THE PHYSICAL EDUCATION CLASS AS A REFERENCE FOR IDENTIFYING VIGOROUS ACTIVITIES USING ACCELEROMETRY IN 8- AND 9-YEAR-OLD CHILDREN

LA CLASE DE EDUCACIÓN FÍSICA COMO REFERENCIA PARA IDENTIFICAR ACTIVIDADES VIGOROSAS CON ACELEROMETRÍA EN NIÑOS DE 8 Y 9 AÑOS

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This research was funded by the Proyecto I+D+I Programa Operativo FEDER Andalucía 2014–2020 (UMA18-FEDERJA-114), la Universidad de Málaga. The PASOS 2019-20 study was primarily funded by the Gasol Foundation and the PROBITAS Foundation.

Received on November 2, 2023
Accepted on December 7, 2023
DOI: 10.24310/riccafd.12.3.2023.17979

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ABSTRACT

The World Health Organization recommends that children and adolescents incorporate vigorous intensity activities but does not define how much vigorous physical activity (VPA) is necessary or what should be the duration of the activity sessions. *Objective:* To define the proportion of VPA in the most active physical education classes (PEC) to identify vigorous intensity physical activity sessions (i.e., activities). *Methods:* The PEC of 490 children (8-9 years old) were evaluated using accelerometry. The health-enhancing PEC were identified through the VPA performed and the weight status of the children. The 66.7 percentile of the VPA performed in the PEC by the children was calculated. *Results:* The average proportion of VPA of the health-enhancing PEC, and that performed by the most active schoolchildren (66.7 percentile) in the total PEC, show similar results. In boys, a VPA proportion of 16.3% and 16.1% was observed, respectively, and in girls 12.0% and 12.8%. *Conclusion:* The use of bouts of ≥60 minutes with ≥16.7% and 12.5% of VPA in boys and girls, respectively, is proposed to identify vigorous activity sessions with accelerometry.

KEY WORDS: guidelines, physical activity, physical education and training, accelerometry, childhood

INTRODUCTION

The World Health Organization (WHO) in its Guidelines on Physical Activity and Sedentary Behavior recommends that children and adolescents “incorporate vigorous-intensity aerobic activities at least three days a week” [1,2]. Sessions of vigorous-intensity activities can include a certain proportion of vigorous physical activity (VPA), but do not necessarily have to be composed entirely of VPA. In fact, physical activity sessions performed by children and adolescents with a significant vigorous intensity component (for example, participating in a football match) stand out for having a variable proportion of physical activity at all intensity levels, but with a proportion of VPA greater than other activities that would not be considered vigorous activities or sessions. Therefore, the vigorous-intensity activities of the WHO recommendation and the VPA obtained through objective evaluation methods are not equivalent concepts.

However, the WHO recommendation does not objectively define what the concept of vigorous-intensity activities refers to, what proportion of VPA it should contain, or what would be the minimum duration of an activity session to be considered as such. This makes it difficult to objectively quantify, through accelerometry, compliance with this recommendation. Given this lack of specificity, few studies have attempted to address the study of this recommendation using accelerometers [3]. Accelerometry is a tool for the objective assessment of physical activity that, unlike other subjective measurement methods (for example, self-reported questionnaires), has proven to be a reliable and valid tool for assessing physical activity in children [4–6].

In order to evaluate the pattern of physical activity performance of vigorous-intensity activity sessions through accelerometry, it is necessary to identify those time bouts that have sufficient duration to be considered as a physical activity session and the minimum proportion of VPA necessary to consider that activities as classified as vigorous-intensity activities.

Physical Education classes (PECs) can be a good example of this type of vigorous-intensity activities mentioned in the WHO recommendation. In addition, all students participate in PECs on a mandatory basis and are conducted in a known environment and schedule [7]. However, not all PECs are the same, and only part of them include enough time and intensity dedicated to the performance of physical activity of healthy intensities [8]. The definition of a Health-Enhancing PEC (HE-PEC) would allow us to know the proportion of VPA achieved by all students during PEC. The definition of bouts of activities or sessions of vigorous intensity based on the performance of children in HE-PEC can be a valid way to operationalize the WHO recommendation on this type of activities.

