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School-based interventions to promote active commuting to school and quality of life in Spanish children and adolescents

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Dedicado a aquellos que estuvieron incondicionalmente y me ayudaron a crecer cada día.

"Serendipia": descubrimiento o un hallazgo afortunado, valioso e inesperado que se produce de manera accidental, casual, o cuando se está buscando una cosa distinta.

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Research Projects and funding

The present International Doctoral Thesis was carried out under the umbrella of two national projects:

1) PACO project (http://profith.ugr.es) was funded by:

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INTERNATIONAL DOCTORAL THESIS

Research Projects and funding

The objective of the present research projects is to promote healthy habits in physical activity in the educational context, thereby improving health and quality of life in the infant-juvenile stage. Both projects have received awards in competitive and prestigious national calls such as the *Nutrition, Physical Activity and Obesity Prevention* (NAOS) Strategy, which aim to give greater visibility to these programs, interventions, or other initiatives. Among their objectives is to contribute to the prevention of obesity by promoting the practice of regular physical activity within the framework of the NAOS Strategy. In addition, these projects have generated a high training capacity from the thesis degree to the doctoral thesis. The present Ph.D. student has had the opportunity to enjoy this training capacity, being the beneficiary of a research initiation grant in the PREVIENE project and researcher contracts in the PACO project.

Abbreviations

AC	Active commuting
ACS	Active commuting to/from school
ALPHA	Assessing Levels of Physical Activity and fitness
ANCOVA	One Way Analysis of Covariance
ANOVA	One Way Analysis of Variance
AVG	Active video game
BATACE	Barreras en el Transporte Activo al Centro Educativo
BMI	Body,Mass Index
CI	Confidence Interval
DAC	Desplazamiento Activo al Colegio
EPHPP	Evaluation of public health practice projects
GPS	Global positioning system
HRQoL	Health Related Quality of Life
ICC	Intra-class Correlation Coefficient
IPAQ	International Physical Activity Questionnaire
MVPA	Moderate-to-vigorous physical activity
OR	Odds Ratio
PA	Physical activity
PACO	Pedalea y Anda al COle
PREVIENE	Promoting Healthy Lifestyles for the School Environment
PRISMA	Systematic Reviews and Meta-Analyses
PE	Physical Education
SD	Standard Deviation
SES	Socioeconomic status
WHO	World Health Organization

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Abstract

Currently, a high percentage of the young population does not meet the recommendations for healthy physical activity. Increasing physical activity in children and young people could improve health-related physical fitness and quality of life in this population. The promotion of daily physical activity habits such as active commuting to school could be a potential alternative to increase physical activity levels in this population. Attractive and novel strategies should be explored to ensure the success of such interventions. Thus, new technologies such as mobile applications focusing on active video games and gamification could be successful tools for promoting the habits of physical activity in the young population.

Therefore, the purposes of the present Doctoral Thesis were to:

Study I. To analyse the trend of active commuting to school (ACS) in Spanish preschoolers (2013-2017).

Study II. To describe a systematic review protocol of school-based interventions for promoting physical activy in pre-schoolers, children, and adolescent students using games and gamification.

Study III. To conduct a systematic review on game-based interventions and gamification for the promotion of physical activity in school context.

Study IV. To design a mobile application based on active video games called "Mystic School" to promote ACS in Spanish adolescents

Study V. To implement and evaluate a school-based intervention integrated into physical education lessons to promote ACS using additionally in the leisure time the Mystic School application among adolescents. (14–15 years old).

Study VI. To analyse the association between quality of life, physical fitness and travel mode in Spanish primary school children.

These purposes were answered through studies, whose methods are:

Study I. Data were obtained from 5 studies conducted across Spain. The study sample comprised 4787 preschool children (4.59 ± 0.77 years old; 51.2% males). The overall changes in ACS were evaluated using multilevel logistic regression analysis.

