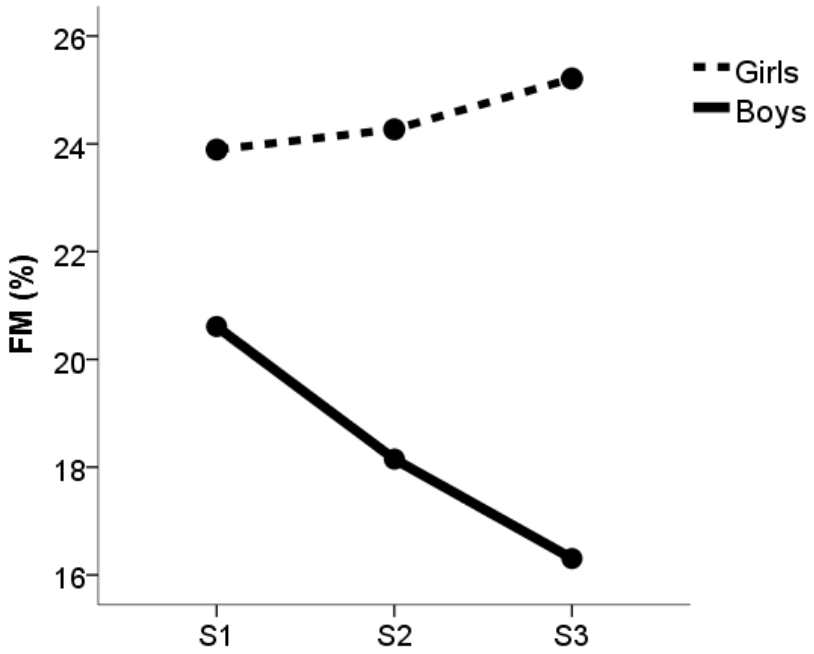

Figure 5. Changes in fat mass percentage at years 1 (S2) and 2 (S3) compared with baseline (S1).

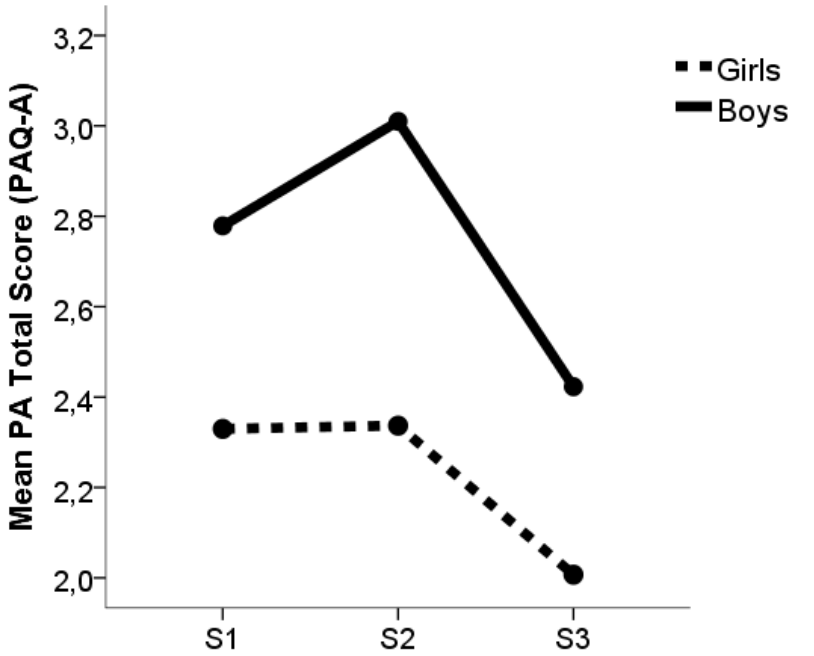

Figure 6. Changes in physical activity at years 1 (S2) and 2 (S3) compared with baseline (S1).

Table 15 shows dependents and independents variables by maturity status classification. There were significant differences among maturity status (late, on time, and early) for FMP between boys and girls. In S3, late girls had more 8.10±2.55% FM than boys; and 9.12±2.78 % for on time girls after adjusting for nutritional variables and PA.

Table 15. Dependents and independents variables by maturation level.

		S1	S2	S3
Age (years)	Late	15.6±0.8 (7)	15.9±0.9 (6)	17.1±0.7 (18)
	On time	14.5±2.4 (44)	14.7±2.2 (38)	15.5±1.9 (33)
	Early	13.9±2.5 (16)	14.7±3.0 (10)	16.4±3.0 (16)
PA Total Score (PAQ-A)	Late	2.2±0.4 (7)	1.9±0.5 (6)	1.8±0.6 (18)
	On time	2.5±0.8 (44)	2.9±0.6 (31)	2.4±0.7 (33)
	Early	2.8±1.0 (16)	2.8±0.5 (7)	2.6±0.6 (16)
FMP (%)	Late	24.3±7.5 (7)	21.6±4.3 (6)	25.2±7.1 (18)*
	On time	23±9.0 (44)	20.9±8.6 (38)	21.4±8.8 (39)*
	Early	25.4±8.5 (16)	25.7±7.9 (10)	19.2±8.2 (16)
Energy (*kcal/day*)	Late	3117±1508 (7)	-	2518±1202 (18)
	On time	3124±1726 (42)	-	2333±1374 (31)
	Early	3334±1269 (16)	-	2422±1559 (16)

S1, S2, S3 (September 2011, 2012 and 2013 respectively); PA, Physical activity; FMP, Fat Mass Percent.
Number inside parenthesis indicates sample size for each maturation level groups.

A non-significant trend of FM reduction was observed across the three stages of change in maturation level (C0 = 0.275±2.70%; C1= -1.490±1.10%; C2= -6.417±2.57%; pairwise comparisons: C0 - C2 = 6.69%, P=0.081 and C1-C2 = 4.93%, P=0.080) (Figure 7).

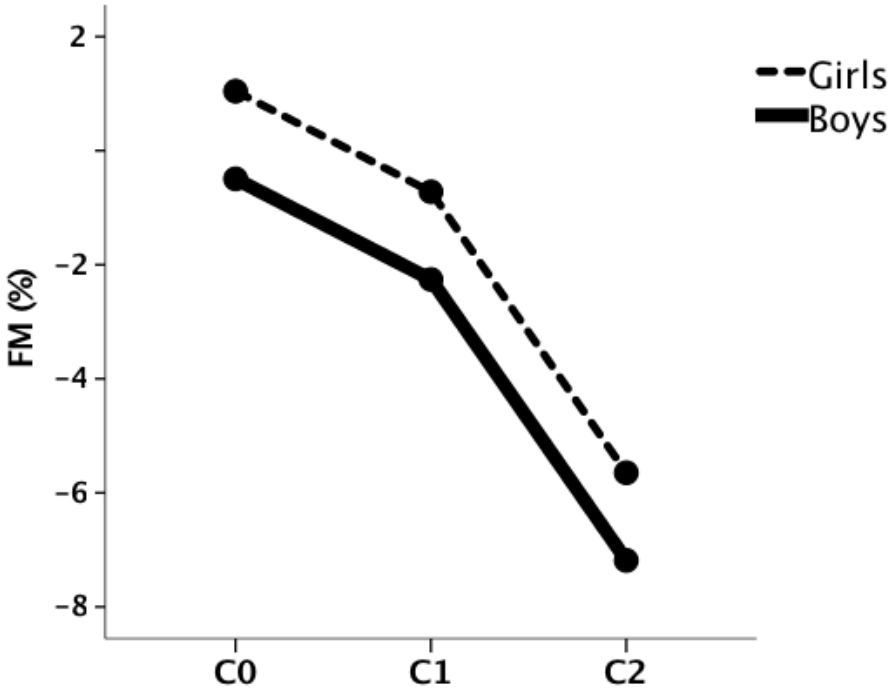

Figure 7. Changes in fat mass percentage after a 2-year follow-up across change in maturation status (C0, change from on time to late; C1, no change; C2, change from late/on time to on time/early) by sex. *P =0.081 and P=0.080,* for pairwise comparisons between C0-C2 and C1-C2 respectively from general lineal model analysis.
P >0.05, for maturation status x sex interaction from general lineal model analysis.

DISCUSSION

The present study evaluated PA and adiposity alterations during adolescence. The main finding of this follow-up analysis was a reduction in PA after S2 period without changes in adiposity. Conversely, a reduction of FMP was only significant between S1 and S2 in boys, while PA was significantly increased. Age was negatively associated with PAQ-A score at all times. Ours results are in accordance with findings in the literature supporting a decline of PA during adolescence [14-21]. Differences between boys and girls in the pattern of PA were confirmed, so that the changes at S2 (boys increased) and S3 (boys reduced significantly more) were significantly different. Consistent with Sallis

(2000), our results provide evidence that male subjects decline more in PA than female subjects, specifically between S2 and S3. Davison et al. (2007) found similar decreases in PA in adolescent girls of similar chronological age.

Results of analyses of interactions among maturity indicators in longitudinal data sets highlight that maturation had marginal influence on the PA behaviors at this age. Late maturing adolescents reported lower levels of PA, although not statistically significant. These findings are in line with relatively more mature adolescents. They may, in fact, be more active than their less mature peers [9], but we could not confirmed, according to other studies [7,26,35], that sexual maturity status is an important determinant in PA pattern. However, nutrition was not a determinant in the changes in PA or FMP analyzed. In this sense, it is important to appreciate that self-report dietary assessment can introduce bias since participants providing data are aware that their dietary habits are is under investigation, which may affect their reported dietary intake [36]. This is often subconscious and has been shown for adolescents, especially girls [37]. Therefore, the obtained results must be analyzed cautiously.