Therefore, the objective of this study is to define, through accelerometry, what proportion of VPA a physical activity session must include to be considered a vigorous-intensity activity session, based on the VPA performed in the HE-PECs.

MATERIAL AND METHODS

Study Design and Sample

A cross-sectional study of PECs was conducted on a sample of 8 and 9-year-old students residing in Andalusia (Spain). All primary schools in Andalusia participating in the ALADINO 2019 Study (ALimentación, Actividad física, Desarrollo INfantil y Obesidad) [9], as well as in the PASOS Study (Physical Activity, Sedentarism and Obesity in Spanish Youth) 2019-20 [10] and in the PASOS Study 2022-23 [11] were invited to participate in this study. In the schools that agreed to participate in this accelerometry study, all 3rd grade primary school students who had been previously selected to participate in these studies were invited.

A pre-determination of the minimum necessary sample size was calculated for each of the estimates to be made. The one that required the largest sample size was the estimation of VPA and moderate-vigorous physical activity (MVPA) thresholds that discriminated between students according to their weight status (i.e., normal weight vs overweight-obesity). To obtain an area under the curve (AUC) of 0.6, with 50% of the sample being overweight-obese, a 95% confidence level and accepting a confidence interval width of 0.15, the minimum necessary sample size was 218 students. It was estimated that approximately half of the participating students would be boys and the other half girls, so a minimum sample of 436 students was considered to obtain representative results also for both sexes.

The inclusion criteria to participate in this study were: 1) Being enrolled in 3rd grade of primary education in a school in Andalusia participating in the ALADINO 2019 Study, PASOS 2019-20 and PASOS 2022-23 during the academic year in which these studies were carried out; and 2) Having an informed consent signed by the legal guardians authorizing participation for this accelerometry study. Participants with limitations for physical activity practice during the evaluation and those who were less or more than 8.0-9.9 (±0.2) years old at the start of the accelerometry evaluation were excluded from the analysis.

Accelerometry

For the objective evaluation of physical activity, GENEActiv accelerometers (Activinsights Ltd., Kimbolton, UK) were used. These are triaxial accelerometers with a dynamic range of ±8 gravity units (g), where 1 g equals Earth's gravitational pull. The accelerometers were configured with a sampling frequency of 40 Hz using GENEActiv PC Software (version 3.2).

The accelerometers were worn on the non-dominant wrist, and participants were asked to wear them continuously for at least 8 consecutive days to ensure a complete assessment of 5 school days. Participants and their families were instructed not to remove the device at any time during the assessment (24 hours protocol). It was emphasized that the device was waterproof, and participants were required to wear it while sleeping.

Data Collection Procedure

Two visits were made to each school. The schools participating in the ALADINO 2019 Study were visited during the autumn of 2019 and winter of 2020, while the participants of the PASOS 2019-20 and 2022-23 studies were visited in the spring of 2019 and 2022, respectively.

In the first visit, accelerometers were individually placed on the participating students. The teachers and each participant were asked to maintain their usual activity during the accelerometry evaluation. In the second visit, the accelerometers were removed, school absenteeism during the evaluation was recorded, and the schedule of the school time and the PECs was noted.

Accelerometry Data Processing

No noise filter was applied prior to processing. Raw accelerometer data files were processed using R (http://cran.r-project.org) with the R package accelerator (version 0.4.0) [12]. The processing included the processing functions of the R GGIR package (version 2.9.2) [13]. In summary, GGIR performed the following tasks: 1) Auto-calibration [14]; 2) Detection of abnormally high sustained values; 3) Non-wear time detection; 4) Calculation of the Euclidean norm minus one with negative values set to zero (ENMONZ or ENMO) [15]. The raw data were simplified by calculating ENMONZ values (measured in milligravity units, mg) in 5-second epochs [16,17]. The GGIR algorithm was found to be inadequate in detecting relatively short non-wear periods, so the GGIR non-wear time definition was supplemented with strict periods of sustained inactivity. These periods needed to last at least 30 minutes, with angle changes in the Z-axis below two degrees, calculated between 8:00AM and 10:00PM.