Study II. This review protocol is registered in International prospective register of systematic reviews (CRD42019123521). Scientific databases include PubMed,Web of Science, SportDiscus, Cochrane Library, ERIC, and PsycINFO. A standardized procedure will e executed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol (PRISMA-P) checklist for conducting systematic review protocols and the PICOS (Population, Interventions, Comparators,

Outcomes, and Study design) tool to address an appropriate search strategy. Detailed information will be extracted, including a quantitative assessment using effect sizes to compare the interventions and a qualitative assessment using the Evaluation of Public Health Practice Projects tool.

Study III. A systematic literature review was conducted to explore games and gamification strategies. It was carried out up to January 2022 in scientific. The initial search yielded 2,105 references, of which 35 studies met the inclusion criteria a) performed in pre-schoolers and adolescents (non-university students), b) through implementation of a school-based intervention based on games and/or gamification and c) reported physical activity as a primary or secondary outcome. Detailed information from each study was extracted, and additional effectiveness assessments was performed. Both risk of bias and quality assessment were assessed according to each study design.

Study IV. A total of 68 students (14-15 years old) from Granada, Jaén and Toledo participated in the testing of the Mystic School application during two phases: phase 1 (n=14) for 2 weeks and phase 2 (n=54) for 1 month. Each phase included a presentation, a follow-up and focus group sessions, which were taken into account in the final design of the Mystic School mobile application. Qualitative analysis was carried out using NVivo software. The categories obtained after the analysis of the focus group information were design, failures, satisfaction and suggestions for improvement related to the Mystic School application.

Study V. A total of 62 students (14-15 years old) and 2 Physical Education teachers from Valencia and Almería participated in the implementation and evaluation an educative proposal (4 Physical Education sessions/one month) which integrate an active video game called Mystic School to promote ACS. After intervention the adolescents' and Physical Education teacher perceptions of Physical Education lessons and the use of Mystic School application were evaluated through focus group and personal interview respectively. The qualitative analysis was carried out through NVivo software.

Study VI. A cross-sectional analysis included 415 children aged 8.47 ± 0.36 years from 14 schools in Granada, Spain. Health-related quality of life scores were assessed using the KINDL-R questionnaire, children's physical fitness using the ALPHA battery, and commuting to and from school was assessed using the valid, reliable and feasible "Questionnaire on mode and frequency of travel to and from school".

The main results extracted from the studies were:

Study I. The rates of ACS in Spanish preschool children are around 52%, and the ACS rates have remained stable throughout the period studied (odds ratio from 0.40 to 0.58, all $p > 0.05$).

Study II. The protocol intends to present the specific methodology that will be used in a systematic review to identify and examine school-based intervention studies focused on game and/or gamification strategies to promote physical activity. The included studies will provide preliminary evidence regarding games or gamification as novel and attractive strategies to improve physical activity levels in the youth population in a school setting.

Study III. The systematic review identified 35 studies: 31 used games and 4 studies used the strategies' gamification. In games, "active video games" used the technology such as Xbox 360 or Nintendo Wii to promote physical activity through dance, sports or adventures games, and web-based game. As for gamification's strategies such as the creation of a narrative, challenging goals, incentives, reinforce positive behavior among with daily reward. The intervention duration predominated is 8-weeks. Moreover, the prevalent instruments to assess physical activity were accelerometer (37,1%) and questionnaires (20%). About Risk of bias assessment, all studies (RCTs) were rate as high risk of bias. And, the quality assessment a total of 25/35 (71,4%) studies were assessed as weak in the global rating. Thus, a total of 23/35 (65,7%) studies reported an increase in the physical activity using outcomes such us step counts and minutes and physical activity levels. In addition, only 8/35 (22,6%) studies incorporated the Cohen's effect and only 2 studies had a size large.

Study IV. In phase 1, adolescents mainly reported mistakes and improvements in relation to the design and functioning of the Mystic School application, such as that avatar movement, step numbers, and multiplayer function. These suggestions were included in the Mystic School application before phase 2. The results after phase 2 testing the Mystic School application were: the possibility of playing without an internet connexion, including more competitive options and prizes, and more difficult during the Mystic Schol application levels. In both phases, problems with the step number counting remained, however, adolescents considered that the Mystic School application was an original idea and fun application to promote physical activity.

