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Original

Effect of a gamified-based intermittent teaching unit in Physical Education on schoolchildren's accelerometer-measured weekly physical activity: A cluster-randomized controlled trial. School-fit study

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ABSTRACT

The main objective of the present study was to analyze the effect of a gamified-based intermittent teaching unit using behavior modification strategies in the Physical Education setting on schoolchildren's accelerometer-measured weekly physical activity levels. A total of 203 primary schoolchildren (39.8% females; 9-12 years) from two public schools were cluster-randomly assigned into the experimental (n = 121) and control (n = 82) groups. The experimental group performed a gamified-based intermittent teaching unit (using the first 15 minutes of each session) three times per week for five weeks. Behavior modification strategies such as activity wristbands, goal setting, and educational counseling were also applied to promote habitual physical activity. Before and during the last intervention week, schoolchildren's physical activity levels were objectively measured through ActiGraph wGT3X+/BT accelerometers. The Multilevel Linear Model results showed that the experimental group schoolchildren statistically significantly improved weekly moderate-to-vigorous physical activity (p < .05, d = 0.42). Moreover, the intervention statistically significantly improved the percentage of schoolchildren achieving, on average, at least 60 minutes of moderate-to-vigorous physical activity and 10,000 steps per day (p < .05, Cramer's V = .521–.549). A gamified-based intermittent teaching unit using behavior modification strategies seems effective for improving schoolchildren's physical activity levels.

Efecto de una unidad didáctica intermitente gamificada en Educación Física sobre la actividad física semanal de los escolares medida con acelerómetros: Un ensayo controlado y aleatorizado por grupos naturales. Estudio School-Fit

Palabras clave:
Niños
Estrategias de modificación de conducta
Programa innovador
Pulseras de actividad
Gamificación

RESUMEN

El objetivo principal del presente estudio es analizar el efecto de una unidad didáctica intermitente gamificada utilizando estrategias de modificación de conducta en el contexto de la Educación Física sobre los niveles de actividad física semanal de los escolares medidos por acelerómetros. Un total de 203 escolares de Educación Primaria (39.8% mujeres; 9–12 años) de dos colegios públicos han sido asignados aleatoriamente al grupo experimental (n = 121) y control (n = 82). El grupo experimental ha realizado una unidad didáctica intermitente gafmiciada (utilizando los primeros 15 minutos de cada

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sesión) tres veces por semana durante cinco semanas. También se han aplicado estrategias de modificación de conducta como pulseras de actividad, establecimiento de metas y asesoramiento educativo para promover la actividad física habitual. Antes y durante la última semana de la intervención, los niveles de actividad física de los escolares han sido medidos objetivamente mediante acelerómetros ActiGraph wGT3X+/BT. Los resultados del Modelo Lineal Multinivel muestran que los escolares del grupo experimental han mejorado de manera estadísticamente significativa la actividad física moderada-vigorosa semanal ($p < .05$, $d = 0.42$). Además, la intervención ha mejorado estadísticamente el porcentaje de escolares que han alcanzado, de media, al menos 60 minutos de actividad física moderada-vigorosa y 10,000 pasos por día ($p < .05$, V de Cramer = .521–.549). Una unidad didáctica intermitente gamificada utilizando estrategias de modificación de conducta parece ser efectiva para mejorar los niveles de actividad física de los escolares.

Introduction

Currently, there is a high prevalence of physical inactivity among school-aged children and adolescents, with only 20% of schoolchildren worldwide achieving the World Health Organization physical activity (PA) recommendations (i.e., at least on average 60 minutes per day of moderate-to-vigorous PA (MVPA) across the week) (OECD/World Health Organization, 2023). The increment of screen time viewing, as well as the mobility restrictions caused by the COVID-19 pandemic, could be the main reasons, among others (OECD/World Health Organization, 2023). The high prevalence of physical inactivity together with the facts that habitual PA is associated with a wide range of physical, social, and mental benefits (OECD/World Health Organization, 2023), make health promotion programs in school-aged children a social and global priority (World Health Organization, 2018).

Most worldwide educational systems have in the National Standards of their curriculum the goal to increase students' habitual PA during their leisure time (Association for Physical Education, 2020; Hardman et al., 2014). Therefore, the Physical Education (PE) subject is a crucial setting to address this problem (World Health Organization, 2018), providing schoolchildren adequate levels of psychological mediator variables such as perceived autonomy or motivation (Kelso et al., 2020), procedural knowledge to practice habitual PA in their environment (Casado-Robles et al., 2022a; Elliot et al., 2013) or enough autonomy for regulating their PA (Viciana et al., 2019). Moreover, PE teachers can apply behavioral modification techniques (e.g., self-monitoring, goal-setting; Michie et al., 2009) and offer schoolchildren opportunities to be able to increase and maintain active behaviors in their daily life (i.e., active commuting, PE classes with around 50% of MVPA, active school-recess, and leisure time involved in sport or PA, during weekdays and weekends) (Casado-Robles et al., 2022b; Elliot et al., 2013; Wong et al., 2021).

However, some PE setting characteristics make it difficult to achieve objectives related to increasing habitual PA: (a) the reduced curricular time allocated to PE (two-three weekly sessions in most of the European countries, Hardman et al., 2014); (b) the high volume of curricular objectives and contents that teachers must develop throughout the school year (Casado-Robles et al., 2019); (c) the impossibility of monitoring the PA of schoolchildren outside the school when the teacher is not present (European Commission/EACEA/Eurydice, 2013); and (d) the low motivation of schoolchildren to increase PA in their leisure time (Franco et al., 2020).