To classify physical activity by intensity, the cut-off points published by Hildebrand et al. [18,19] for GENEActiv accelerometers, placed on the non-dominant wrist, in children aged 7 to 11 years, and expressed in ENMONZ (mg) were used. The specific cut-off points used were as follows: VPA (over 695.8 mg), MVPA (over 191.6 mg) and sedentary behavior (SB, less than 56.3 mg).

Validity and classification of physical education classes

PECs were studied individually (i.e., the PECs performed by each participant) and as a group (i.e., the PECs performed by each group of participants in the same classroom).

At the individual level, a PEC was considered invalid if it accumulated more than one minute of non-wear time, if at least three minutes of MVPA were not performed, or if the PEC contained more than 30 minutes of SB. Thus, individual PECs were excluded from the analysis for cases that did not participate in those group PECs performed by their classmates. An evaluation was considered valid when it had at least three valid school times, of which at least one was with PEC and another without PEC. The school time was considered valid when the accelerometer was on for at least 4 hours and also did not accumulate more than one hour of non-wear time during school hours. Weekends, holidays different from the weekend, and days of school absenteeism were also identified, which were not included in the analyses.

For the study of group PECs, the values of all participating students in each group PEC were aggregated. To ensure that each group PEC had actually been carried out in the established official schedule, the average of the proportion of VPA, MVPA and SED of the group of participating students in each class was calculated and compared with the average values of the rest of the theoretical classes (i.e., without including the PECs and recess). If it was not possible to distinguish the level of physical activity performed in the group PECs scheduled in the official schedule from the rest of the theoretical classes of the school time, the teachers were asked to confirm whether that group PEC had been carried out normally or had been replaced by another theoretical class that did not involve physical activity. If the teachers confirmed that a PEC had been replaced by a theoretical class, it was classified as a group PEC not carried out or not active, and it was eliminated from the analyses.

To identify the health-enhancing group PECs, the threshold for the proportion of VPA and MVPA that allowed to discriminate participants according to their weight status (normal weight vs overweight-obesity) was calculated. The resulting threshold was used to classify group PECs as Health-Enhancing PECs (HE-PECs) if they exceeded the VPA or MVPA threshold, and as Less Active PECs (LA-PECs) if they did not reach these thresholds.

Other Study Variables

Sex and date of birth were collected in the informed consents. Age was calculated as the difference between the start day of the accelerometry evaluation and the participant's date of birth.

Weight and height were measured between April and June 2019 for the population of the PASOS 2019-20 Study, between October and December 2019 in the participants of the ALADINO 2019 Study, and between April and June 2022 in the participants of the PASOS 2022-23 Study. In the ALADINO 2019 Study, the TANITA UM-076 scale and the SECA 206 portable stadiometer were used, while in the PASOS 2019 and 2022 Studies, the SECA 869 scale and the SECA 217 portable stadiometer were used. The scales used were able to record weights between 0-150 kg with an accuracy of 100 grams, and the stadiometers recorded measurements between 20-205 cm with an accuracy of 1 mm. The body mass index (BMI) was calculated as weight divided by height squared (kg/m^2).

Weight status was classified into 2 categories, normal weight and overweight-obesity, using the WHO growth standards [20].

The highest level of education of the parents (university studies or not) and the school status (public or private) [21] were also collected.

Statistical Analysis

Receiver Operating Characteristic (ROC) curves were used to select VPA and MVPA thresholds associated with overweight-obesity. The optimal threshold was determined based on the Youden index (J = sensitivity + specificity - 1) [22]. Group PECs were classified as HE-PECs or LA-PECs depending on whether they reached at least one of these two thresholds.

The mean, standard deviation (SD), and total of PECs were calculated, as well as their average duration and SD. A description of the studied sample was made: for quantitative variables, the mean and SD were calculated, and for qualitative variables, the frequency and proportion were calculated.

To evaluate whether there were differences by sex in all the studied variables, the chi-square test was used for qualitative variables, and the Student's t-test was used for quantitative variables if they followed a normal distribution, or the Mann-Whitney U test in case of non-normality.