Regarding adiposity levels, in the present study, late and on time maturing girls had higher levels of FMP than boys. A probable explanation for the gender influence on the change in adiposity levels could be due to anthropometric differences in muscle mass between boys and girls at puberty. FMP tends to decline during male adolescence because of the rapid growth of lean mass, specifically muscle mass [32]. However, in this study the influence of maturation was similar in boys and girls since no interactions between sex, maturation and dependent variables (PA and FMP) were found. Moreover, we observed that change in level of maturation seemed to be a determinant for change in FMP, but

with a similar trend for both genders. So, those students, who change from a less mature state to another more mature (C2), had a trend to a greater FMP reduction (figure 3), although similar in boys and girls.

The strength of this study was to explore the relationship among PA, adiposity, nutrition, and maturation, which have not been previously analyzed all together in a longitudinal perspective. However, it is important to recognize a number of limitations associated with the current investigation. Firstly, the height of the parents was asked in a general health questionnaire instead of measured with stadiometer. Another potential limitation is that the method used to estimate biological maturity status was devised from data collected in the United States and further research must be required to validate the equation in Spanish people.

An additional limitation is the use of the PAQ-A, a self-report measure, to assess PA levels. Limitations of self-reports items include the tendency for people to report socially desirable responses. Despite these limitations, the PAQ-A has demonstrated to be a low cost, easy to use, and reasonably valid measure of PA behaviors that is well suited for use with Spanish adolescents [31]. Although objective measures of PA, such as triaxial accelerometry or heart rate monitors are ideal, even these methods have their limitations such as cost, and this practice has been criticized due to the fact that accelerometers and self-report instruments measure different things [38]. Accelerometry measures body movement, while questionnaires often ask respondents to rate the activities related to the effort or frequency. Moreover, the activities reported in the first item of the PAQ-A, as the skateboarding and cycling, are difficult to be captured with accelerometers because these devices only acceleration from activities where center of

gravity has oscillation. Additionally, questionnaires are valuable instruments to track PA in school settings, where the use of expensive and complex instruments is unviable.

In summary, our findings provide long-term longitudinal evidence that body composition and PA changes observed were not parallel. Also, these data seem to suggest that PA and FM alteration patterns were more influenced by sex than by maturation. Finally, the drop in PA levels describes the issue of physical inactivity among adolescents and the need to develop appropriate interventions to prevent this decrease.

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CHAPTER V: LIMITATIONS

In addition to the limitations contained in each study, several limitations of the current dissertation should be mentioned:

- The selection of the sample studied was not randomized (volunteer participants sample). Our sample size was relatively small but significant for the purpose of studies. Moreover, our participants had similar BMI and PAQ-A scores when compared with other Spanish children and adolescents from previous studies. Nevertheless, an intention to treat analysis must be necessary in order to confirm our sample was representative of Spanish population in this range of age.

- In general, the questionnaire (PAQ) used in the studies does not capture some important windows of the day where activity is likely to occur (e.g., before school, commuting to school). Therefore, predicted minutes of activity obtained from the PAQ would most likely underestimate daily activity. The PAQ also captures total weekend activity with a single item but it is likely that activity patterns vary considerably between Saturday and Sunday for most youth.

- Other limitation of the PAQ, and perhaps most significant, is that it does not include any measure of sedentary behaviors, which may influence the determination of the cut-off points.

- Subjectivity and limited recall ability are known limitations of self-reported PA, particularly in young people [1].

- Finally, in the third study, there was a lack of assessment of PA level with objective methods, as well as a lack of dietetic supervision on sample studied.

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CHAPTER VI: GENERAL CONCLUSIONS

A. This dissertation presents novel data from a reliability and validity study of the PAQ-C in children (study I). The results suggest that PAQ-C had a high reliability but a questionable validity for assessing PA in our sample of Spanish children. These findings would suggest that the PAQ-C requires additional development to be a useful measure of PA in Spanish children.

B. We have suggested that PAQ could be further improved. Thus, the PAQ is limited to three items that ask activity at school and another three that ask activity out-of-school. The remaining PAQ items are broad and ask about activity in the last seven days. The inclusion of items that assess transportation to and from school, and activity before school, as well as separate items for both Saturday and Sunday periods, would lead to a more comprehensive understanding of activity patterns in youth. These time periods are important settings and therefore some activity is likely to occur. The inclusion of items that ask about sedentary behaviors would also add value to the PAQ.

C. The main finding of Study II was to determine a PAQ-C and PAQ-A score cut-off point of 2.75 to discriminate 60 minutes of MVPA, which was associated within a total volume of 10664 steps/day for children and 9701 steps/day for adolescents. This classification will be helpful in order to focus school and community interventions on those groups with unhealthy lifestyles.

D. According with the ROC analysis, our results suggest that PAQ-A can be a useful tool to classify adolescents as active or inactive following international recommendations as criteria. However, this does not apply to the PAQ-C.

E. In the 3rd study, we observed body composition and PA changes observed were not parallel. PA and FM alteration patterns were mainly influenced by gender; additionally a non-significant trend for an influence of the change in maturation status was found. Finally, the drop in PA levels describes the issue of physical inactivity among adolescents and the need to develop appropriate interventions to prevent this decrease.

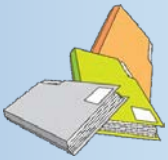
Overall conclusion

The PAQ appears to be a more appropriate tool to measure PA in adolescents than in children, and it may discriminate active and inactive young in adolescence according to international guidelines.

We suggest, as long as the budget is possible, the use of both instruments (self-reports and accelerometers) when assessing PA levels, especially when assessing PA in epidemiological studies and in the initial assessment and the design of efficient and effective intervention programs to enhance PA levels in children and adolescents. Specifically, schedule and type of PA from PAQ and quantify of PA from ACLs may permit us to obtain a better interpretation of PA effectiveness in order to diagnose and prescribe solutions for inactive and sedentary behavior.

Assessments conducted longitudinally in this period using the PAQ-A show the problematic of progressive decline of PA among adolescents, which seems to be influenced by the sex, regardless of maturation.

APPENDIX



APPENDIX I
Physical Activity Questionnaire for Children

Cuestionario de actividad física para niños (PAQ-C)

Nombre y apellidos: Edad:

Queremos conocer cuál es tu nivel de actividad física en los últimos 7 días (última semana). Esto incluye todas aquellas **actividades como deportes, gimnasia o danza que** hacen sudar o sentirte cansado, o juegos que hagan que se acelere tu respiración como jugar al pilla-pilla, saltar a la comba, correr, trepar y otras.

Recuerda:
1. No hay preguntas buenas o malas. Esto NO es un examen.
2. Contesta las preguntas de la forma más honesta y sincera posible. Esto es muy importante

---

1. Actividad Física en tu tiempo libre: ¿Has hecho alguna de estas actividades en los últimos 7 días (última semana)? Si tu respuesta es sí: ¿cuántas veces las has hecho? (*MARCA UN SOLO CÍRCULO POR ACTIVIDAD*)

	No	1-2	3-4	5-6	7 veces o +
Saltar a la comba.....	○	○	○	○	○
Patinar	○	○	○	○	○
Jugar a juegos como el pilla-pilla...	○	○	○	○	○
Montar en bicicleta.....	○	○	○	○	○
Caminar (como ejercicio).....	○	○	○	○	○
Correr/footing.....	○	○	○	○	○
Aeróbic/spinning.....	○	○	○	○	○
Natación.....	○	○	○	○	○
Bailar/danza.....	○	○	○	○	○
Bádminton.....	○	○	○	○	○
Rugby.....	○	○	○	○	○
Montar en monopatín.....	○	○	○	○	○
Fútbol / fútbol-sala.....	○	○	○	○	○
Voleibol.....	○	○	○	○	○
Hockey.....	○	○	○	○	○
Baloncesto.....	○	○	○	○	○
Esquiar.....	○	○	○	○	○
Tenis.....	○	○	○	○	○
Balonmano.....	○	○	○	○	○
Atletismo.....	○	○	○	○	○
Gimnasia rítmica.....	○	○	○	○	○
Artes marciales (judo, kárate, ...)..	○	○	○	○	○
Otros:_____	○	○	○	○	○
Otros:_____	○	○	○	○	○

2. En los últimos 7 días, durante las clases de educación física, ¿cuántas veces estuviste muy activo durante las clases: jugando intensamente, corriendo, saltando, haciendo lanzamientos? (SEÑALA SÓLO UNA)

No hice/hago educación física.....	❍
Casi nunca.....	❍
Algunas veces.....	❍
A menudo.....	❍
Siempre.....	❍

3. En los últimos 7 días, ¿cuál ha sido tu actividad más frecuente durante los recreos? (SEÑALA SÓLO UNA)

Estar sentado (hablar, leer, trabajo de clase)....	❍
Estar o pasear por los alrededores.....	❍
Correr o jugar un poco.....	❍
Correr y jugar bastante.....	❍
Correr y jugar intensamente todo el tiempo....	❍

4. En los últimos 7 días ¿qué hiciste normalmente a la hora de la comida (antes y después de comer)? (SEÑALA SÓLO UNA)

Estar sentado (hablar, leer, trabajo de clase)....	❍
Estar o pasear por los alrededores.....	❍
Correr o jugar un poco.....	❍
Correr y jugar bastante.....	❍
Correr y jugar intensamente todo el tiempo....	❍