In order to facilitate the solving of this complex issue, intermittent teaching units proposed by Viciana and Mayorga-Vega (2016) could be applied. This innovative structure of the teaching unit consists of working a particular objective during only a few minutes of a PE session (e.g., the first 15 minutes) and for several sessions, leaving the rest of the PE session for working on any other different objective. Therefore, limited PE sessions' time could be used more efficiently for developing various objectives, prolonging and distributing the time used to learning in general and the practice specifically to a longer term. Previous empirical studies have shown the effectiveness of this teaching unit structure in developing and maintaining over time health-related physical fitness levels (Guijarro-Romero et al., 2020). For example, Guijarro-Romero et al. (2020) showed that an intermittent teaching unit consisting of working intensely through physical fitness exercises (e.g., interval training, running games) during the first 18-20 minutes of the main part of the PE session, high school students' cardiorespiratory fitness, assessed with the 20-meter shuttle run test, improved. However, to date it has not been applied in order to promote habitual PA in schoolchildren.

Additionally, methodology used by PE teachers is particularly relevant, especially with children. Gamification is an active teaching methodology in PE that is progressively receiving more attention (Arufe-Giráldez et al., 2022). Gamification is defined as the use of game elements in non-game contexts with the aim of seeking behavior modification or facilitating significant learning outcomes (Deterding et al., 2011). Particularly, it provides participants' motivation and enjoyment, making students actively participate in their own educational process, motivating them to continue practicing, and producing positive social and collaborative interactions (Arufe-Giráldez et al., 2022; Kapp, 2012). The introduction of some elements like progress mechanics (e.g., points, badges, leaderboards), narrative and characters, player control, immediate feedback, opportunity for collaborative problem solving, learning with increasing challenges, opportunity for mastery and leveling up, and social connection make the educational environment "gamified" (Blázquez & Flores, 2020). In a recent meta-analysis with eighteen studies (three of them in primary school) performed by Mazeas et al. (2022), scientific evidence of the effectiveness of gamification in PE for promoting PA practice was found.

Furthermore, technology has recently emerged as an important ally of both schoolchildren and PE teachers in achieving objectives related to increasing habitual PA (Strath & Rowley, 2018). Self-monitoring behavior (e.g., through activity wristbands) is an essential technique for PA promotion programs (Michie et al., 2009). For instance, activity wristbands help schoolchildren to understand the interpretation of PA levels and to confirm the achievement of the daily World Health Organization international PA recommendations (Colley et al., 2012; Mayorga-Vega et al., 2021). Moreover, they provide support to PE teachers for controlling and evaluating schoolchildren's habitual PA in periods of time where they are not present, showing adequate validity data in some PA variables, such as daily steps performed in free living-conditions (Mayorga-Vega et al., 2023). Furthermore, activity wristbands have particular characteristics that make these devices feasible and useful to be used

in PE setting (Maher et al., 2017). For example, activity wristbands are easy to use by students (there are even some specific models adapted to children), are small and light to wear, include an attractive display, provide valid and self-monitoring PA parameters, and goal alerts, and also are economically affordable by teachers and families in general (Casado-Robles et al., 2022b; Maher et al., 2017).

In the meta-analysis of 45 studies performed by Casado-Robles et al. (2022b), activity wristbands have demonstrated to be an effective behavior modification strategy in PA promotion programs increasing PA levels performed by schoolchildren. Other different strategies have also been used together with activity wristbands, such as goal-setting and educational counseling sessions (Casado-Robles et al., 2022b). Moreover, the inclusion of a greater number of strategies in the programs had a higher effect on school-aged children's daily PA (Casado-Robles et al., 2022b). However, some gaps were detected by Casado-Robles et al. (2022b): (a) specifically with samples of children, studies were scarce, especially in the school context, and further studies should be developed; and (b) there were no studies with all the strategies previously mentioned applied at the same time in a particular program with school-aged children. Therefore, considering previously highlighted gaps by Casado-Robles et al. (2022b), together with the scarce evidence of gamified interventions in the PE setting to promote objectively-measured school-age children PA (only three studies; Mazeas et al., 2022), it seems to be an appropriate methodological approach with schoolchildren to confluence gamification with all the aforementioned behavior modification strategies into the PE context, with the aim of increasing schoolchildren's habitual PA, using activity wristbands as the main behavioral modification technique. Additionally, in order to check the effectiveness of the intervention on schoolchildren's objective habitual PA levels, valid instruments should be used to measure schoolchildren's PA (Neil-Sztramko et al., 2021). Among the large number of instruments for the assessment of schoolchildren's objective PA levels, research-grade accelerometers like the ActiGraph accelerometers, are considered as the most valid instruments for objectively assessing schoolchildren's PA (Romanzini et al., 2014; Trost et al., 2011). Research-grade accelerometers provide the intensity, volume, and frequency of schoolchildren's PA (Migueles et al., 2017). Unfortunately, to the best of our knowledge, no previous study in the PE setting has been found analyzing the effect of a gamified intervention using multiple behavior modification strategies (including activity wristbands, goal-setting, and educational counseling) on schoolchildren's objective habitual PA levels. The present study was designed to address the above-mentioned gaps by investigating the effectiveness of an intermittent teaching unit in the PE setting based on gamification and using behavior modification strategies on schoolchildren's accelerometer-measured weekly PA levels. Consequently, the main objective of the present study was to analyze the effect of an intermittent teaching unit based on gamification and using behavior modification strategies (e.g., activity wristbands, goal-setting, and educational counseling) in the PE setting on primary schoolchildren's accelerometer-measured weekly PA levels. The main hypothesis was that students who perform the intermittent teaching unit based on gamification and using behavior modification strategies will show higher habitual PA levels compared with schoolchildren in the control conditions.