The mean and SD of the proportion of VPA, MVPA, and SED of the participants during the PECs were calculated. The 66.7 percentile of the average proportion of VPA and MVPA was also calculated, as well as the 33.3 percentile in the average proportion of SED. It was calculated for the total participants, by sex, and by weight status.

The mean and SD of the proportion of VPA and MVPA in the total of PECs, in those performed by boys and girls, and in those classified as HE-PECs and LA-PECs were calculated.

For all analyses, a significance level of $p<0.05$ was established. The statistical analysis was performed with the SPSS software (IBM® SPSS® Statistics) version 25 for macOS (IBM Software Group, Chicago, IL).

RESULTS

Figure 1 shows the flowchart of participant recruitment. Of the 690 informed consents delivered, 528 students had authorization to participate, of which, 490 were included in the analysis.

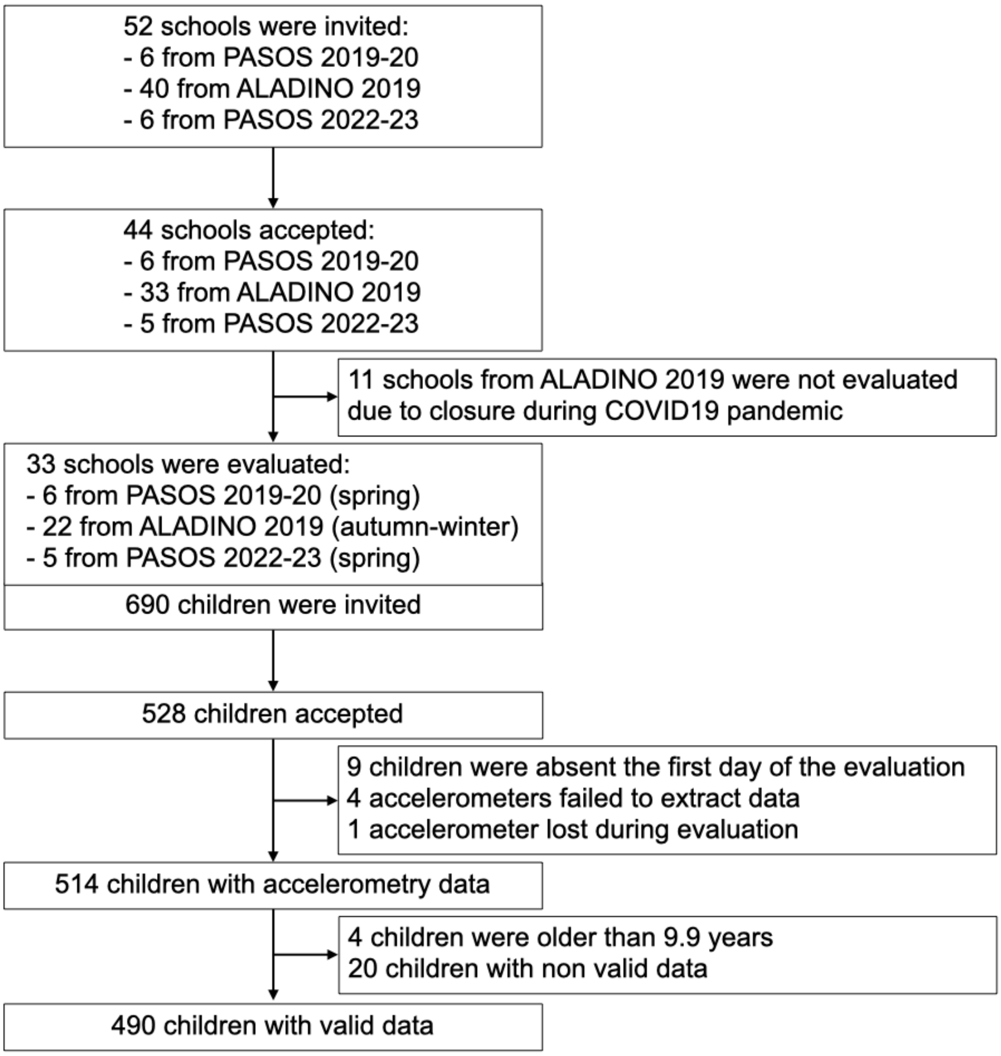

Figure 1. Flowchart of participants included in the analyses.