5. En los últimos 7 días, inmediatamente después de la escuela hasta las 6, ¿cuántos días jugaste a algún juego, hiciste deporte o bailes en los que estuvieras muy activo? (SEÑALA SÓLO UNA)

Ninguno.....	❍
1 vez en la última semana.....	❍
2-3 veces en la última semana.....	❍
4 veces en la última semana.....	❍
5 veces o más en la última semana.....	❍

6. En los últimos 7 días, ¿cuantos días a partir de media tarde (entre las 6 y las 10) hiciste deportes, baile o jugaste a juegos en los que estuvieras muy activo? (SEÑALA SÓLO UNA)

Ninguno.....	❍
1 vez en la última semana.....	❍
2-3 veces en la última semana.....	❍
4 veces en la última semana.....	❍
5 veces o más en la última semana.....	❍

7. El último fin de semana, ¿cuántas veces hiciste deportes, baile o jugar a juegos en los que estuviste muy activo? (SEÑALA SÓLO UNA)

Ninguno.....	❍
1 vez en la última semana.....	❍
2-3 veces en la última semana.....	❍
4 veces en la última semana.....	❍
5 veces o más en la última semana.....	❍

8. ¿Cuál de las siguientes frases describen mejor tu última semana? Lee las cinco antes de decidir cuál te describe mejor. (SEÑALA SÓLO UNA)

Todo o la mayoría de mi tiempo libre lo dediqué a actividades que suponen poco esfuerzo físico	❍
Algunas veces (1 o 2 veces) hice actividades físicas en mi tiempo libre (por ejemplo, hacer deportes, correr, nadar, montar en bicicleta, hacer aeróbic)	❍
A menudo (3-4 veces a la semana) hice actividad física en mi tiempo libre	❍
Bastante a menudo (5-6 veces en la última semana) hice actividad física en mi tiempo libre.....	❍
Muy a menudo (7 o más veces en la última semana) hice actividad física en mi tiempo libre.....	❍

9. Señala con qué frecuencia hiciste actividad física para cada día de la semana (como hacer deporte, jugar, bailar o cualquier otra actividad física)

	Ninguna	Poca	Normal	Bastante	Mucha
Lunes.....	❍	❍	❍	❍	❍
Martes.....	❍	❍	❍	❍	❍
Miércoles.....	❍	❍	❍	❍	❍
Jueves.....	❍	❍	❍	❍	❍
Viernes.....	❍	❍	❍	❍	❍
Sábado.....	❍	❍	❍	❍	❍
Domingo.....	❍	❍	❍	❍	❍

10. ¿Estuviste enfermo esta última semana o algo impidió que hicieras normalmente actividades físicas?

Sí	❍
No.....	❍

APPENDIX II
Physical Activity Questionnaire for Adolescents

Cuestionario de actividad física para adolescentes (PAQ-A)

Nombre y apellidos: Edad:

Queremos conocer cuál es tu nivel de actividad física en los últimos 7 días (última semana). Esto incluye todas aquellas **actividades como deportes, gimnasia o danza que** te hacen sudar o sentirte cansado, o juegos que hagan que se acelere tu respiración como jugar al pilla-pilla, saltar a la comba, correr, trepar y otras.

Recuerda:
1. No hay preguntas buenas o malas. Esto NO es un examen.
2. Contesta las preguntas de la forma más honesta y sincera posible. Esto es muy importante

---

1. Actividad Física en tu tiempo libre: ¿Has hecho alguna de estas actividades en los últimos 7 días (última semana)? Si tu respuesta es sí: ¿cuántas veces las has hecho? (*Marca un solo círculo por actividad*)

	No	1-2	3-4	5-6	7 veces o +
Saltar a la comba.....	○	○	○	○	○
Patinar	○	○	○	○	○
Jugar a juegos como el pilla-pilla...	○	○	○	○	○
Montar en bicicleta.....	○	○	○	○	○
Caminar (como ejercicio).....	○	○	○	○	○
Correr/footing.....	○	○	○	○	○
Aeróbic/spinning.....	○	○	○	○	○
Natación.....	○	○	○	○	○
Bailar/danza.....	○	○	○	○	○
Bádminton.....	○	○	○	○	○
Rugby.....	○	○	○	○	○
Montar en monopatín.....	○	○	○	○	○
Fútbol-fútbol-sala.....	○	○	○	○	○
Voleibol.....	○	○	○	○	○
Hockey.....	○	○	○	○	○
Baloncesto.....	○	○	○	○	○
Esquiar.....	○	○	○	○	○
Otros deportes de raqueta.....	○	○	○	○	○
Balonmano.....	○	○	○	○	○
Atletismo.....	○	○	○	○	○
Musculación/pesas.....	○	○	○	○	○
Artes marciales (judo, kárate, ...)..	○	○	○	○	○
Otros:_____	○	○	○	○	○
Otros:_____	○	○	○	○	○

2. En los últimos 7 días, durante las clases de educación física, ¿cuántas veces estuviste muy activo durante las clases: jugando intensamente, corriendo, saltando, haciendo lanzamientos? (Señala sólo una)

No hice/hago educación física……..	❍
Casi nunca……	❍
Algunas veces……..	❍
A menudo……	❍
Siempre……	❍

3. En los últimos 7 días ¿qué hiciste normalmente a la hora de la comida (antes y después de comer)? (Señala sólo una)

Estar sentado (hablar, leer, trabajo de clase)....	❍
Estar o pasear por los alrededores……	❍
Correr o jugar un poco...……..	❍
Correr y jugar bastante……	❍
Correr y jugar intensamente todo el tiempo.…	❍

4. En los últimos 7 días, inmediatamente después de la escuela hasta las 6, ¿cuántos días jugaste a algún juego, hiciste deporte o bailes en los que estuvieras muy activo? (Señala sólo una)

Ninguno……	❍
1 vez en la última semana……	❍
2-3 veces en la última semana……..	❍
4 veces en la última semana……	❍
5 veces o más en la última semana……...	❍

5. En los últimos 7 días, cuantas días a partir de media tarde (entre las 6 y las 10) hiciste deportes, baile o jugaste a juegos en los que estuvieras muy activo? (Señala sólo una)

Ninguno……	❍
1 vez en la última semana……	❍
2-3 veces en la última semana……..	❍
4 veces en la última semana……	❍
5 veces o más en la última semana……...	❍

6. El último fin de semana, ¿cuántas veces hiciste deportes, baile o jugar a juegos en los que estuviste muy activo? (Señala sólo una)

Ninguno……	❍
1 vez en la última semana……	❍
2-3 veces en la última semana……..	❍
4 veces en la última semana……	❍
5 veces o más en la última semana……...	❍

7. ¿Cuál de las siguientes frases describen mejor tu última semana? Lee las cinco antes de decidir cuál te describe mejor. (Señala sólo una)

Todo o la mayoría de mi tiempo libre lo dediqué a actividades que suponen poco esfuerzo físico	❍
Algunas veces (1 o 2 veces) hice actividades físicas en mi tiempo libre (por ejemplo, hacer deportes, correr, nadar, montar en bicicleta, hacer aeróbic)	❍
A menudo (3-4 veces a la semana) hice actividad física en mi tiempo libre	❍
Bastante a menudo (5-6 veces en la última semana) hice actividad física en mi tiempo libre.....	❍
Muy a menudo (7 o más veces en la última semana) hice actividad física en mi tiempo libre.....	❍

8. Señala con qué frecuencia hiciste actividad física para cada día de la semana (como hacer deporte, jugar, bailar o cualquier otra actividad física)

	Ninguna	Poca	Normal	Bastante	Mucha
Lunes.....	❍	❍	❍	❍	❍
Martes.....	❍	❍	❍	❍	❍
Miércoles.....	❍	❍	❍	❍	❍
Jueves.....	❍	❍	❍	❍	❍
Viernes.....	❍	❍	❍	❍	❍
Sábado.....	❍	❍	❍	❍	❍
Domingo.....	❍	❍	❍	❍	❍

9. ¿Estuviste enfermo esta última semana o algo impidió que hicieras normalmente actividades físicas?

Sí	❍
No.....	❍

APPENDIX III
GEOS Project Documents

UNIVERSIDAD DE MÁLAGA
LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Proyecto GEOS

Consentimiento Informado para la Participación en el Estudio

Yo, (nombre y apellidos del padre/madre) _____
con DNI nº:_____, autorizo a mi hijo/a_____
del curso ____a la participación en el estudio GEOS en el centro educativo _____. Además:

- He leído la hoja de información que se ha entregado.
- He recibido suficiente información sobre el estudio.
- Podré resolver todas las dudas sobre el estudio con el Dr. Elvis Álvarez Carnero investigador principal del proyecto (Universidad de Málaga) y con el/la Profesor/a _____, docente del centro educativo _____.

Comprendo que su participación es voluntaria.

Comprendo que el niño/a puede o puedo retirarse/lo del estudio:

1. *Cuando quiera.*
2. *Sin tener que dar explicaciones.*
3. *Sin que esto repercuta en su evaluación educativa.*

Doy la conformidad para que mi hijo/a participe en el estudio GEOS:

"Educación Física Escolar, Gasto Energético, Obesidad y Salud Infantil: ¿Es la Intervención Escolar de los Profesores de Educación Física un Arma Real en la Guerra contra la Obesidad?"