Method

Study design

The present study is reported according to the CONSORT for cluster randomized trials guidelines (Campbell et al., 2012). For practical reasons and due to the nature of the present study (i.e., pre-established classes in a school setting), a cluster randomized controlled trial design was used (Guijarro-Romero et al., 2020).

Participants

All 273 schoolchildren (39.9% females) from the fourth to sixth grades of Primary Education (i.e., 9–12 years old) were invited to participate in the study. All the schoolchildren's families had a middle socioeconomic level. The inclusion criteria were: (a) being enrolled in the fourth to sixth grade at the primary education level (grades where the school approvals were obtained and that had a high maturity level to autonomously use activity wristbands); (b) participating in the normal PE sessions (i.e., being exempt of performing the subject or not presenting any physical disability that prevented performing the tasks during the sessions); (c) being exempt of any health problem like heart diseases, uncontrolled asthma, or bone/joint problems that would make them unable to engage in PA normally; (d) presenting the corresponding signed written consent by their legal guardians, and (e) giving their own corresponding verbal assent. The exclusion criteria were: (a) not having recorded a valid week (i.e., at least 600 minutes of valid wear time during at least two weekdays and one weekend day) at both the pre- and post-intervention, and (b) not having an attendance rate equal to or greater than 85% for PE sessions during the intervention period.

From the 273 schoolchildren (39.9% females) that were invited to participate in the present study, 203 schoolchildren (40.7% females) agreed and met the inclusion criteria. However, in the end 88 schoolchildren (51 males and 37 females; $M_{age} = 10.1 \pm 0.8$ years; 22 fourth graders, 38 fifth graders, and 28 sixth graders) passed the exclusion criteria (Figure 1).

Instruments

Anthropometric instruments. Participants' body mass and height were measured through a scale (Seca, Ltd., Hamburg, Germany; accuracy = 0.1 kg) and a stadiometer (Holtain Ltd., Crymmych, Pembs, United Kingdom; accuracy = 0.1 cm) following the *International Standards for Anthropometric Assessment* (Stewart et al., 2011).

Accelerometer. Schoolchildren's PA was objectively measured by a wGT3X+/BT accelerometer (ActiGraph, LLC, Pensacola, FL, USA). Accelerometers were adjusted by the researchers on schoolchildren's right hip using an elastic waistband (Migueles et al., 2017). Initializing, downloading, wear time validation, and scoring were performed using the ActiLife Lifestyle Monitoring System Software version 6.13.4 (ActiGraph, LLC, Pensacola, FL, USA). The first day with the data obtained was considered as a familiarization day and it was not used for statistical analyses (Mayorga-Vega et al., 2018). Accelerometers were initialized with a sample ration of 30 Hz (Evenson et al., 2008; Trost et al., 2011). Since short bursts of rapidly changing activity characterize schoolchildren's behavior, a one-second *epoch* was used (Migueles et al., 2017). A minimum wear time of 600 minutes per day was set (Migueles et al., 2017). Non-wear periods were set with a minimum length of 60 minutes of consecutive zero-count *epochs* with up to two minutes spike tolerance (Oliver et al., 2011). ActiGraph accelerometer-measured PA has shown a high reliability and validity among schoolchildren (e.g., MVPA, ROC-AUC = .90, Se = .88, Sp = .92) (Romanzini et al., 2014; Trost et al., 2011).

Study variables

Body mass, body height, body mass index, and body weight status. Participants' *body mass* and *height* were measured in shorts, T-shirts, and barefoot. For the body mass measure, the student stood in the center of the scale without support and with their