In the analysis using ROC curves of the proportion of VPA and MVPA in PECs based on weight status (normal weight vs overweight-obesity), an AUC of 0.59 (Confidence Interval (CI) 95%: 0.53, 0.64) was obtained for the proportion of VPA in PECs and 0.55 (CI 95%: 0.50, 0.61) for MVPA. The resulting thresholds were 13.9% (rounded to 14%) and 32.5% for the proportion of VPA and MVPA in PECs, respectively. These thresholds were used to classify group PECs into: Health-Enhancing PECs (HE-PECs, i.e., those that exceeded on average any of these two thresholds), and Less Active PECs (LA-PECs, i.e., those that did not exceed any of these two thresholds).

Table 1 shows the descriptive statistics of the participants included in the analysis. The minimum number of PECs performed by each child was 1 and the maximum was 5 PECs, with an average participation per children of 2.1 PECs (SD 0.9), of which 72.8% were HE-PECs.

Table 1. Descriptive statistics of the participants.

	Total n = 490			Boys n (%) = 247 (50.4)			Girls n (%) = 243 (49.6)			
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**p**
Age (years)	490	8.7	0.4	247	8.7	0.4	243	8.7	0.4	0.563
Weight (kg)	456	32.6	8.6	227	33.1	8.5	229	32.2	8.6	0.131
Height (cm)	456	132.2	6.4	227	132.8	6.4	229	131.6	6.4	0.060
BMI (kg/m^2)	456	18.5	3.7	227	18.6	3.6	229	18.4	3.7	0.295
PEC (n)	490	2.1	0.9	247	2.0	0.8	243	2.1	0.9	0.395
HE-PEC (n)	490	1.5	0.9	247	1.4	0.9	243	1.5	0.9	0.513
		n	**%**		**n**	**%**		**n**	**%**	
Weight status										
Normal weight		230/456	50.4		107/227	47.1		123/229	53.7	0.160
Overweight/Obesity		226/456	49.6		120/227	52.9		106/229	46.3	
Season										
Winter		187/490	38.2		90/247	36.5		97/243	39.9	0.448
Spring		125/490	25.5		69/247	27.9		56/243	23.1	
Autumn		178/490	36.3		88/247	35.6		90/243	37.0	
Parents' educational level										
Non-university		185/334	55.4		88/160	55.0		97/174	55.7	0.891
University		149/334	44.6		72/160	45.0		77/174	44.3	
School status										
Public		391/490	20.2		196/247	79.4		195/243	80.2	0.805
Private		99/490	79.8		51/247	20.6		48/243	19.8	

n, number of participants; SD, standard deviation; p, p-value for the difference between boys and girls (Mann-Whitney U test or chi-square test); BMI, body mass index; PEC, physical education classes; HE-, health-enhancing.

Table 2 shows the average proportion of VPA, MVPA, and SB performed by the participants during the PECs in which they participated. On average, participants accumulated 12.3% VPA, 38.4% MVPA, and 29.4% SB during their PECs. The most active children (i.e., the most active and least inactive tertile) performed at least 14.4% VPA, 43.5% MVPA, and 23.7% SB. The most active boys performed at least 16.1% VPA and 45.4% MVPA, while the most active girls performed at least 12.8% VPA and 39.8% MVPA.

Table 2. Average proportion (%) of physical activity and 66.7 and 33.3 percentile performed by 8-9 year old children during physical education classes.