En _____, _____ de _____ del 201_

Firma del Participante Firma del padre, madre o tutor

Facultad de Ciencias de la Educación
Departamento de Didáctica de la Expresión Musical, Plástica y Corporal
Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA
LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

Málaga, a __ de _____ de 201_

Nosotros/as _____, director/a del centro educativo _____, portavoz del claustro de este centro; y presidente/a de la Asociación de Madres y Padres del Alumnado, respectivamente:

Considerando la información presentada por los investigadores del Proyecto GEOS de la Universidad de Málaga y en colaboración con la Universidad de la Coruña. El cual se encuentra encuadrado dentro del plan nacional de investigación I+D+i, subvencionado por el Ministerio de Economía y Competitividad (DEP2011-30565). ACEPTAMOS la participación de los estudiantes de nuestro centro en dicho proyecto, sin que ello suponga una obligación académica para los mismos. Adicionalmente, nos comprometemos a colaboran con el buen funcionamiento de aquellas actividades del proyecto que discurran en nuestro centro, entre ellas:

- Facilitar un horario de reunión conjunta durante el mes de Junio del 2013 con los padres/tutores legales interesados en resolver dudas.
- Permitir que los escolares participen durante 3 mañanas en el proyecto (1 mañana durante el mes de septiembre del 2013, 1 mañana durante el mes de Junio del 2014 y 1 mañana durante el mes de septiembre del 2014).
- Facilitar que los profesores de educación física colaboren en las evaluaciones (gestión de los alumnos, recogida de datos, recogida de documentos y recogida de muestras en el estudio de gasto energético).

El/la directora/a del Centro Presidente/a de la AMPA

_____ _____

Facultad de Ciencias de la Educación
Departamento de Didáctica de la Expresión Musical, Plástica y Corporal
Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA
LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Proyecto GEOS

Documento Informativo para posibles participantes

1. **Objetivos:**
   - Estudiar el gasto energético (calorías que gasta durante la semana), los hábitos de alimentación (cantidad y calidad de las calorías ingeridas) y la composición corporal (sobrepeso y obesidad) de escolares andaluces.
   - Evaluar la condición física de los escolares (resistencia, fuerza, velocidad y flexibilidad).

2. **Metodología Empleada:**
   - Antropometría: Mediciones de talla, peso, pliegues de grasa y perímetros corporales.
   - Impedancia Bioeléctrica: Estimaciones de masa magra.
   - Agua doblemente marcada: Utilización de agua marcada con dos isótopos estables (deuterio y oxígeno 18) para medir el gasto energético y la cantidad de agua dentro del cuerpo de los escolares.
   - Batería de condición física: Evaluación de la resistencia cardiovascular, la fuerza, la flexibilidad, la capacidad de salto y la coordinación.
   - Cuestionarios: Recogida de datos de alimentación, prácticas de actividad física, estilo de vida, salud y maduración.

3. **Beneficios derivados del estudio:**
   - Conocimiento con elevada precisión del gasto energético, composición corporal e ingesta calórica en edades infantiles y juveniles, y de sus asociaciones con la salud de los escolares.
   - Observar la evolución de los comportamientos saludables, la composición corporal y del gasto calórico durante el año escolar.

4. El estudio se realizará en dos días. La batería de condición física se realizará durante la tarde, el resto de tests se realizarán durante una mañana.
5. Todos los tests y evaluaciones han sido utilizados en poblaciones semejantes en diversos estudios españoles y en otros países, no conociéndose efectos adversos resultantes de los mismos.
6. La participación en el estudio tiene un carácter TOTALMENTE voluntario, así como la posibilidad de retirarse del mismo en cualquier momento sin dar ninguna explicación.
7. Todo el tratamiento de datos tendrá un riguroso celo y solamente el investigador principal del proyecto tendrá acceso a la base de datos de nombres de los participantes. Para efectos de tratamiento estadístico los participantes aparecerán identificados con un código numérico, garantizándose el anonimato en todo momento.
8. Cada una de las pruebas y valoraciones serán supervisadas por especialistas en fisiología del ejercicio (médicos deportivos y licenciados en ciencias de la actividad física).
9. El investigador responsable del estudio mantendrá informado al participante y a sus tutores, y se les entregará un informe final personalizado con los resultados del estudio.

Los padres o tutores podrán consultar cualquier duda o tema relacionado con el estudio durante la reunión informativa el día ___ de _____ a las __:__ horas en el _____.

La participación no supondrá alteración alguna del desarrollo normal de las clases, no implicando más pérdida lectiva para el alumno que la del día de las pruebas con el consentimiento y la colaboración del profesorado.

TODOS LOS PROCEDIMIENTOS UTILIZADOS ESTÁN ACORDES CON LA DECLARACIÓN DE HELSINKI PARA ESTUDIOS CON HUMANOS

Facultad de Ciencias de la Educación
Departamento de Didáctica de la Expresión Musical, Plástica y Corporal
Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA
LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

ID:_____ ID_Padres:_____ ID_ACL:_____ ID_POD:_____

Nombre:_____ FN:_____ Género:___

Nº DIA :	FECHA:

1. BIAs.

Peso:_____ Estatura:_____ TANNER V:_____ TANNER G: _____

	TBW	ECW	%MG	R50	Rx50	Z50	PA
Tanita		X		X	X	X	X
MediSys							
Omron	X	X		X	X	X	X
Tanita4	TBW	Tronco	%MG	MS_Der	MS_Iz	MI_Der	MI_Iz
VISCAN	PC		%MG		Ratio		

2. Antropometría.

Variables	1ª Medida	2ª Medida	Media
Perímetro Brazo			
Perímetro antebrazo (Der. / Izq.)			
Perímetro Cintura (Crestas Ilíacas)			
Perímetro Muslo			
Perímetro de la Pierna			
Pliegue Tricipital			
Pliegue Antebrazo (Der. / Izq.)			
Pliegue Subescapular			
Pliegue Crural			
Pliegue Gemelar			

3. Evaluación de la Condición Física.

Variables	1ª Medida	2ª Medida	AJUSTES/NOTAS
CMJ			
CMJA			
Prensión Izq.			Distancia:
Prensión **DER.**			Distancia:
15 metros			
30 metros			
Sit&Reach			Distancia:
Back-Reach			
F. Isométrica M.I.			

Facultad de Ciencias de la Educación
Departamento de Didáctica de la Expresión Musical, Plástica y Corporal
Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA
LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Blood Pressure

RESTING SIT 5 MINUTES
DON'T TALK!!!

Perímetro Brazo	

	PAS	PAD	HR	TIME
RIGHT				
LEFT				
RIGHT				
LEFT				

CARDIOVASCULAR FITNESS

TIME:_____ STEP HEIGHT:_____

HR STAND (AFTER 1 MINUTE)

HR 1st Stage		HR 2nd St		HR 3rd St		HR 4th St		HR 5th St	
1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd

TOTAL TIME (MINUTES AND SECONDS): _____:_____

RECOVERY (HR AFTER)

1ST MINUTE	2ND MINUTE	3RD MINUTE

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Departamento de Didáctica de la Expresión Musical, Plástica y Corporal
Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

INSTRUCCIONES PARA EL USO DEL ACELERÓMETRO

1. Lleva el cinturón durante todo el día hasta que te indiquen los profesores de Educación Física.
2. Quítate el cinturón justo antes de irte a la cama. Déjalo en algún lugar en el que te acuerdes de ponértelo en cuanto te levantes por la mañana.
3. Asegúrate de que el aparato rojo está en el lado derecho de tu cintura.
4. Asegúrate de que el cinturón está bien ajustado a tu cintura. Puedes llevarlo por encima o por debajo de la ropa.
5. Es frágil. No lo golpees ni lo dejes caer al suelo.
6. NO DEJES QUE SE MOJE. Quítate el cinturón mientras te duchas, te bañas o practicas cualquier actividad en la que se pueda mojar. No olvides ponértelo cuando salgas del agua.
7. Por favor, anota en el diario a qué hora te pones y te quitas el acelerómetro y para qué.

INSTRUCCIONES PARA EL USO DEL ACELERÓMETRO

1. Lleva el cinturón durante todo el día hasta que te indiquen los profesores de Educación Física.
2. Quítate el cinturón justo antes de irte a la cama. Déjalo en algún lugar en el que te acuerdes de ponértelo en cuanto te levantes por la mañana.
3. Asegúrate de que el aparato rojo está en el lado derecho de tu cintura.
4. Asegúrate de que el cinturón está bien ajustado a tu cintura. Puedes llevarlo por encima o por debajo de la ropa.
5. Es frágil. No lo golpees ni lo dejes caer al suelo.
6. NO DEJES QUE SE MOJE. Quítate el cinturón mientras te duchas, te bañas o practicas cualquier actividad en la que se pueda mojar. No olvides ponértelo cuando salgas del agua.
7. Por favor, anota en el diario a qué hora te pones y te quitas el acelerómetro y para qué.

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Campus de Teatinos, s/n. 29071-Málaga Tlf.: 952 13 24 51

UNIVERSIDAD DE MÁLAGA

LABORATORIO DE BIODINÁMICA Y COMPOSICIÓN CORPORAL

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

DIARIO DEL ACELERÓMETRO

En la tabla de la derecha puedes ver un ejemplo de cómo rellenar el diario. Anota las horas en las que te pones el cinturón al levantarte y te lo quitas al acostarte. Cada vez que te lo quites durante más de 5 minutos durante el día, anota también el tiempo y la actividad por la que te lo has quitado (por ejemplo, natación). Recuerda que debes llevarlo puesto el máximo tiempo posible para que los datos sean válidos. ¡No lo olvides!