Study V. The adolescents enjoyed the sessions during Physical Education lessons as they agreed that these were different activities from what they usually did. In addition, they commented that they would add more sessions and include more activities. Additionally, the active video game Mystic School included to increase physical activity through ACS resulting novelty and funny strategy for the students.

However, it requires much deeper improvements.

Study VI. Cardiorespiratory fitness was positively correlated with all dimensions of health-related quality of life in boys, whereas higher muscular strength (standing long jump) was positively correlated with the emotional wellbeing dimension in girls. In addition, boys who actively commute to school (walking) presented better cardiorespiratory fitness. Moreover, children who actively commuted to school presented better scores for the emotional wellbeing, family, and school dimensions, as well as total scores (both, $p < .05$) of health-related quality of life.

The main conclusions from the four studies were:

Study I. In preschool children, the current study obtained a promising result on ACS, showing pattern stability in the period examined, which is a positive result regarding the evidence of a decreasing trend among children and adolescents in many countries.

Study II. This systematic review protocol contributes to establishing future systematic reviews using games and gamification strategies in school settings in order to examine their effect on physical activity outcomes among youth. Additionally, an update and clarification on the different terms in the school context have been included.

Study III. Findings from the systematic review suggest that physical activity interventions-based on games/gamification can increase physical activity youth people, but additional studies are needed to confirm the effects. The AVGs are mainly applicationlicated to promote physical activity because it seems an attractive strategy in at short term. Nevertheless, including the family and parents' implication is needed as well as proportionating an attractive content.

Study IV. Adolescents found the Mystic School application was an attractive and innovative tool. The Mystic School application could be a useful tool for the Physical Education teacher to integrate content from this curriculum area related to the promotion of physical activity such as the ACS.

Study V. This study provided key information educative proposal to promote physical activity through ACS in Physical Education from an active perspective. Adolescents' students and Physical Education teachers found the educational proposal and the use of Mystic School as funny and interesting. However, the application must be improved.

Study VI. Health-related quality of life was positively correlated with cardiorespiratory fitness in boys (all dimensions), whereas muscular strength (standing long jump) was positively correlated with the emotional wellbeing dimension only in girls. Active

commuting to and from school was associated with higher levels of cardiorespiratory fitness, school dimension, and KINDL-R total score. Improving cardiorespiratory fitness might be especially useful to improve health-related quality of life in children, and vice versa.

Resumen

Actualmente, un alto porcentaje de la población joven no cumple las recomendaciones de actividad física saludable. El aumento de la actividad física en niños y adolescentes podría mejorar la aptitud física relacionada con la salud y la calidad de vida de esta población. La promoción de hábitos de actividad física diaria, como el desplazamiento activo al colegio, podría ser una alternativa potencial para aumentar los niveles de actividad física en esta población. Por lo tanto, se deben explorar estrategias atractivas y novedosas para asegurar el éxito de dichas intervenciones. Así, las nuevas tecnologías como las aplicaciones móviles centradas en los videojuegos activos y la gamificación podrían ser herramientas exitosas para promover los hábitos de actividad física en la población joven.

Por ello, los propósitos de la presente Tesis Doctoral fueron:

Estudio I. Analizar la tendencia de los desplazamientos activos al colegio en niños preescolares españoles (2013-2017).

Estudio II. Describir un protocolo de revisión sistemática de las intervenciones escolares para la promoción de la actividad física en preescolares, niños y adolescentes utilizando juegos y gamificación.

Estudio III. Realizar una revisión sistemática sobre las intervenciones basadas en juegos y gamificación para la promoción de la actividad física en el contexto escolar.

Estudio IV. Diseñar una aplicación móvil Mystic School para promover el desplazamiento activo al colegio en adolescentes españoles: el estudio PACO.

Estudio V. Implementar y evaluar una intervención escolar integrada en las clases de Educación Física para promover el desplazamiento activo al colegio utilizando adicionalmente en el tiempo libre la aplicación Mystic School entre adolescentes (14-15 años).