	VPA					MVPA				SB			
-	n	P67	Mean	SD	p	P67	Mean	SD	p	P33	Mean	SD	p
All	490	14.4	12.3	6.2		43.5	38.4	11.5		23.7	29.4	11.0	
Boys	247	16.1	13.7	6.6	<0.001	45.4	40.8	11.8	<0.001	22.1	27.5	10.7	<0.001
Girls	243	12.8	10.8	5.4		39.8	35.9	10.7		25.8	31.3	11.0	
All													
Normal weight	230	15.5	13.2	6.4	0.002	44.2	39.5	11.2	0.067	23.9	29.0	10.9	0.641
Overweight/Obesity	226	13.2	11.5	5.8		43.0	37.6	11.4		23.4	29.4	10.8	
Boys													
Normal weight	107	17.3	15.0	6.5	0.013	47.7	42.1	11.5	0.207	22.2	27.1	11.0	0.655
Overweight/Obesity	120	15.2	12.9	6.3		45.1	40.2	11.5		21.8	27.3	10.0	
Girls													
Normal weight	123	14.4	11.7	5.9	0.017	40.7	37.3	10.4	0.060	25.1	30.6	10.6	0.531
Overweight/Obesity	106	11.4	9.9	4.7		38.4	34.6	10.6		26.0	31.8	11.1	

VPA, vigorous physical activity; MVPA, moderate-vigorous physical activity; SB, sedentary behavior; n, number of participants; P67, 66.7 percentile; P33, 33.3 percentile; SD, standard deviation; p, p-value for the difference between categories (Mann-Whitney U test).

Los escolares con evaluaciones válidas participaron en un total de 73 CEF grupales válidas (en promedio, 2,2 CEF por cada grupo de participantes y 13,9 alumnos participantes en cada CEF grupal), 50 de las cuales (68,5%) fueron clasificadas como CEF-SA (1,5 CEF por cada grupo y 14,4 alumnos participantes en cada CEF-SA). En cuanto al total de CEF individuales válidas, los participantes acumularon 1.017 CEF individuales válidas.

Children with valid evaluations participated in a total of 73 valid group PECs (on average, 2.2 PECs per group of participants and 13.9 children participating in each group PEC), 50 of which (68.5%) were classified as HE-PECs (1.5 PECs per group and 14.4 students participating in each HE-PEC). As for the total valid individual PECs, participants accumulated 1017 valid individual PECs.

Table 3 shows the average proportion of VPA and MVPA performed in the total of PECs, in the HE-PECs and in the LA-PECs. On average, boys and girls accumulated 16.3% (SD 7.4) and 12.0% (SD 6.0) VPA, respectively, during the HE-PECs. The average duration of the PECs was 54.2 (SD 11.3) minutes. These values were used to define the proportion of VPA and the bout duration to identify sessions of vigorous intensity activities through accelerometry.

Table 3. Proportion of physical activity performed by children in the total of physical education classes (PECs), in those classified as health-enhancing PECs and in those classified as less active PECs.

	All				Boys				Girls				
	n	Mean	SD	p*	n	Mean	SD	p*	n	Mean	SD	p*	p†
VPA (%)													
All PECs	1017	11.9	7.2		503	13.6	7.9		514	10.2	6.0		<0.001
LA-PECs	296	6.4	3.8	<0.001	143	6.8	4.1	<0.001	153	6.0	3.4	<0.001	0.114
HE-PECs	721	14.2	7.1		360	16.3	7.5		361	12.0	6.0		<0.001
MVPA (%)													
All PECs	1017	38.4	13.3		503	41.0	14.1		514	35.7	11.8		<0.001
LA-PECs	296	28.0	9.9	<0.001	143	28.1	10.6	<0.001	153	28.0	9.3	<0.001	0.768
HE-PECs	721	42.6	12.1		360	46.2	11.9		361	39.0	11.3		<0.001

VPA, vigorous physical activity; MVPA, moderate-vigorous physical activity; PEC, physical education class; HE-, health-enhancing; LA-, less active; n, number of PECs; SD, standard deviation; p*, p-value for the difference between HE-PECs and LA-PECs (Mann-Whitney U test); p†, p-value for the difference between boys and girls (Mann-Whitney U test).

It was established that a session of vigorous intensity activities is performed when at least 10.0 and 7.5 minutes of VPA are accumulated in an hour in boys and girls, respectively. That is, 16.7% in boys and 12.5% in girls of VPA in a bout of at least 60 minutes.

DISCUSSION

Our study presents a new method to identify sessions of vigorous intensity activities through accelerometry, based on the proportion of VPA performed in the HE-PECs. Knowing the performance of this type of activities through objective assessment methods is of special relevance because they are the cornerstone of one of the two activity recommendations in the WHO Guidelines [2].