Día	VIERNES 30 MAYO
Me levanto	7:30
Me acuesto	23:00
Actividad	Horario
1.Natación	18:00-19:00

Nombre y apellidos / Código:

Día									
Me levanto									
Me acuesto									
Actividad	Horario	Horario	Horario	Horario	Horario	Horario	Horario	Horario	Horario

APPENDIX IV
Curriculum Vitae (Short)

Formación Académica Universitaria

- **Diplomatura:** Maestro. Especialidad Educación Física.
  Centro: Universidad de Málaga.
  Fecha: Junio de 2008

- **Licenciatura:** Licenciado en Ciencias de la Actividad Física y el Deporte.
  Centro: Universidad de Granada.
  Fecha: Junio de 2010

- **Licenciatura:** Licenciado en Psicopedagogía
  Centro: Universidad de Málaga. Facultad de Ciencias de la Educación.
  Fecha: Julio de 2014

- **Máster:** Máster Oficial en Nutrición Humana.
  Centro: Universidad de Granada.
  Fecha: Junio de 2013

- **Máster:** Máster Oficial en Investigación en Actividad Física y Deporte.
  Centro: Universidad de Granada.
  Fecha: Diciembre de 2011

Premios Concedidos

- **Nombre:** Premio a los mejores expedientes académicos.
  Organismo: Universidad de Granada. Comisión de becas propias.
  Fecha: Curso 2008/2009.
  Titulación: Ciencias de la Actividad Física y el Deporte.

Participación en Proyectos de Investigación Financiados

- **Título:** Impacto de la Educación Física Escolar en el Gasto Energético, la Obesidad y la Salud Infantil: ¿Es la Intervención Escolar de los Profesores de Educación Física un Arma Real en la Guerra contra la Obesidad? Estudio GEOS.
  Entidad Financiadora: Ministerio de Economía y Competitividad
  Tipo de Convocatoria: Plan Nacional I+D+i. DEP2011-30565
  Duración: Desde 01/01/2014 Hasta 31/12/2014
  Investigador Principal: Elvis Álvarez Carnero
  Grado de Responsabilidad/Participación: Investigador

- **Título:** Physical activity in women with fibromialgia: effects on pain, health and quality of life.
  Entidad Financiadora: Ministerio de Economía y Competitividad
  Tipo de Convocatoria: Plan Nacional I+D+i. DEP2010-15639
  Duración: Desde 26/12/2012 Hasta 31/12/2013
  Investigador Principal: Manuel Delgado Fernández
  Grado de Responsabilidad/Participación: Investigador

- **Título:** Niveles de actividad física, condición física, salud y calidad de vida en población andaluza con fibromialgia: efectos del ejercicio físico y determinantes genéticos.
  Entidad Financiadora: Junta de Andalucía.
  Tipo de Convocatoria: Autonómica CTCD-201000019242-TRA
  Duración: Desde 24/08/2010 Hasta 23/08/2013
  Investigador Principal: Manuel Delgado Fernández
  Grado de Responsabilidad/Participación: Investigador colaborador

- **Título:** Intervención para la mejora de la calidad de vida relacionada con la salud para enfermos de fibromialgia.
  Entidad Financiadora: Universidad de Granada
  Tipo de Convocatoria: Autonómica.
  Duración: Desde 18/01/2011 Hasta 18/01/2012
  Investigador Principal: Manuel Delgado Fernández

Grado de Responsabilidad/Participación: Investigador colaborador

🗁 **Título:** Perfil del paciente con fibromialgia: características biomédicas, genéticas y psicosociales.
Entidad Financiadora: Cátedra Real Madrid
Tipo de Convocatoria: Nacional. Cátedra Real Madrid 2010/04RM
Duración: Desde 24/08/2010 Hasta 23/08/2013
Investigador Principal: Manuel Delgado Fernández
Grado de Responsabilidad/Participación: Investigador colaborador

Estancias en Centros de Investigación Extranjeros

✈ **Centro:** Exercise and Health Laboratory. Faculty of Human Kinetics. University of Lisbon
País: Portugal
Duración: 3 meses
Fecha: 26 de Julio - 23 de Octubre de 2015

Becas Concedidas en Régimen de Concurrencia Competitiva

- **Beca/Ayuda:** Programa FPU (Formación del Profesorado Universitario) AP2010-0583.
  Institución: Ministerio de Educación, Cultura y Deporte
  Fecha: Noviembre 2012 - Abril 2016

- **Beca/Ayuda:** Alumno colaborador en el sistema de créditos europeos (ECTS)
  Institución: Universidad de Granada
  Fecha: Abril 2013 - Junio 2013

- **Beca/Ayuda:** Programa 6A becas-contratos FPU del Plan Propio de Investigación
  Institución: Universidad de Granada
  Fecha: Mayo 2012 – Octubre 2012

- **Beca/Ayuda:** Ayuda para curso de inmersión en lengua inglesa
  Institución: Universidad Internacional Menéndez Pelayo
  Fecha: Del 28 de noviembre al 02 de diciembre de 2011

- **Beca/Ayuda:** Ayuda para curso de lengua francesa o alemana en el extranjero
  Institución: Ministerio de Educación, Cultura y Deporte.
  Fecha: Del 11 de septiembre al 01 de octubre de 2011.

- **Beca/Ayuda:** Alumno colaborador para la implantación de experiencias piloto de aplicación del sistema de créditos europeos (ECTS)
  Institución: Universidad de Granada.
  Fecha: Del 11 de septiembre al 01 de octubre de 2011.

- **Beca/Ayuda:** Ayuda para curso de lengua inglesa en el extranjero
  Institución: Ministerio de Educación, Cultura y Deporte.
  Fecha: Septiembre - Octubre 2008.

- **Beca/Ayuda:** Ayuda para curso de inmersión en lengua inglesa
  Institución: Universidad Internacional Menéndez Pelayo
  Fecha: Del 14 al 18 de abril de 2008

Contribuciones a Congresos Nacionales e Internacionales

- **Congreso:** *III Congreso de Nutrición Deportiva, Cineantropometría y Salud.*
  Autores: Benítez-Porres J., Carnero E.A., Alvero-Cruz J.R.,
  Título: Influencia de la nutrición y la maduración en los cambios del nivel de actividad física y la composición corporal en adolescentes.
  Lugar y año: Cocentaina (Alicante), 2015.
  Tipo de participación: Póster debatible.

- **Congreso:** *1er Congresso Iberoamericano "Desporto, Educação, Actividade Física e Saúde"*
  Autores: Benítez-Porres J., López-Fernández, I., Alvero-Cruz J.R., Carnero E.A.

Título: Estimación de valores de corte para el cuestionario de actividad física para niños (PAQ-C) utilizando recomendaciones internacionales de actividad física como criterio.

Lugar y año: Lisboa, 2015.

Tipo de participación: Póster debatible.

- **Congreso:** *1er Congresso Iberoamericano "Desporto, Educação, Actividade Física e Saúde"*

  Autores: Benítez-Porres J., López-Fernández, I., Barrera-Expósito J., Alvero-Cruz J.R., Carnero E.A.

  Título: Puntos de corte para clasificar adolescentes activos a través del cuestionario de actividad física para adolescentes (PAQ-A).

  Lugar y año: Lisboa, 2015.

  Tipo de participación: Comunicación oral.

- **Congreso:** *20th Annual ECSS Congress: sustainable sport.*

  Autores: Benítez-Porres J., Dorado-Guzmán M., Barrera-Expósito M., Correas-Gómez L., Alvero-Cruz J.R., Carnero E.A.

  Título: Construct validity of the physical activity questionnaire for adolescents (PAQ-A): maximal oxygen uptake criterion.

  Lugar y año: Malmö, 2015.

  Tipo de participación: Póster debatible.

- **Congreso:** *14th Annual Meeting of the International Society of Behavioral Nutrition and Physical Activity.*

  Autores: Benítez-Porres J., Fernández Vázquez R., Martínez Blanco J., Alvero-Cruz J.R.

  Título: Association of body mass index and abdominal adiposity with cognitive function and functional status in the elderly.

  Lugar y año: Edimburgo, 2015.

  Tipo de participación: Póster debatible.

- **Congreso:** *62nd Annual Meeting, 6th World Congress on Exercise is Medicine and World Congress on The Basic Science of Exercise Fatigue.*

Autores: Benítez-Porres J., López-Fernández I. Raya J.F., Carnero S.A., Alvero-Cruz J.R., Carnero E.A.
Título: Validity and Reliability of the PAQ-C Questionnaire in Spanish Children.
Lugar y año: California, 2015.
Tipo de participación: Póster debatible.

- **Congreso:** *62nd Annual Meeting, 6th World Congress on Exercise is Medicine and World Congress on The Basic Science of Exercise Fatigue.*
  Autores: García Romero J, Fernández Millán J, Alvero-Cruz J.R., Peñaloza P., Jimenez M., Benitez-Porres J., Lopez I., Carrillo de Albornoz M., Carnero E.A.
  Título: Effects of High Intensity Interval or Continuous Moderate Training on Metabolic Thresholds: the PTRAINIM Randomized Control Trial.
  Lugar y año: California, 2015.
  Tipo de participación: Comunicación oral.

- **Congreso:** *6º Congreso Internacional de Actividad Físico-Deportivas para Mayores.*
  Autores: Benítez-Porres J., García Vega M.M., Rodríguez Linares M.V., Martínez Blanco J.
  Título: Relationship between body composition and cognitive function in elderly.
  Lugar y año: Málaga, 2015.
  Tipo de participación: Comunicación oral.