Estudio VI. Analizar la asociación entre la calidad de vida, la condición física y el modo de desplazamiento al colegio en niños españoles de primaria.

Estos propósitos fueron respondidos a través de estudios, cuyos métodos son:

Estudio I. Los datos se obtuvieron de 5 estudios realizados en España. La muestra del estudio estaba formada por 4787 niños en edad preescolar (4,59 ± 0,77 años; 51,2% varones). Los cambios globales en los desplazamientos activos al colegio se evaluaron mediante un análisis de regresión logística multinivel.

Estudio II. Este protocolo de revisión está registrado en el registro prospectivo internacional de revisiones sistemáticas (CRD42019123521). Las bases de datos científicas incluyen PubMed, Web of Science, SportDiscus, Cochrane Library, ERIC y PsycINFO. Se ejecutará un procedimiento estandarizado siguiendo la lista de verificación de los Elementos de Información Preferidos para Revisiones Sistemáticas y Meta-Análisis (PRISMA-P) para la realización de protocolos de revisiones sistemáticas y la herramienta PICOS (Población, Intervenciones, Comparadores, Resultados y Diseño del Estudio) para abordar una estrategia de búsqueda adecuada. Se extraerá información detallada, incluyendo una evaluación cuantitativa utilizando los tamaños del efecto para comparar las intervenciones y una evaluación cualitativa utilizando la herramienta de Evaluación de Proyectos de Práctica de Salud Pública.

Estudio III. Se realizó una revisión sistemática de la literatura para explorar los juegos y las estrategias de gamificación. Se llevó a cabo hasta enero de 2022. La búsqueda inicial encontró 2.105 estudios. Un total de 35 estudios cumplieron con los criterios de inclusión a) realizados en preescolares y adolescentes (estudiantes no universitarios), b) mediante la implementación de una intervención escolar basada en juegos y/o gamificación y c) reportados como resultado primario o secundario. Se extrajo información detallada de cada estudio y se realizaron evaluaciones adicionales de efectividad. Se evaluó tanto el riesgo de sesgo como la evaluación de la calidad según el diseño de cada estudio.

Estudio IV. Un total de 68 estudiantes (14-15 años) de Granada, Jaén y Toledo participaron en el testeo de la aplicación Mystic School durante dos fases: la fase 1 (n=14) durante 2 semanas y la fase 2 (n=54) durante 1 mes. Cada fase incluyó una presentación, un seguimiento y sesiones de grupos focales, que se tuvieron en cuenta en el diseño final de la aplicación Mystic School. El análisis cualitativo se llevó a cabo mediante el software NVivo. Las categorías obtenidas tras el análisis de la información del grupo focal fueron diseño, fallos, satisfacción y sugerencias de mejora relacionadas con la aplicación Mystic School.

Estudio V. Un total de 62 estudiantes (14-15 años) y 2 profesores de Educación Física de Valencia y Almería participaron en la implementación y evaluación de una propuesta educativa (4 sesiones de Educación Física/un mes) que integraba un

videojuego activo llamado Mystic School para promover el desplazamiento activo al colegio. Tras la intervención, se evaluó la percepción de los adolescentes y de los profesores de Educación Física sobre las clases y el uso de la aplicación Mystic School mediante un grupo focal y una entrevista personal, respectivamente.

Estudio VI. Un análisis transversal incluyó a 415 niños de 8,47 ± 0,36 años de 14 colegios de Granada, España. Se evaluaron las puntuaciones de CVRS mediante el cuestionario KINDL-R, la aptitud física de los niños mediante la batería ALPHA, y los desplazamientos hacia y desde el colegio mediante el "Cuestionario sobre el modo y la frecuencia de los desplazamientos hacia y desde el colegio", válido, fiable y viable.

Los principales resultados extraídos de los estudios fueron:

Estudio I. Las tasas de desplazamiento activo al colegio en los niños preescolares españoles se sitúan en torno al 52%, y las tasas de desplazamiento activo al colegio se han mantenido estables a lo largo del periodo estudiado (odds ratio de 0,40 a 0,58, todas p > 0,05).