In its 2010 Global Recommendations on Physical Activity for Health [23], as well as in its current 2020 Guidelines on Physical Activity and Sedentary Behavior [2], the WHO proposes to "incorporate vigorous intensity activities at least three times a week". Therefore, for more than a decade, there has been the possibility to study healthy patterns of physical activity based on VPA. However, in the current Guidelines, no concrete definition is provided of what is considered vigorous intensity activities. Nor is a specific duration or minimum threshold of physical activity at a certain intensity established to identify this type of activities [1,2]. This would allow studying the prevalence of this recommendation through objective evaluation tools such as accelerometry.

Gammon et al. [3] proposed an approach in which they combined compliance with the recommendation to perform on average at least 60 minutes of daily MVPA with the performance of a minimum of 15 minutes of daily VPA for at least three days a week. However, this attempt to operationalize the recommendation on vigorous intensity activities does not evaluate the pattern of physical activity that requires concentrating the VPA in a physical activity session.

Stone et al. [24] suggested that the inclusion of VPA intervals in the general pattern of physical activity can improve cardiovascular health in children. However, these authors did not study the difference between performing VPA spread throughout the day or concentrated in specific activities with a certain proportion of VPA. Other studies have highlighted the relationship between different patterns of physical activity and cardiovascular health in children and adolescents [25–27]. For example, Chinapaw et al. [26] highlighted that distributing physical activity in periods of at least 10 minutes can have a relevant impact on reducing cardiometabolic risk in children. Despite this, there is still a lack of conclusive evidence that defines what is the optimal VPA pattern in relation to health variables.

Migueles et al. [28] conducted an intervention study in children with overweight and obesity in the same region (Andalusia, Spain) and in a population of similar age to our study. The intervention group performed between three and five physical activity sessions based on the WHO Physical Activity Guidelines [2], including vigorous intensity activities, in which they maintained a concentration of high-intensity physical activity measured with a heart rate monitor for more than 40% of the time of the organized physical activity sessions. This approach significantly reduced the cardiovascular risk of the participants. Therefore, replicating the VPA pattern recommended by the WHO through activities with a certain concentration of VPA is associated with improvements in cardiovascular health.

For all these reasons, a new method is proposed to operationalize the identification of vigorous intensity activities evaluated by accelerometry, which establishes a minimum proportion of VPA (16.7% for boys and 12.5% for girls) in bouts of at least 60 minutes (i.e., at least 10.0 or 7.5 minutes of VPA in an hour). These thresholds represent the minimum proportion of VPA for physical activity sessions with a significant vigorous component. The thresholds that represented the average proportion of VPA in the HE-PECs were selected. These results are similar to the 66.7 percentile of the average VPA performed by the participants in the total PECs (i.e., in the set of HE-PECs and LA-PECs). Additionally, these results agree with those observed by Huertas-Delgado et al. [29], who studied the VPA accumulated in PECs designed to be especially active (*Unidades Didácticas Activas*) and obtained a proportion of VPA similar to that observed in the HE-PECs.

This type of VPA bouts has not been used before to know the patterns of physical activity or the percentage of compliance with the WHO recommendation on vigorous intensity activities. Even so, it is an easy method to program through GGIR [13] or accelerator [12]. In addition, this method is not only designed to discriminate activities of 60 minutes, but it can also detect activities of shorter or longer duration, as long as the volume of VPA accumulated in the surrounding 60 minutes exceeds the established threshold. In short, the method presented allows operationalizing the vigorous intensity activities of the WHO, opening the possibility of studying through accelerometry the proportion of compliance with the recommendation to incorporate this type of activities at least three days a week.

When comparing the physical activity performed in the PECs according to weight status, only significant differences were observed in the average proportion of VPA. These results are in line with previous studies [29–32], and highlight the superiority of VPA evaluated with accelerometry as a screening tool in child public health with respect to lower intensity physical activity [16,33,34].