- **Congreso:** *II Congreso de Nutrición Deportiva, Cineantropometría y Salud.*
  Autores: Benítez-Porres J., López-Fernández I., Raya J.F., Correas-Gómez L., Carrillo de Albornoz M., Carnero E.A., Alvero-Cruz J.R.
  Título: Actividad física y la adiposidad visceral abdominal en la niñez.
  Lugar y año: Cocentaina (Alicante), 2014.
  Tipo de participación: Comunicación oral.

- **Congreso:** *II Congreso de Nutrición Deportiva, Cineantropometría y Salud.*
  Autores: Benítez-Porres J., Barrera-Expósito J., Sainz-Martín N., Dorado-Guzmán M., Carrillo de Albornoz M., Correas-Gómez L., Carnero E.A., Alvero-Cruz J.R.

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Lugar y año: Cocentaina (Alicante), 2014.

Tipo de participación: Póster debatible.

- **Congreso:** *13th International Sport Sciences Congress.*

  Autores: Benítez-Porres J., Raya J.F., Carrillo M., Alvero-Cruz J.R., Carnero E.A.

  Título: Relationship between frequency of physical activity and abdominal visceral fat in children.

  Lugar y año: Konya (Turquía), 2014.

  Tipo de participación: Póster debatible.

- **Congreso:** *World Conference on Kinanthropometry.*

  Autores: Benítez-Porres J., Raya J.F., Correas-Gómez L., Carrillo M., Alvero-Cruz J.R., Carnero E.A.

  Título: Estimation of Internal Abdominal Fat from Anthropometry Measurements in Children.

  Lugar y año: Murcia, 2014.

  Tipo de participación: Póster.

- **Congreso:** *World Conference on Kinanthropometry.*

  Autores: Raya J.F., Benítez-Porres J., Correas-Gómez L., Carrillo M., Alvero-Cruz J.R., Carnero E.A.

  Título: An anthropometric model to estimate appendicular lean muscle in children.

  Lugar y año: Murcia, 2014.

  Tipo de participación: Póster.

- **Congreso:** *19th Annual Congress of the European College of Sport Science: Sport Science around the Canals.*

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- **Congreso:** *61st Annual Meeting of the American College of Sports Medicine, World Congress on Exercise is Medicine and World Congress on The Role of Inflammation in Exercise, Health and Disease.*
  Autores: Benítez-Porres J., Alvero-Cruz J.R., Barrera-Expósito, J., Dorado-Guzmán M., Carnero E.A.
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  Lugar y año: Granada, 2011.
  Tipo de participación: Póster debatible.

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- **Autores:** Javier Benítez Porres, María del Mar Fernández Martínez, José Ramón Alvero Cruz y Pilar Aranda
  Título del Libro: Nutrición y cineantropometría en el deporte.

Título Capítulo: Calidad de la dieta de mujeres marroquíes en edad perimenopáusica y menopáusica

Edita: Universidad de Alicante

Páginas (inicial y final): Pendiente

País de Publicación: España

Año de publicación: 2016

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📖 **Autores:** José Ramón Alvero Cruz, Rosalía Fernández Vázquez, Javier Benítez Porres y José Enrique Sirvent Belando

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Edita: Universidad de Alicante

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📖 **Autores:** Javier Benítez-Porres, Iván López-Fernández, Juan Francisco Raya, Margarita Carrillo de Albornoz, Elvis Álvarez Carnero y José Ramón Alvero Cruz

Título del Libro: Nutrición y cineantropometría en el deporte

Título Capítulo: Actividad física y adiposidad visceral abdominal en niños

Edita: Universidad de Alicante

Páginas (inicial y final): Pendiente

País de Publicación: España

Año de publicación: 2016

ISBN/Deposito legal: Pendiente

📖 **Autores:** Javier Benítez Porres

Título del Libro: Innovaciones con tecnologías emergentes

Título Capítulo: Aprender jugando: una experiencia con Kahoot en docencia universitaria

Edita: Universidad de Málaga

Páginas (inicial y final): 1-11

País de Publicación: España

Año de publicación: 2015

ISBN/Deposito legal: 978-84-606-5930-3

📖 **Autores:** Javier Benítez Porres

Título del Libro: Educar para transformar: Aprendizaje experiencial

Título Capítulo: Socrative como herramienta para la integración de contenidos

Edita: Universidad Europea de Madrid

Páginas (inicial y final): 824-831

País de Publicación: España

Año de publicación: 2015

ISBN/Deposito legal: 78-84-95433-70-1

📖 **Autores:** Javier Benítez Porres, Javier Martínez Blanco, Rosalía Fernández Vázquez, José Ramón Alvero Cruz

Título del Libro: Longevidad y salud. Innovación en la actividad física.

Título Capítulo: Sarcopenia y ejercicio físico

Edita: Área de Cultura y Deportes de la Diputación de Málaga

Páginas (inicial y final): 700-708

País de Publicación: España

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APPENDIX V
Global Summary

INTRODUCCIÓN

La actividad física (AF) ha sido identificada como un agente importante en la prevención de enfermedades crónicas como la obesidad, las cardiopatías, y el síndrome metabólico [1,2]. Con objeto de estudiar e interpretar con mayor precisión los patrones de AF durante la infancia y la adolescencia, se hace necesario desarrollar y validar instrumentos capaces de evaluar adecuada y ampliamente la AF realizada, para identificar su impacto en la salud en la población escolar de educación primaria y secundaria. De esta forma, cuantificar correctamente la AF será de gran ayuda a la hora de diseñar las intervenciones en el ámbito escolar y comunitario, en aquellos grupos de población con un estilo de vida poco saludable.

Actividad Física y Salud en Niños y Adolescentes

La AF es reconocida por aportar importantes beneficios en todos los segmentos de población [1-5]. La Organización Mundial de la Salud (OMS) viene publicando y actualizando directrices oficiales [6] que proporcionan recomendaciones específicas sobre el tipo y la cantidad de AF necesaria en las diferentes etapas de la vida, diferenciando entre niños y adolescentes, adultos, ancianos y personas con necesidades especiales. En la revisión publicada en 2010 por Janssen y Leblanc [1] se resumen los diversos beneficios de la AF realizada de forma regular para con la salud. De acuerdo con esta revisión, se ha demostrado que la AF mejora los niveles de composición corporal, el proceso de homeostasis de la glucosa, la sensibilidad a la insulina, el perfil de lipoproteínas (por ejemplo, a través de la

reducción de los niveles de triglicéridos, el aumento de los niveles de la lipoproteína HDL y la disminución de la lipoproteína LDL); y reduce la presión arterial, la inflamación sistémica y la coagulación en sangre, fomentando la tonificación muscular y mejorando la función cardiaca y endotelial. En resumen, la práctica de AF regular es fundamental para obtener y conservar un buen estado de salud física.

Como se ha comentado, realizar AF de forma regular es importante en todas las etapas de la vida, pero actualmente hay un considerable interés en la promoción de la misma en nuestros jóvenes. Esto se debe en gran parte a la creciente preocupación por los índices de obesidad. La infancia y la adolescencia son períodos importantes debido a los notables cambios fisiológicos y psicológicos que se producen: como la regulación hormonal, el desarrollo de la composición corporal o los cambios transitorios en la sensibilidad a la insulina [7]. Concretamente, muchos de los hábitos establecidos en los períodos de la infancia y la adolescencia tienden a perpetuarse en la adultez. La prevención de la obesidad en los primeros años de vida resulta fundamental, ya que la evidencia científica sugiere que los jóvenes con sobrepeso tienen un riesgo cinco veces mayor de padecer sobrepeso en su vida adulta que aquellos niños con normo-peso en la misma etapa [8]. En España, la prevalencia de padecer obesidad tanto en la niñez como en la adolescencia es alta [9,10]. En este sentido, los estudios longitudinales, tanto de seguimiento como de intervención, pueden ayudar a los investigadores a estar más cerca de comprender los determinantes y mediadores entre la AF y la adiposidad [11]. Además, una de las principales ventajas de este tipo de diseño es que se puede abordar la causalidad inversa.

Las necesidades de niños y adolescentes, por su naturaleza, requieren unas pautas de actuación concretas y específicas. Las directrices sobre AF sugieren que ambos deben

acumular, al menos, 60 minutos de AF moderada-vigorosa (AFMV). El volumen recomendado en jóvenes es el doble del recomendado para las personas adultas, principalmente porque los primeros tienen necesidades mayores de gasto energético y por la necesidad e importancia de formarlos en un estilo de vida saludable desde una edad temprana. Los Estados Unidos no es el único país que ha adoptado directrices de AF para sus jóvenes. Otras naciones, entre las que destacan Australia, Reino Unido y Canadá, han publicado sus propias directrices. Y aunque existen discrepancias menores entre ellas, todas ellas sugieren que los jóvenes deben realizar 60 minutos o más de AFMV diaria.

El mensaje de estas recomendaciones internacionales ha generado un gran interés en la comprensión y la promoción de AF en niños y adolescentes. Y es en este punto donde los centros educativos se perfilan como un escenario prometedor para alcanzar estas metas e impactar en el estilo de vida de nuestros jóvenes.

En este contexto, contamos con una variedad de herramientas y métodos destinadas a la evaluación de la AF, que difieren en cuanto a validez y viabilidad dentro del aula. Sin embargo, debemos diseñar nuestras acciones con métodos más prácticos que puedan ser utilizados en el contexto escolar, ya que existe un creciente interés por registrar los niveles de AF que acontecen durante la jornada escolar.