Estudio II. El protocolo pretende presentar la metodología específica que se utilizará en una revisión sistemática para identificar y examinar los estudios de intervención escolar centrados en estrategias de juego y/o gamificación para promover la actividad física. Los estudios incluidos proporcionarán pruebas preliminares sobre los juegos o la gamificación como estrategias novedosas y atractivas para mejorar los niveles de actividad física en la población juvenil en un entorno escolar.

Estudio III. Esta revisión identificó 35 estudios: 31 utilizaron juegos y 4 estudios utilizaron la gamificación de las estrategias. En cuanto a los juegos, los "videojuegos activos" utilizaron la tecnología, como la Xbox 360 o la Nintendo Wii, para promover la actividad física a través de la danza, los deportes o los juegos de aventuras, y el juego en línea. En cuanto a las estrategias de gamificación como la creación de una narrativa, objetivos desafiantes, incentivos, reforzar el comportamiento positivo entre con recompensa diaria. La duración de la intervención predominante es de 8 semanas. Además, los instrumentos predominantes para evaluar la actividad física fueron el acelerómetro en 13/35 (37,1%) estudios y los cuestionarios en 7/35 (20%) estudios. En cuanto a la evaluación del riesgo de sesgo, todos los estudios (ensayos controlados aleatorios) se calificaron de alto riesgo de sesgo. En cuanto a la evaluación de la calidad, un total de 25/35 (71,4%) estudios fueron evaluados como débiles en la calificación global. Un total de 23/35 (65,7%) estudios informaron de un aumento de la actividad física utilizando resultados como el recuento de pasos y minutos y los niveles de actividad física. Además, sólo 8/35 (22,6%) estudios incorporaron el efecto

de Cohen y sólo 2 estudios tenían un tamaño grande.

Estudio IV. En la fase 1, los adolescentes comunicaron principalmente errores y mejoras en relación con el diseño y el funcionamiento de la aplicación Mystic School, como que el movimiento del avatar, el número de pasos y la función multijugador. Estas sugerencias se incluyeron en la aplicación Mystic School antes de la fase 2. Los resultados tras la fase 2 de prueba de la aplicación Mystic School fueron: la posibilidad de jugar sin conexión a Internet, la inclusión de más opciones competitivas y premios, y una mayor dificultad durante los niveles de la aplicación Mystic School. En ambas fases, se mantuvieron los problemas con el conteo de números de pasos, sin embargo, los adolescentes consideraron que la aplicación Mystic School era una idea original y una aplicación divertida para promover la actividad física.

Estudio V. Los adolescentes disfrutaron de las sesiones durante las clases de Educación Física, ya que coincidieron en que se trataba de actividades diferentes a las que realizaban habitualmente. Además, comentaron que añadirían más sesiones e incluirían más actividades. En la misma línea, el videojuego activo Mystic School incluido para aumentar la actividad física a través del desplazamiento activo a la escuela resultó una estrategia novedosa para los estudiantes. Sin embargo, requiere mejoras mucho más profundas.

Estudio VI. La aptitud cardiorrespiratoria se correlacionó positivamente con todas las dimensiones de la calidad de vida relacionada con la salud en los chicos, mientras que una mayor fuerza muscular (salto de longitud de pie) se correlacionó positivamente con la dimensión de bienestar emocional en las chicas. Además, los niños que se desplazaban activamente al colegio (caminando) presentaban una mejor aptitud cardiorrespiratoria. Además, los niños que se desplazaban activamente al colegio (caminando) presentaban mejores puntuaciones en las dimensiones de bienestar emocional, familia y colegio, así como en las puntuaciones totales (ambas, $p < 0,05$) de la calidad de vida relacionada con la salud.

Las principales conclusiones de los cuatro estudios fueron:

Estudio I. En los niños preescolares, el presente estudio obtuvo un resultado prometedor sobre los desplazamientos activos a la escuela, mostrando una estabilidad del patrón en el período examinado, lo cual es un resultado positivo en relación con la evidencia de una tendencia a la baja entre los niños y adolescentes de muchos países.