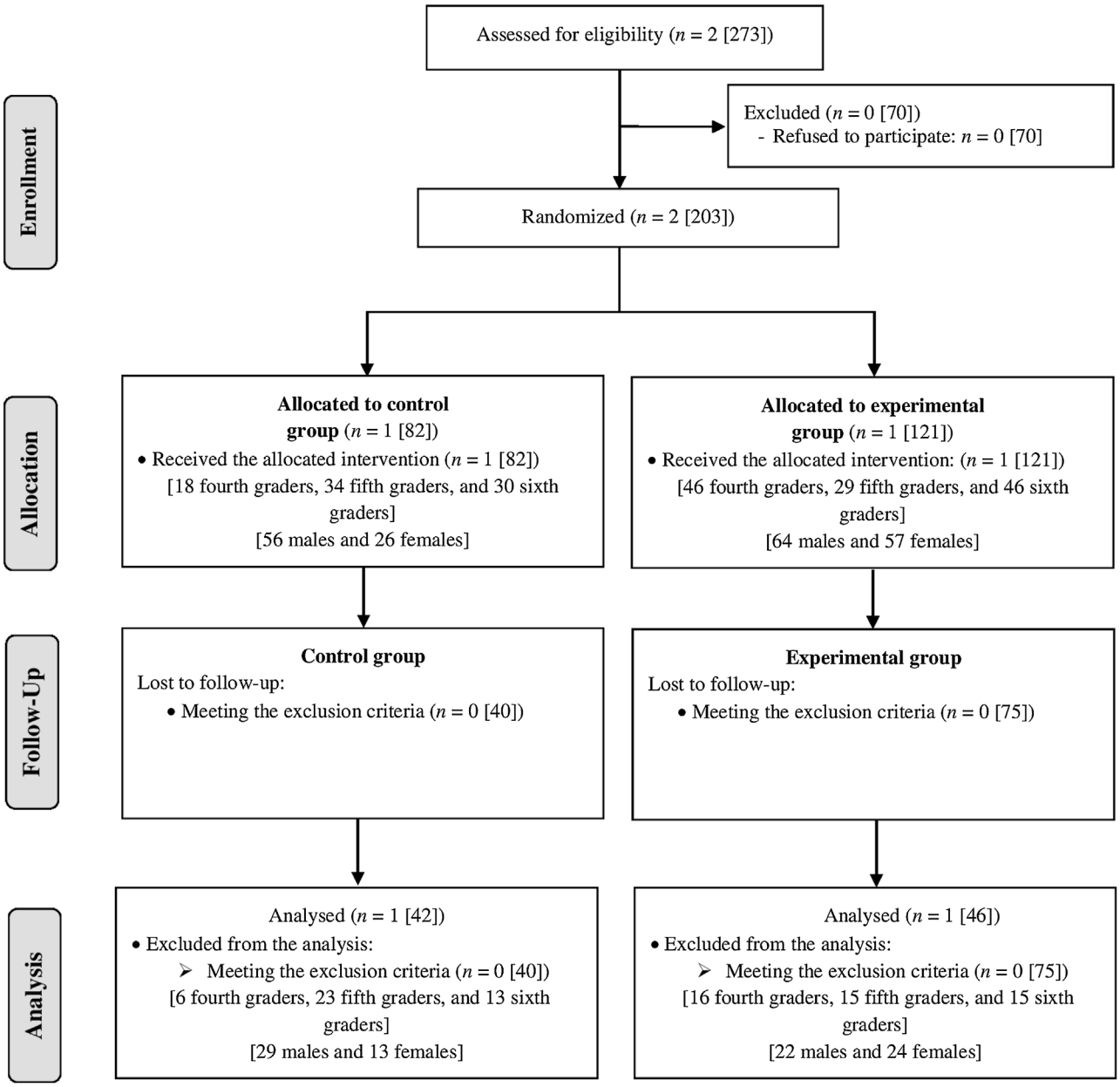

Figure 1. Flow chart of participants included in the present study. All numbers are school centers [students].

weight distributed evenly on both feet. For the body height assessment, participants stood with their feet together with the heels, buttocks, and upper part of the back touching the stadiometer, and with the head placed in the Frankfort plane. Two measurements of both body mass and height were performed and the average of each was calculated (Stewart et al., 2011). Then, the *body mass index* was calculated as body mass divided by body height squared (kg/m^2). Finally, participants' body weight status was categorized by the body mass index cut-points as overweight/obese or non-overweight/obese (Cole et al., 2000).

Steps. Step count was assessed by the default settings of ActiLife for step count. Moreover, schoolchildren's steps were dichotomized as meeting or not meeting the daily recommendation of at least 10,000 steps (Mayorga-Vega et al., 2021).

Moderate-to-vigorous physical activity. For the percentage of time engaged in MVPA, Evenson's cut-off points were used (i.e., ≥ 2,296 counts/minute) (Evenson et al., 2008; Trost et al., 2011). This threshold has demonstrated the best evidence supporting score validity for assessing MVPA among schoolchildren in the cross-validation study performed by Trost et al. (2011). Furthermore, schoolchildren's MVPA was dichotomized as meeting or not meeting the daily recommendation of at least 60 minutes of MVPA (World Health Organization, 2020).

Total physical activity. To calculate the schoolchildren's *total PA*, Evenson's cut-off points were used (i.e., ≥ 101 counts/min) (Evenson et al., 2008).

To calculate *steps, MVPA*, and *total PA* variables during the whole week, a minimum criterion of two weekdays and one weekend day

with valid time was established (Mattocks et al., 2008). Afterward, the schoolchildren's weekly PA levels were calculated as follows: (5 × mean value of valid weekdays) + (2 × mean value of valid weekend days)/ 7 (Mayorga-Vega et al., 2022).

Procedure

The protocol of the present study conforms to the Declaration of Helsinki statements (64th WMA, Brazil, October 2013) and it was approved by the Ethical Committee for Human Studies at the University of Granada (code number: 1252/CEIH/2020). Recruitment of participants was carried out in June of 2022. The principals and the PE teachers of two state school centers of Granada (Granada, Spain) chosen by convenience were contacted and personally informed by the research team about the study, requesting its permission to be conducted. After obtaining the approval to carry out the present study, to avoid contamination of treatments, randomization was conducted at the school-level, using a computerized random number generator. Each school had two 4th, two 5th, and two 6th grade pre-established classes. This was done before the pre-intervention evaluation was administered by an independent researcher blinded to the study aim and following a 1:1 ratio into the experimental (EG) or control (CG) groups. Schoolchildren and their legal tutors were fully informed about the study features. Participants' verbal assent and their legal guardians' signed written informed consent were obtained before taking part in the study. Prior to carrying out the intervention, participants' gender and age information were obtained from school reports and their anthropometric measures were taken. Also, before the intervention, the guidelines for correctly delivering the sessions of the EG were designed by the researchers and given to the PE teacher. The main researcher supervised all the sessions and made sure all guidelines were considered during the program. The intervention was done from October to December 2022 (see the intervention section). PA data collection of both study groups was carried out before and during the last week of the teaching unit (pre-intervention and post-intervention, respectively) through wGT3X+/BT accelerometers. Schoolchildren were instructed to wear the accelerometer for eight consecutive days from waking to bedtime and to take the accelerometer off only when they engaged in aquatic activities or took a bath/shower. During the waking time, schoolchildren were urged to maintain their habitual PA levels. Information regarding the correct wearing of the accelerometer was explained prior to the initial attachment. This information was provided to the schoolchildren and parents in written form to ensure they could check and correct the attachment on a regular basis. All evaluations were performed by the same tester, instrument, and protocols.