Medidas de la Actividad Física en Jóvenes

Siguiendo los postulados de Corder [12] y Sirard [13], esta sección ofrecerá una breve clasificación de los métodos existentes para medir o estimar AF en niños y adolescentes (obviando los métodos destinados a evaluar puramente el gasto energético como el agua

doblemente marcada o la calorimetría indirecta). Las fortalezas y debilidades pueden consultarse en la tabla 1. Dichos métodos pueden ser clasificados en dos grupos según su naturaleza: métodos objetivos y subjetivos.

La primera categoría implica la medición de parámetros fisiológicos o biomecánicos y utilizan esta información para estimar distintos parámetros en la AF. Esta categoría englobaría a los monitores de frecuencia cardiaca, la acelerometría, los podómetros y los sistemas combinados.

La segunda categoría incluye cuestionarios, entrevistas, diarios de actividad, y la técnica de observación directa. Estos métodos varían en cuanto a las variables que miden o estiman y por lo tanto en sus objetivos y resultados finales.

En las tablas 2, 3 y 4 se especifican aquellos cuestionarios que han sido diseñados en los últimos 20 años para estimar la AF en niños, adolescentes o ambos.

Independientemente del método utilizado, tres conceptos clave deben entenderse al considerar la exactitud y precisión de cualquier técnica de medición: la fiabilidad, la validez y la capacidad de respuesta [14].

Un aspecto relativo a la fiabilidad es la reproducibilidad de un método, es decir, la obtención de los mismos resultados cuando el método es utilizado por diferentes evaluadores independientes. La fiabilidad es un requisito previo para la validez.

La validez es la capacidad de un instrumento para medir o evaluar fehacientemente aquello para lo que ha sido diseñado. Idealmente, la validez debe ser considerada como el grado de concordancia entre métodos [15,16], ya que el coeficiente de correlación puede resultar en ocasiones tendencioso [17].

Por su parte, la capacidad de respuesta (a veces denominada sensibilidad) se refiere a la capacidad del instrumento o medida para detectar cambios en el tiempo. La fiabilidad y validez son requisitos de la capacidad de respuesta.

El desarrollo de métodos más exactos y precisos es una importante prioridad en la investigación en salud pública. Los cuestionarios (método subjetivo) son herramientas de bajo costo y fáciles de usar, pero su validez es a menudo cuestionable. Las medidas objetivas a menudo se utilizan con frecuencia para validar medidas menos precisas (métodos subjetivos), pero esto no mejora directamente la exactitud o precisión del cuestionario.

El Cuestionario de Actividad Física (PAQ)

Se trata de un cuestionario desarrollado específicamente para niños (PAQ-C) que posteriormente se adaptó para adolescentes (PAQ-A). Tanto el PAQ-C como el PAQ-A son herramientas auto-administradas que invitan a recordar la AF realizada en los últimos 7 días (semana anterior), y están compuestos por 8 y 9 ítems respectivamente, diseñados para evaluar el nivel general de AFMV durante la jornada escolar, después de las clases y por la noche, separando los días de entre semana del fin de semana (el PAQ-A es idéntico al PAQ-C; sin embargo, sólo cuenta con 8 ítems, ya que no incluye la pregunta sobre el recreo) [18].

El PAQ fue diseñado para ser administrado durante la jornada escolar sin pretender estimar la intensidad de la AF realizada o el gasto energético que conlleva [19]. Ambas versiones del cuestionario están limitadas en su capacidad de explicar dimensiones importantes de la AF, como son la frecuencia, el tiempo o la intensidad, puesto que se diseñaron para proporcionar un indicador general de los niveles de AF.

Sin embargo, existen evidencias en la literatura que defienden las propiedades psicométricas del PAQ [19-25], y diferentes artículos de revisión han corroborado la utilidad del mismo por contar con los mejores indicadores de validez y fiabilidad en comparación con el resto de cuestionarios diseñados para la misma población [26,27]. Biddle y colaboradores [28], en su revisión sobre cuestionarios auto-administrados para la juventud, identificaron al PAQ como una de las herramientas más prometedoras disponibles para estudios de campo. Aunque es cierto que el PAQ ha mostrado un gran potencial para evaluar AF, su sistema de puntuación se basa en una escala ordinal que carece de un verdadero significado [29,30]. Esta limitación plantea algunas preocupaciones al asumir una relación lineal entre los resultados obtenidos en la puntuación final y el resto de variables independientes [31]. Las puntuaciones continuas (por ejemplo, METs o minutos de AFMV) ofrecen más ventajas en este contexto, ya que pueden añadir una valiosa información sobre el camino a adoptar en los programas de promoción de la salud [29,32].

Como vemos, una limitación consensuada del PAQ es que la lectura de su puntuación final no es fácil de interpretar [28]. Una de las posibles soluciones a adoptar para solventar dicha limitación es calibrar los valores de los resultados brutos en una unidad más significativa. Este proceso permitiría que las diferentes escalas fuesen similares en magnitud y variabilidad, lo que supone que asumen la misma unidad de medida [33,34]. Con

este enfoque, los datos brutos de cualquier medida de auto-informe pueden ser calibrados para que coincidan con los proporcionados por otros métodos más objetivos, como por ejemplo la acelerometría.

Por lo tanto, la falta de uniformidad e información en el significado de la puntuación final del cuestionario supone la principal limitación de esta herramienta, que no proporcionaría una medida de resultado útil como la sumatoria de los minutos totales invertidos en realizar AF o el poder diferenciar a niños y adolescentes activos de aquellos sedentarios.

Uno de los principales escollos a la hora de calibrar las herramientas de auto-informe para lograr tal fin es la falta de un criterio específico. Si bien existen técnicas avanzadas que pueden minimizar el impacto de esta limitación [32,35], un diseño de calibración sencillo probablemente mejoraría la utilidad de cuestionarios como el PAQ. Dada su relevancia y utilización en diferentes investigaciones y trabajos de campo [36-44] y, las medidas propuestas en el presente documento mejorarían en gran medida su utilidad. Por lo tanto, la presente tesis doctoral proporciona evidencias de que la utilidad de las herramientas como el PAQ-C y el PAQ-A puede ser mejorada.

OBJETIVOS E HIPÓTESIS

Los objetivos generales de la presente tesis doctoral fueron, por un lado, validar las características psicométricas del PAQ en niños españoles y determinar cuáles son los puntos de corte que mejorarían la utilidad del cuestionario para futuras investigaciones; y, por otra parte, estudiar los cambios longitudinales en la composición corporal y el nivel de AF durante la adolescencia utilizando el PAQ para su estimación.

Se realizaron dos estudios como parte de la evaluación del PAQ. El primer estudio evaluó las propiedades de validez y de medición de la versión original del PAQ-C. El segundo estudio tuvo como objetivo desarrollar y probar diferentes enfoques de calibración para clasificar a la juventud como activa o inactiva siguiendo las recomendaciones internacionales de AF como criterio. Finalmente, un tercer estudio de seguimiento se centró en una preocupación actual como es la falta de AF, y se llevó a cabo en el mismo una evaluación longitudinal de los cambios producidos en los patrones de AF y composición corporal en adolescentes durante tres cursos académicos.

Así, los objetivos específicos de esta tesis doctoral son:

- Evaluar la fiabilidad y validez del cuestionario PAQ-C en niños españoles utilizando acelerometría triaxial como criterio (Estudio I).

- Determinar los valores de corte en la puntuación final del PAQ-C y del PAQ-A para clasificar a los jóvenes según las recomendaciones internacionales de AF (Estudio II).

- Explorar de forma longitudinal las alteraciones producidas en los patrones de AF y en la composición corporal en adolescentes españoles (Estudio III).

Teniendo en cuenta las evidencias recogidas hasta la fecha en la literatura relacionada con niños y adolescentes, se formularon las siguientes hipótesis de estudio:

- El PAQ-C tiene una fiabilidad adecuada y una validez razonable para estimar la AF en niños españoles (Estudio I).

- La puntuación PAQ puede relacionarse con las recomendaciones internacionales de AF establecidas para categorizar a los jóvenes de acuerdo con su percepción subjetiva de AF realizada (Estudio II).

- Los hombres son físicamente más activos que las mujeres durante la adolescencia, donde el nivel de AF disminuye por igual en ambos sexos (Estudio III).

- El sexo y la maduración juegan un papel independiente en los cambios en la composición corporal y los patrones de AF (Estudio III).

MATERIAL Y MÉTODOS

En la tabla 5 se muestra un resumen del diseño, los participantes, las variables principales, el material y los métodos estadísticos utilizados en cada uno de los estudios que componen esta tesis.

Las variables principales en los tres trabajos fueron medidas de la siguiente forma: el nivel de AF se evaluó a través del PAQ-C o PAQ-A y acelerometría triaxial (Actigraph GT3X); la composición corporal se estimó mediante mediciones antropométricas; la madurez sexual se calculó a través del porcentaje previsto de la estatura en la etapa adulta; y, por último, la ingesta calórica se evaluó mediante un cuestionario de frecuencia de alimentos auto-administrado.

Reclutamiento de la Muestra

La totalidad de los participantes eran estudiantes de educación primaria y secundaria obligatoria, pertenecientes a diferentes centros educativos de las Comunidades Autónomas de Andalucía y/o Galicia. La selección de la muestra se llevó a cabo a través de un sistema probabilístico en concordancia con los siguientes criterios: que la muestra fuese de fácil acceso y que fuese representativa de la etapa de educación primaria y secundaria.