Estudio II. Este protocolo de revisión sistemática contribuye a establecer futuras

revisiones sistemáticas que utilicen juegos y estrategias de gamificación en entornos escolares para examinar su efecto en los resultados de la actividad física entre los jóvenes. Además, se ha incluido una actualización y aclaración sobre los diferentes términos en el contexto escolar.

Estudio III. Los resultados de la revisión sistemática sugieren que las intervenciones de actividad física basadas en juegos/gamificación pueden aumentar la actividad física de los jóvenes, pero se necesitan estudios adicionales para confirmar los efectos. Los videojuegos activos se aplican principalmente para promover la actividad física porque parece una estrategia atractiva a corto plazo. Sin embargo, es necesario incluir a la familia y la implicación de los padres, así como proporcionar un contenido atractivo.

Estudio IV. Los adolescentes consideran que la aplicación Mystic School es una herramienta atractiva e innovadora. La aplicación Mystic School podría ser una herramienta útil para que el profesor de Educación Física integre contenidos de esta área curricular relacionados con la promoción de la actividad física como el desplazamiento activo al colegio.

Estudio V. Este estudio proporcionó información clave propuesta educativa para promover la actividad física a través del desplazamiento activo a la escuela en la Educación Física desde una perspectiva activa. Los alumnos adolescentes y los profesores de Educación Física consideraron interesante la propuesta educativa y el uso de Mystic School. Sin embargo, la aplicación móvil debe ser mejorada.

Estudio VI. La calidad de vida relacionado con la salud se correlacionó positivamente con la aptitud cardiorrespiratoria en los chicos (todas las dimensiones), mientras que la fuerza muscular (salto de longitud de pie) se correlacionó positivamente con la dimensión de bienestar emocional sólo en las chicas. Los desplazamientos activos hacia y desde el colegio se asociaron con niveles más altos de aptitud cardiorrespiratoria, dimensión escolar y puntuación total del KINDL-R. La mejora de la aptitud cardiorrespiratoria podría ser especialmente útil para mejorar la calidad de vida relacionada con la salud en los niños, y viceversa.

INTRODUCTION

INTRODUCTION

Physical activity and health in children and adolescents.

Physical activity (PA) is defined as any activity of the body with the involvement of skeletal muscle that results in energy expenditure (Caspersen, Powell, & Christenson, 1985). Industrialization and increasing technological developments in society have changed lifestyles toward a more sedentary model that has reduced daily PA levels, negatively contributing to health. Consequently, physical inactivity has been recognized as a primary risk factor for global mortality and morbidity (WHO, 2020). Specifically in Spain, the prevalence of overweight and obesity in childhood is more than 30% (Martínez-Vizcaíno et al., 2012; Miqueleiz et al., 2014). Sedentary lifestyles is strongly associated with the growth in overweight and obesity, which contributes to the development of several diseases from early life to adulthood (Park, Moon, Kim, Kong, & Oh, 2020). Current levels of physical inactivity stand out as a global pandemic (Kohl et al., 2012). Therefore, international health organizations have been working for a decade on the elaboration and promotion of PA guidelines. However, nowadays, four in five adolescents are insufficiently physically active globally (Guthold, Stevens, Riley, & Bull, 2020), with no comparable global PA data for children in the preschool stage (WHO, 2020). The scientific evidence supports the theory that daily PA is positively associated with multiple health effects from an early age. Concretely, the PA practice in preschool children (i.e., children under 6 years old) has been positively associated with physical, psychological, social, and cognitive benefits (Carson et al., 2017; Kuzik et al., 2017; Marcus et al., 2000; Penedo & Dahn, 2005). Specifically, regular PA in preschool children prevents obesity (Jiménez-Pavón, Kelly, & Reilly, 2010), helps the development of motor skills, increases psychosocial health, and improves cardiometabolic health indicators (Timmons et al., 2012). In addition, early childhood development is an important determinant for long-term health outcomes in adulthood (Saigal et al., 2005). PA practice is positively associated with a good level of physical fitness in young people (Fang et al., 2017). However, a very large number of studies has shown that the physical fitness of pre-school children is declining at an alarming rate (Janssen & LeBlanc, 2010; Timmons et al., 2012). This could be due to the fact that around 80% of European children (<6 years) have a low prevalence of PA during childhood (Kovács et al., 2014). Moreover, Hnatiuk et al. (Hnatiuk, Salmon, Hinkley, Okely, & Trost, 2014) reported that there is considerable variation in the estimated prevalence of PA in preschool children (2-5 years). This sample showed a sedentary time ranging from 34% to 94% and only a prevalence of MVPA that ranged from 2 to 40%. Thus, strategies to promote