Intervention

The EG schoolchildren performed a gamified-based (Blázquez & Flores, 2020), intermittent teaching unit (Viciana & Mayorga-Vega, 2016) during five weeks (three sessions/week) aimed at promoting healthy PA habits. Specifically, the first 15 minutes of each session were used for this objective during the teaching unit. The rest of sessions' time other contents and PE objectives were worked (football and basketball). The first week of the intervention was used to present and organize the entire proposal (i.e., explanation of the mission and its objective, of the activity wristband operation, the personalized healthy passport, diary, and the creation of teams and their representative avatars). The narrative of the intervention consists of a trip of a character created named "Andaluzo" who had the mission of traveling by the Andalusia region (south of Spain) visiting all its provinces (i.e., "The adventure of Andaluzo") and discovering traditional games in each province. The eight provinces of Andalusia corresponded to the eight levels of the Andaluzo's adventure, which had to be overcome during weeks two to five of the intervention. Therefore, in each of those four weeks the schoolchildren had to achieve two levels. For this, four progressive step challenges had to be accomplished. In order to progress in each level along the mission the schoolchildren had to achieve a minimum number of daily steps per week (adaptive steps goal-setting), both individually and per teams: 9,000, 10,000, 11,000, and 12,000 steps/day in weeks two, three, four, and five, respectively. Thus, the achievement of the challenges was equally important at the individual level as it was for teams, since the achievements at the individual level affected the achievement of the team. Schoolchildren who passed each step challenge received a stamp in their healthy passport. Additionally, as the teams were overcoming the levels, their avatars were advancing on a map of the mission, which was posted on the wall of the classroom with all avatars of all teams. Also, each time a level was passed, a typical game of the province that had been reached was deactivated, which schoolchildren practiced during the remaining time of one of the PE sessions.

Likewise, they were talked to about some cultural aspects of said provinces in order to know the culture of the discovered new geographical places. Schoolchildren wore an activity wristband the whole day that was specifically designed for schoolchildren (Garmin Vivofit Junior 3) to promote habitual PA. Notification of achieved step goal was activated in the activity wristband. During these first 15 minutes of the sessions, the information recorded by the activity wristband was analyzed in order to provide schoolchildren with feedback of their daily PA habits. Together with the use of gamification, activity wristbands, and adaptive step goal-setting, educational counseling was also applied during the intervention (Casado-Robles et al., 2022b). Educational counseling included information about: (1) PA recommendations; (2) benefits of habitual PA practice; (3) types of PA that can be performed depending on their intensity to achieve the PA recommendations (PA pyramid); (4) barriers toward PA practice and their possible solutions; (5) healthy PA practice proposals for periods such as recess and leisure time, where active behavior only depend on their will; (6) sensitizing videos and news about PA practice; and (7) health commandments. Finally, after the gamified-based intermittent teaching unit, all schoolchildren received the Andaluzo's adventure diploma and were encouraged to autonomously maintain the PA challenge of 12,000 steps per day.

Regarding the CG schoolchildren, they also carried out three PE sessions per week during the intervention period. During these sessions, contents of basket and football were developed during the entire session. However, this group did not wear activity wristbands or receive any behavior modification specific strategy developed in the EG.

Data analysis

A priori sample size calculation was estimated with the Optimal Design Plus Empirical Evidence Software Version 3.01 for Windows with the cluster randomized trials with the person-level outcomes function. Parameters were set as follows: significance level $\alpha = .05$, number of participants $n = 10$, effect size $\delta = 0.60$ (Casado-Robles et al., 2022b), intra-class correlation coefficient $\rho = .01$, and statistical power $(1 - \beta) = .80$, and dropout = 37% (Howie & Straker, 2016). A minimum final sample size of 120 participants (10 participants per cluster; minimum initial sample size equal to 191) was estimated.

Descriptive statistics (means and standard deviations, adjusted means and standard errors or percentages) were computed. Firstly, all the statistical test assumptions were checked by common procedures (e.g., histograms and Q-Q plots for normality) and met. Then, the one-way analyses of variance (ANOVA) (continuous variables) and the chi-squared test (categorical variables) were conducted to

examine potential differences in terms of general characteristics between the two groups.

Next, the effect of the gamified-based intermittent teaching unit on schoolchildren's weekly PA (i.e., continuous variable) was examined. Since the implementation of the missing data requires strong assumptions that are hard to justify, "complete case" analyses including only those whose outcomes were known were used (i.e., $n = 88$) (Campbell et al., 2012). Because the unit of intervention was the class, we used a Multilevel Linear Model with participants nested within classes and measures nested within participants (Li et al., 2017). From all the potential confounding variables explored (i.e., gender, grade, body mass, body height, body mass index, activity wristband previous use, and activity wristband current use), covariable gender was used. The maximum likelihood estimation method was used. Subsequently, the *post hoc* within-subject pairwise comparisons with the Bonferroni adjustment were carried out. On the other hand, the exacted McNemar's test was used in order to examine the effect of the gamified-based intermittent teaching unit on the percentage of schoolchildren achieving, at least, an average of 60 minutes of MVPA/10,000 steps per day across the week. Effect sizes were estimated using the Cohen's *d* (continuous variables) and Cramer's V (categorical variables) for the pairwise comparisons. All statistical analyses were performed using SPSS version 25.0 for Windows (IBM® SPSS® Statistics). The statistical significance level was set at $p < .05$.