Uno de los docentes especialista en educación física de la escuela llevó a cabo el proceso de selección. De forma breve, se les estregaba un documento informativo con la propuesta de estudio que previamente había sido aprobada en el Consejo escolar. Después de obtener la confirmación administrativa, se les hacía llegar a los padres y madres o tutores

legales la información completa de los procedimientos y evaluaciones. Además, se les convocó a una reunión informativa, con objeto de responder todas las dudas y preguntas que pudiesen tener. En esta reunión se les entregaba el consentimiento informado por escrito.

Finalmente, los participantes fueron incluidos o excluidos en el proyecto de acuerdo con los siguientes criterios de inclusión:

- Tener firmado el documento de consentimiento informado.
- No padecer ninguna enfermedad aguda o crónica.
- No estar bajo el efecto de medicamentos que puedan interferir con las variables de composición corporal y/o capacidad perceptiva.
- Estar de acuerdo en completar todas las evaluaciones a lo largo de los 4 años.

Procedimiento Común

Todas las evaluaciones se llevaron a cabo, por lo general, a lo largo de una jornada escolar ordinaria y de forma idéntica. Los participantes asisten en la hora fijada (8:30) y en ayunas a las instalaciones deportivas (gimnasios) de los distintos centros educativos. Uno de los investigadores explica la organización general de las distintas mediciones y se les informa de la hora en la que pueden volver a ingerir alimentos.

El orden de las evaluaciones fue el siguiente: se mide peso y altura; posteriormente, tras recibir una breve explicación con ejemplos, completan los cuestionarios pertinentes (PAQ-C, PAQ-A o FFQ); entre tanto, los participantes iban siendo llamados, en parejas del

mismo sexo, para la evaluación de la composición corporal (antropometría), la cual fue llevada a cabo en una habitación privada por dos investigadores acreditados en concordancia con los estándares de la ISAK.

Finalmente, se les colocaba el acelerómetro en la cintura y se les entregaba el diario de actividades donde debían registrar la AF realizada en ausencia del monitor. El acelerómetro se recogía 8 días después.

RESULTADOS

a) En el primer estudio, el análisis de fiabilidad test-retest mostró un coeficiente de correlación intraclase de 0,96 para la puntuación final del PAQ-C, el cual obtuvo una valor de consistencia (α de Cronbach) de 0,76. Por otra parte, se observaron pocas y bajas correlaciones (rho=0,228-,278, P<0,05 en todos) entre el PAQ-C y la acelerometría. El análisis de precisión realizado a través del coeficiente de correlación de concordancia indicó una baja precisión del PAQ-C en comparación con el acelerómetro triaxial (r=0,192, P=0,092). En resumen, los resultados sugieren que el PAQ-C tiene una alta fiabilidad pero una validez cuestionable para valorar la AF en niños españoles.

b) El hallazgo principal del segundo estudio fue determinar unos puntos de corte de 2,75 en el PAQ-A y 2,73 en el PAQ-C para discriminar 60 minutos de AFMV, los cuales se asocian con un volumen total de 10664 pasos/día para niños y 9701 pasos/día para adolescentes. Sin embargo, los valores del área bajo la curva (ABC) indicaron que este valor en el PAQ-C no era significativo (P>0,05), siendo un discriminador débil (ABC<0,7) entre niños activos y sedentarios. Así, de acuerdo con el análisis de las curvas ROC, sólo el PAQ-A sería una herramienta útil para clasificar a los adolescentes como activos o inactivos siguiendo las recomendaciones internacionales de AF como criterios.

c) En el tercer estudio, de diseño longitudinal, se encontraron diferencias significativas en el porcentaje de masa grasa entre S1, S2 y S3 (23,41±8,24 vs. 21,89±7,82 vs. 22,05±8,06, P<0,05; respectivamente); observándose una interacción significativa

con el sexo (F=4.387, P<0.05 entre S2-S3), pero no con la maduración. En cuanto a los niveles de AF, S2 fue significativamente mayor que S3 (2,58±0,72 vs. 2,29±0,73; P<0,001). Se dio una interacción significativa entre los niveles de AF y la maduración (F=4.889, P<0.05 entre S2-S3). Estos resultados sugieren que los cambios producidos en la composición corporal durante la adolescencia no son impulsados por los cambios en los patrones de AF. Además, el análisis de interacciones entre variables sugiere que el sexo del sujeto afecta en los comportamientos relacionados con la AF, no siendo así la maduración del mismo o las variables nutricionales.

LIMITACIONES

Además de las limitaciones descritas en el apartado "Discusión" de cada estudio, deben mencionarse/añadirse las siguientes:

- La selección de la muestra incluida en los diferentes estudios no fue aleatoria. El tamaño de la muestra fue relativamente pequeño en el primer y tercer estudio, pero significativo para los objetivos de ambos. Sin embargo, no se puede considerar una muestra representativa del país estudiado.

- En todos los estudios hubo una ausencia en la medición de la composición corporal a través de técnicas consideradas estándar de oro como la absorciometría de rayos X de doble energía (DXA).

- En general, el cuestionario (PAQ) utilizado en los estudios no capta algunos espacios de tiempo importantes en el día a día, donde es probable que se produzca AF (por ejemplo, en los desplazamientos al centro educativo). Por lo tanto, el tiempo de AF estimado a través del PAQ probablemente subestime la actividad diaria total. Además, El PAQ recopila la AF durante el fin de semana con un único ítem, pero es probable que los patrones de AF varíen considerablemente entre el sábado y el domingo en la mayoría de los jóvenes.

  Hay que tener en cuenta que algunas de las preguntas recogidas en ambas versiones del cuestionario se solapan y pueden recoger datos del mismo periodo de tiempo. Por ejemplo, en la pregunta 8 y la pregunta 9 se pregunta acerca de los niveles generales de la actividad durante los últimos 7 días. Estos son útiles para la

evaluación de los patrones generales pero son redundantes con otros elementos y por lo tanto no de mucho valor para fines de calibración.

- Otra limitación del PAQ, y quizás la más importante, es que no incluye ninguna pregunta relativa al comportamiento sedentario.

- La capacidad para recordar la AF realizada en los últimos 7 días es subjetiva y limitada, especialmente en jóvenes.

- Por último, en el tercer estudio, hubo una falta de evaluación del nivel de AF con métodos objetivos como la acelerometría, así como una falta de supervisión dietética a lo largo del periodo estudiado.

CONCLUSIONES GENERALES

A. La presente tesis doctoral aporta nuevos datos relativos a la fiabilidad y validez del PAQ-C en niños españoles (primer estudio). Los resultados sugieren que el PAQ-C tiene una alta fiabilidad, no obstante, su validez es cuestionable. Estos hallazgos sugieren que el PAQ-C requiere mejoras para ser una medida de AF útil en niños españoles.

B. En este sentido, se sugiere que el PAQ tiene margen de mejora. En el PAQ solo tres ítems preguntan sobre la AF realizada en el contexto escolar y otros tres sobre la AF realizada fuera del mismo. Los ítems restantes son de carácter amplio y preguntan sobre la AF realizada en los últimos siete días. La inclusión de ítems que evalúen el transporte hacia y desde la escuela, así como presentar por separado cuestiones para sábado y domingo, ayudarían a tener una comprensión más completa sobre los patrones de AF en los jóvenes. La inclusión de elementos que registren minutos de conducta sedentaria también añadiría valor al cuestionario.

C. El principal hallazgo del segundo estudio fue determinar un valor de corte en el PAQ-A de 2,75 para discriminar 60 minutos de AFMV, el cual se asocia con una cantidad de 9701 pasos diarios. Esta clasificación será especialmente útil en intervenciones escolares y comunitarias en aquellos grupos de adolescentes con un estilo de vida poco saludable.

D. El PAQ-A puede ser una herramienta útil para clasificar a los adolescentes siguiendo las recomendaciones internacionales de AF como criterio. Sin embargo, esto no fue aplicable al PAQ-C.

E. En el tercer estudio (longitudinal) sobre la AF, la adiposidad, la nutrición y la maduración, nuestros resultados proporcionan la evidencia de que los cambios producidos en la composición corporal y en los niveles de AF no son paralelos. Las alteraciones dadas en los niveles de AF y de masa grasa están influenciadas por el sexo del sujeto, independientemente de la maduración del mismo. Por último, la caída en los niveles de AF destaca el problema de la falta de hábitos saludables entre los adolescentes y la necesidad de desarrollar intervenciones apropiadas para prevenir esta disminución.

En resumen, El PAQ parece ser una herramienta más adecuada para medir la AF en los adolescentes que en los niños, pudiendo discriminar entre jóvenes activos o sedentarios en la adolescencia de acuerdo con las directrices internacionales de AF.

Se sugiere, siempre y cuando sea viable, el uso de ambos instrumentos (cuestionarios y acelerómetros) para evaluar los niveles de AF, especialmente en evaluaciones al inicio del curso académico y en el diseño de programas de intervención para fomentar hábitos saludables en niños y adolescentes. Con el uso de cuestionarios como el PAQ, se obtiene información sobre el tipo y la frecuencia de AF; mientras que los acelerómetros nos proporcionan la cantidad real e intensidad de dicha AF. La obtención de ambos tipos de información permitirá una mejor interpretación del patrón de AF con el fin de diagnosticar y prescribir soluciones para combatir el sedentarismo.

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