PA in the pre-school population are needed. However, there are no uniform detailed guidelines for PA recommendations at the preschool stage (Skouteris et al., 2012; Venetsanou, Kambas, & Giannakidou, 2015). Until very recently, PA recommendations have been established only for three population-age groups (5–17, 18–64, and over 65 years), and they did not include global recommendations for children under the age of five years. The early childhood education stage (< 6 years old) is considered one of the most important periods for learning habits through routines, thus serving as an opportunity to establish healthy lifestyles based on PA behaviours (Hodges, Smith, Tidwell, & Berry, 2013). For this reason, recently, the PA guidelines for preschool children have been updated in several countries (Draper Ce Fau - Tomaz et al., 2020; Guerra et al., 2020; Tremblay et al., 2017). Moreover, the WHO (2020) published specific guidelines on PA, sedentary behaviour, and sleep for children under 5 years of age. In these recommended guidelines the pattern of overall 24-hour activity is suggested for children < 5 years of age to meet daily PA time recommendations. Additionally, recommendations for reducing sedentary time, especially sedentary screen time, and improving healthy sleep habits have been included. Regarding PA recommendations, in brief, children in the preschool stage (2 to 5 years old) need to spend at least 180 minutes in a variety of physical activities at any intensity, including moderate to vigorous-intensity physical activity, spread throughout the day; more is better.

However, PA recommendations are much lower in country-specific recommendations (Gutierrez-Hervas, Cortés-Castell, Juste-Ruíz, & Rizo-Baeza, 2020; Sigmundová et al., 2016; Tinner et al., 2019). As for the young population (5 to 18 years old), several studies support the confirmation that PA, especially with a moderate to vigorous intensity (greater benefits), is associated with numerous health benefits in school-aged children and youth and with achievement of substantial health benefits (Janssen & LeBlanc, 2010). Many health benefits in adolescents are concretely related to PA such as a decrease in cardiovascular risks (Andersen et al., 2006) and mental health issues (Rodriguez-Ayllon et al., 2019), with increases in fitness, cognition, academic achievement (Donnelly et al., 2016), and social health (Janssen & LeBlanc, 2010). However, despite evidence-based PA health benefits, more than 70-80% of children and adolescents do not meet the PA recommendations for health, and four out of five adolescents do not meet PA guidelines (Guthold et al., 2020). Spain is one of the countries with the highest prevalence of physical inactivity and sedentary behaviours, with less than 20% of children and adolescents meeting international recommendations (Guthold et al., 2020). Moreover, the systematic reviews developed by Sallis, Prochaska, & Taylor (2000) and Pate, Pfeiffer, Trost, Ziegler, & Dowda (2004) found that this lack of PA