Results

General characteristics

The results of the one-way ANOVA and the chi-square test did not show statistically significant differences in terms of general characteristics between the two groups ($p > .05$), except for *grade* ($p < .05$) (Supplementary Table S1). Regarding the attendance rate, the included EG participants obtained an average of 97.0% (14.5 sessions).

Effect of the gamified-based teaching unit on schoolchildren's weekly physical activity

The Multilevel Linear Model results, followed by the within-group pairwise comparisons, showed that the EG schoolchildren statistically significantly improved weekly MVPA ($p < .05$) from pre-intervention to post-intervention measures. Furthermore, the results showed that the CG schoolchildren statistically significantly reduced weekly *total* PA and *steps* ($p < .05$) (Table 1). For the valid wear-time statistically significance differences were not found $p > .05$).

The results of the exact McNemar's test showed that the EG statistically significantly increased the percentage of schoolchildren achieving, on average, at least 60 minutes of MVPA per day ($p = .021$, Cramer's V = .549) and 10,000 steps per day ($p = .039$, Cramer's V = .521). However, for the CG statistically significant differences were not found ($p > .05$) (Figure 2).

Discussion

The main objective of the present study was to analyze the effect of an intermittent teaching unit based on gamification and using behavior modification strategies (e.g., activity wristbands, goal-setting, and educational counseling) in the PE setting on primary schoolchildren's accelerometer-measured weekly PA levels. The findings of the present study have shown that the schoolchildren who performed the gamified-based intermittent teaching unit improved their weekly MVPA levels. Moreover, although no differences were found in schoolchildren's total PA nor steps, the pre-intervention levels of these variables were maintained with respect to the decrease in both in the CG after the intervention. Together with the gamification of the intervention, the use of activity wristbands, goal-setting (i.e., adaptive step challenges), and educational counseling, which have shown to be the most effective strategies in activity wristband-based programs (Casado-Robles et al., 2022b), could influence this positive result. Regarding the magnitude of the effects of the intervention, previous studies that have applied programs with similar behavior modification strategies found lower effects on schoolchildren's MVPA ($d = 0.22$, 95% confidence interval 0.13-0.31) (Casado-Robles et al., 2022b) than in the present study ($d = 0.42$). In this sense, according to Casado-Robles et al. (2022b), PA programs that incorporate a greater number of behavior modification strategies are more effective to improve schoolchildren's PA levels. Regarding daily steps, surprisingly although gamification, activity wristbands, goal-setting, and educational counseling have shown to be more effective for influencing this variable in PA promotion programs (Casado-Robles et al., 2022b; Mazeas et al., 2022), they did not influence it in the present study. Several reasons may explain this finding. Firstly, the pre- and post-intervention evaluations carried out with accelerometry were performed at the beginning of autumn and in the middle of winter, respectively, in which adverse climatology factors may affect the post-intervention week evaluation. According to the revision of 26 studies made by Zheng et al. (2021), rainfall, low temperature, short day length, and season are the most influencing climatology factors that negatively affect schoolchildren's PA levels. In fact, after the intervention period the CG significantly reduced daily steps, as well as total PA. Even, a light decrease, not significant, is observed in CG schoolchildren's MVPA levels. However, the fact that the EG maintained daily steps and total PA levels after the intervention, while the CG diminished both, point out that the intervention could influence in this maintenance, avoiding the normal decrease in this variable as a consequence of the adverse weather conditions due to rain and lower temperatures (Zheng et al., 2021). Moreover, although non-significant, EG schoolchildren's daily steps and total PA showed a light increment after the intervention. This suggests that if similar climatological conditions (such as day length, absence of rain, or warm temperature) would take place in the post-intervention evaluation week, significant differences could have been registered with respect to the pre-intervention values. Secondly, another possible explanation of the lack of change in this variable in the EG might be the high starting values of EG schoolchildren for this variable (e.g., 61% had over 60 minutes of MVPA and 46% 10,000 steps per day). In this line Casado-Robles et al. (2022b) found that the programs were less effective for schoolchildren with high initial values of accomplishment with PA recommendations (i.e., schoolchildren physically active). This aspect should be highlighted in the present study, because compared to 20% of worldwide schoolchildren physically active (OECD/World Health Organization, 2023), in the present study this percentage was 61% before the intervention. Regarding the effect sizes of the intervention on daily steps and total PA, previous studies with programs with similar behavior modification strategies found slightly higher effects on schoolchildren's daily steps ($d = 0.61$, 95% confidence interval 0.48-0.75) and lower effects on total PA ($d = 0.15$, 95% confidence interval 0.04-0.26) (Casado-Robles et al., 2022b) than in the present study (daily steps: $d = 0.49$; total PA: $d = 0.35$). Therefore, considering these outcomes, it seems that the gamified-based teaching unit applied influenced the awareness of healthy PA, since although total PA did not increase because of the abovementioned reasons, the proportion of it corresponding to MVPA did.