In line with our results, Grao-Cruces et al. [30] observed that boys performed more VPA and MVPA in the PECs than girls. Mooses et al. [31] and Meyer et al. [32] obtained similar results in MVPA during the PECs. In contrast, Huertas-Delgado et al. [29] found no difference between boys and girls in the average proportion of VPA performed in the PECs (boys (average minutes; SD): 17.2; 10.4; girls: 15.4; 9.4; p=0.088), while they did find it in the proportion of MVPA (boys: 36.1; 14.1; girls: 32.9; 12.8; p=0.023). However, these results may be biased by the intervention carried out by 42% of the participants with the aim of increasing the physical activity performed during the PECs. In fact, the proportion of VPA and MVPA was higher in the intervened PECs compared to the traditional PECs (VPA: 18.2% vs 15.0%; MVPA: 36.6% vs 33.2%).

In conclusion, a new method is presented to identify vigorous intensity activities evaluated by accelerometry and based on the VPA performed in the most active physical education classes. The WHO recommends incorporating this type of activities at least three times a week in children and adolescents, so the definition and identification of these activities through objective evaluation methods is of great relevance. A session of vigorous intensity activities is defined as a bout of at least 60 minutes that reaches at least 16.7% in boys and 12.5% in girls of VPA (i.e., at least 10.0 and 7.5 minutes of VPA per hour, respectively). This new method to identify vigorous activity sessions will allow for the objective study of physical activity patterns that to date have not been studied with sufficient specificity, and with it, to know the proportion of compliance with the recommendation of vigorous intensity activities, which can complement the study of other recommendations based on the average daily accumulation of physical activity.

STRENGTHS, LIMITATIONS, AND FUTURE DIRECTIONS

This study provides a detailed and contextualized understanding of physical activity patterns in schoolchildren during PECs, as well as a new method to study vigorous intensity activities. The use of accelerometry as a measurement tool was key, providing objective, reliable, and valid data on children's physical activity and avoiding biases inherent in other methods, such as self-reported questionnaires [4–6]. The low percentage of non-compliance in obtaining accelerometry data (3.9%) [35] and the design of the protocol with the GENEActiv accelerometer placed on the wrist [36] optimized adherence and ensured accurate data capture. In addition, the GENEActiv accelerometer allowed us to obtain raw data without any prior filtering hidden under license, which can underestimate the results of high-intensity physical activity, especially in children [37,38].

Despite the strengths of this study, it also has limitations. The sample of this study is composed of three subsamples from different studies, carried out in three different academic years, and with two different sample selection methodologies. This situation can have an effect on the results obtained. In addition, the population participating in the ALADINO 2019 Study was evaluated in autumn and winter, while the populations of the PASOS 2019-20 and 2022-23 Studies were evaluated in spring. In spring there are more hours of light and better climatic conditions to perform physical activity [39,40]. Even so, we have not found significant differences in the study variables when comparing the three subsamples. On the other hand, there are inherent limitations to the study of physical activity through accelerometry when comparing results from different studies, such as the accelerometer model, the anatomical location, the methodology of processing raw data, with emphasis on the duration of epochs, or the cut-off points selected to determine the intensity of physical activity [16,17,37,38,41]. In addition, accelerometry does not adequately capture the intensity caused by physical activities such as cycling or strength training with overload. Therefore, the combination of accelerometry with heart rate measurement can offer more accurate results [42]. Participants were restricted to schoolchildren aged 8-9 years from a specific region of Spain, so the findings may not be generalizable to younger children or older youth, as well as to schoolchildren from other regions or countries. Finally, the observational nature of this cross-sectional study excludes any cause-and-effect association between physical activity or compliance with recommendations and sex, overweight, or performance in PECs.

The findings of this study will be used in evaluations of habitual physical activity, carried out through accelerometry, over several complete and consecutive days, and without recording the activities they perform. The aim will be to identify vigorous intensity activities to know the prevalence of the WHO recommendation to incorporate this type of activities at least three days a week. In addition, this method can be used to identify vigorous activities in studies of habitual physical activity through accelerometry with machine learning-based processing.

ACKNOWLEDGMENTS

The authors express their gratitude to the participating schools and families for their valuable collaboration in this project.

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