A recent systematic review and metanalysis revealed that only three studies have examined the effects of gamified interventions

Table 1
Effect of the gamified-based intermittent teaching unit on schoolchildren's weekly physical activity levels

	Pre-intervention	Post-intervention	Multilevel Linear Model[a]			Effect sizes[b]
	Mean (SE)	Mean (SE)	−2 LL	F	P	d
MVPA						
Control (*n* = 42)	66.2 (2.6)	62.9 (2.8)	1,441.580	7.092	.009	0.42
Experimental (*n* = 46)	67.3 (2.5)	71.4 (2.7)*				
Total PA						
Control (*n* = 42)	185.6 (5.3)	177.2 (5.8)*	1,698.955	4.520	.036	0.35
Experimental (*n* = 46)	185.2 (5.1)	189.4 (5.6)				
Steps						
Control (*n* = 42)	10,364.0 (351.8)	9,655.0 (385.7)*	3,184.740	7.893	.006	0.49
Experimental (*n* = 46)	10,660.6 (336.0)	11,132.3 (368.3)				

Note. SE = Standard error; −2 LL = −2 log-likelihood; MVPA = Moderate-to-vigorous physical activity; PA = Physical activity; [a] Multilevel Linear Model with participants nested within classes and measures nested within participants as random effects, and with the between-subjects factor *group* (control, experimental), the within-subject factor *time* (pre-intervention, post-intervention) and gender as *covariable* as fixed effects was selected (i.e., two-way mixed nested ANCOVA); *Post-hoc* within-subject pairwise comparisons with Bonferroni adjustment for each group independently: *$p < .05$. [b] Cohen's *d* effect size.

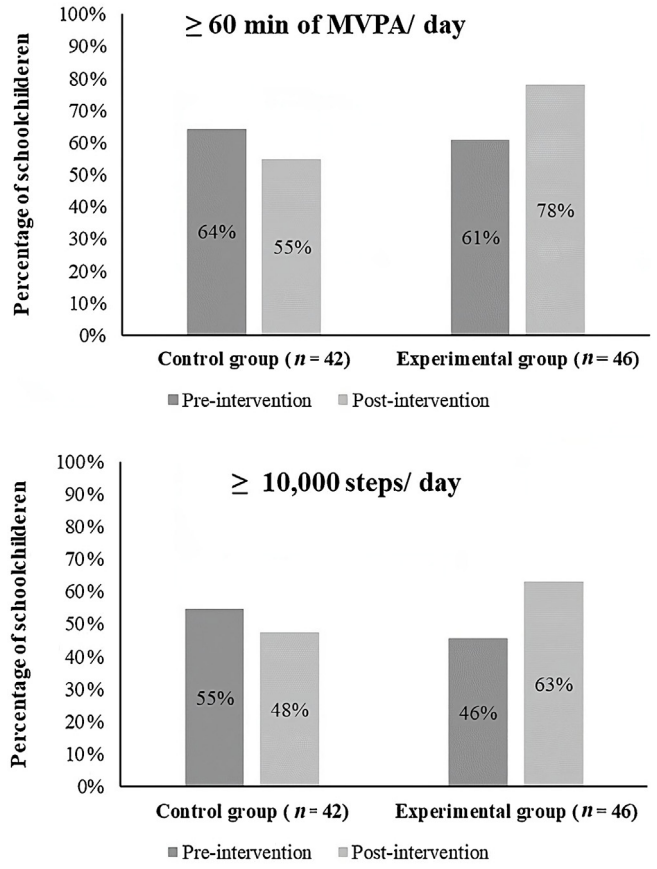

Figure 2. Effect of the gamified-based intermittent teaching unit on the percentage of schoolchildren achieving, on average, at least 60 minutes of moderate-to-vigorous physical activity (MVPA) per day and 10,000 steps per day across the week. Values are reported as percentage.

in the PE setting on schoolchildren's objective PA levels (Mazeas et al., 2022). However, to the best of our knowledge, this is the first study that analyzes the effect of a gamified intervention based on the use of behavior modification strategies on schoolchildren's objective habitual PA levels. These findings are similar to previous studies in the PE setting that have performed gamified interventions for promoting schoolchildren's PA (Garde et al., 2016, 2018). For example, Garde et al. (2016) examined the effect of a one-week gamified intervention based on the use of a mobile exergame on schoolchildren objective PA levels (i.e., steps per day and active minutes). These authors found that during the intervention week schoolchildren achieved higher levels of PA (i.e., steps per day and active minutes) compared to the control week in which no intervention was performed. Similarly, Garde et al. (2018) also examined the effect of a two-week gamified intervention based on the use of a mobile exergame on schoolchildren objective PA levels. These authors found that after the first week of the intervention schoolchildren achieved higher levels of PA, while after the second week and follow-up, no differences in PA levels were found. However, the gamification applied was based on a mobile exergame whose levels were quite limited. Therefore, according to these authors, when gamified elements disappear (e.g., new levels to achieve) together with the novelty effect, motivation toward PA may decrease and influence schoolchildren's PA practice. In this sense, motivational strategies like encouraging students to get involved in new challenges or using information and communication technologies for educational purposes could be used to satisfy schoolchildren's need of novelty (González-Cutre et al., 2021). For example, suggesting schoolchildren to maintain the daily PA levels achieved after the intervention and using applications specifically designed for schoolchildren to record and analyze their individual progress on their physical activity levels (González-Cutre et al., 2021). Additionally, with the aim of achieving higher effects on schoolchildren's PA levels, additional behavior modification strategies like activity wristbands, goal setting, and educational counseling should be included as part of the PA promotion programs (Casado-Robles et al., 2022b). Other studies that have performed gamified interventions to promote PA practice with adolescents and adults found that the application of this methodology together with other behavior modification strategies (e.g., wearables or goal-setting) were effective for improving PA levels (e.g., Corepal et al., 2019). Therefore, incorporating gamification combined with other behavior modification strategies seems to be an effective way to improve schoolchildren's PA levels. Regarding the magnitude of the effects of the intervention, previous studies that have applied gamification programs found higher effects on schoolchildren's daily steps and total PA (d = 0.93, 95% confidence interval 0.57-1.29) (Garde et al., 2016, 2018) than in the present study (d = 0.42). However, as it is has been mentioned previously, it should be highlighted that after the second week of the intervention, no changes in schoolchildren's PA levels were found compared to the baseline (Garde et al., 2018). In this sense, the short duration of the interventions (i.e., one-two weeks) together with the novelty effect could be the reasons of this effect difference. According to Neil-Sztramko et al. (2021) achieving health-enhancing PA levels, represent a behavior change that requires time.

Additionally, the gamified-based intermittent teaching unit using behavior modification strategies increased the percentage of EG schoolchildren that did at least an average of 60 minutes of MVPA per day (i.e., from 61% to 78%) or 10,000 steps per day

(i.e., from 46% to 63%) after the intervention according to Figure 2. Therefore, the gamified intervention applied positively contributed to enhance the accomplishment of PA recommendations in the study population (World Health Organization, 2020). Considering the high levels of physical inactivity among children (OECD/World Health Organization, 2023), this is another important outcome of the present study, since it means that after the intervention there is a higher percentage of schoolchildren that comply with the worldwide PA recommendation (World Health Organization, 2020). That is, it increased the percentage of physically active schoolchildren. Unfortunately, as far as we know, no previous studies performed in the PE setting have examined the percentage of schoolchildren that achieve this PA threshold after a gamified intervention based on behavior modification strategies (Casado-Robles et al., 2022b). Similarly, Galy et al. (2019) found that after applying a technology-supported educational program, the low-active students at the beginning of the program (i.e., those who fulfill the PA recommendation approximately 2.4 days/week), met this recommendation approximately 3.5 days/week at the end of the program. These results suggest that this kind of intervention based on gamified methodology combined with behavior modification strategies may be a precursor to schoolchildren's fulfillment of worldwide PA recommendations.

The main strength of the present study was that, to our knowledge, this is the first study that analyzes the effect of a gamified intervention based on the use of behavior modification strategies on schoolchildren's objective habitual PA levels. Additionally, PA was objectively measured through a research-grade accelerometer, which has shown excellent validity for assessing PA in schoolchildren (Romanzini et al., 2014; Trost et al., 2011). Finally, the development of the teaching unit (i.e., intervention program), distributing the learning time in short periods of only 15 minutes during the lessons instead of concentrated (i.e., entire lessons) is a novelty in the habitual PA promotion programs (Viciana & Mayorga-Vega, 2016). Nevertheless, this study also has some limitations that should be acknowledged. Firstly, the non-probabilistic and relatively small sample size, provides a lower generalization power. This limits the generalizability of the obtained outcomes to the particular studied population and context. However, due to human, time, and material resource restrictions, a probabilistic and larger sample could not be examined. Secondly, even though having initially recruited enough participants for adequate power and having not lost any of them during the development of the study, there was a decline in compliance in wearing the accelerometer and providing valid data. Nevertheless, the non-compliance rate values observed in this study seem typical for this kind of study (Howie & Straker, 2016). Finally, the weather conditions are a key aspect that can influence the assessments performed as part of school programs. However, it is an aspect that has a difficult solution because an intervention whose duration entails several weeks, will have pre-post assessments under different weather conditions in areas with marked seasons. Nevertheless, the use of a cluster-randomized controlled trial design with a CG allows authors to control that results are due to the intervention applied and not to possible external factors. Future research studies should include a probabilistic and larger sample, which would provide a higher generalization of the obtained outcomes. Additionally, it would be interesting to reproduce the present study including additional psycho-social support like school teachers or parents with the purpose of checking if better results on schoolchildren's accelerometer wear compliance are obtained. Moreover, it would also be interesting reproducing the present study including a follow-up assessment to check if the post-intervention results are maintained after a few months.

Conclusions

An intermittent teaching unit based on gamification and using behavior modification strategies in PE improved the MVPA of primary schoolchildren, as well as the percentage of students who achieved at least an average of 60 minutes of MVPA and 10,000 steps per day. Moreover, together with improving schoolchildren's PA levels, performing intermittent teaching units would allow PE teachers to develop other PE curricular objectives at the same time during the same lessons. Therefore, to cover these important objectives set by current legislation in most countries, it is proposed that PE teachers follow programs like the one proposed in this study in order to improve the situation of inactivity prevalence in schoolchildren. Teachers are the first step to find healthy changes through PE, and this intermittent teaching unit and its special distribution of the learning time along the semester seems to be an effective way to achieve this purpose.

CrediT authorship contribution statement

Santiago Guijarro-Romero: conceptualization, investigation, methodology, project administration, resources, roles/writing - original draft, writing- review & editing.

Daniel Mayorga-Vega: conceptualization, data curation, formal analysis, methodology, supervision, visualization, writing- original draft, writing - review & editing.

Carolina Casado-Robles: conceptualization, data curation, methodology, writing- review & editing.

Jesús Viciana: conceptualization, funding acquisition, investigation, methodology, visualization, writing - original draft, writing-review & editing.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.psicoe.2024.500156.

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