practice affects girls to a higher degree than boys. The WHO (2020) physical activity guidelines recommendations have recently been updated. The guidelines included recommendations for children and adolescents (5 to 17 years of age) (Bull et al., 2020). For example, one update states that "regular PA during childhood and the youth stage improves physical fitness (cardiorespiratory and muscular fitness), cardiometabolic health (blood pressure, dyslipidaemia, glucose, and insulin resistance), bone health, cognitive outcomes (academic performance, executive function), mental health (reduced symptoms of depression), and body composition (reduced adiposity)". To confer these health benefits, the WHO strongly recommends (based on moderate and certainty evidence), that children and adolescents accomplish at least an average of 60 minutes per day of moderate to vigorous-intensity (MVPA), mostly aerobic physical activity. Additionally, vigorous-intensity aerobic activities (VPA), as well as those that strengthen muscle and bone, should be performed at least 3 days a week. To reach these PA recommendations, children and adolescents should undertake PA in four different domains according to the socioecological model for the domains of active living (Sallis et al., 2006) as part of recreation and leisure time (play, games, sports, or planned exercise), at the school (Physical Education and/or active recess), during transportation (wheeling, walking, and cycling), and in their households (helping in active house tasks).

Thus, the guidelines provide an opportunity to integrate all behaviours along the movement continuum (Tremblay et al., 2017). Accordingly, recent advancements in the field suggest that recommendations and new interventions to promote PA should focus on the key determinants of healthy lifestyle behaviours rather than simply on health outcomes. Promoting the enjoyment gained and the need to address multiple lifestyle behaviours is a good first step toward promoting healthy living (Warburton & Bredin, 2017). In this sense, getting children and adolescents to meet the recommended levels of PA will generate more active and healthy adults (Telama et al., 2014).

Health-related quality of life in children and adolescents.

Health-related quality of life (HRQoL) refers to the subjective perception of an individual's well-being in different physical, mental and social dimensions of health (Ayers et al., 2007). Previously, HRQoL has been applied in populations with diseases or pathologies (Busutil et al., 2017; Hand, 2016; Kraai, Vermeulen, Hillege, Jaarsma, & Hoekstra, 2018; Trikkalinou, Papazafiropoulou, & Melidonis, 2017). However, in the last few years, the study of HRQoL has become more and more common because it has been confirmed as a major public health reference indicator in different age ranges, contributing to the early

detection of some health problems (Chai et al., 2010). HRQoL is an interesting tool to promote healthy behaviour and thus, to obtain good habits that generate a healthy growth from childhood such as the reduction of depression and improvement of self-esteem (Ortega, Ruiz, Castillo, & Sjöström, 2008). Conversely, if one does not know about HRQoL, one cannot take action to help children with low HRQoL, and as a consequence, the child is less likely to become a healthy adult. (Riley et al., 2006). Moreover, a negative HRQoL outcome can lead to health problems such as obesity (Halasi et al., 2018) and perception of body (Petracci & Cavrini, 2013), among other consequences (Duchesne et al., 2017; Lin, 2019; W. Liu et al., 2016).

The promotion of healthy habits is necessary, such as the regular practice of PA. This behaviour seems to be positively associated with better levels of HRQoL in children and adolescents (Marker, Steele, & Noser, 2018). Specifically, better HRQoL is associated with higher MVPA levels in young people (Wafa et al., 2016) and, consequently, contributes to a lower risk of mortality and disease (Dinu, Pagliai, Macchi, & Sofi, 2019). Previously, a study analysed the relationship between HRQoL and physical fitness in children and showed that school and physical well-being dimensions of HRQoL were associated with higher levels of cardiorespiratory fitness (CRF) and muscle strength in children. (Redondo-Tebar et al., 2019).

Currently, a wide variety of interventions has been applied to improve quality of life through the promotion of PA in young people. To date, several systematic reviews have demonstrated the relationship between PA, sedentary behaviour and health-related quality of life in the general healthy population of children and adolescents (Liu, Wu, & Ming, 2015; Marker et al., 2018; Wu et al., 2017). Therefore, studies assessing HRQoL in this population and after exercise or PA interventions are needed to quantify aspects to be taken into account such as the type, frequency, duration and intensity of PA to intervene in the individual and positively modify HRQoL. Furthermore, with this information, intervention strategies could be implemented in the educational context to improve HRQoL through PA in order to take advantage of the educational environment as an opportunity for the acquisition of healthy habits from an early age.

Health-related physical fitness in children and adolescents

Physical Fitness (PF) refers to a group of measurable characteristics related to health and physical skills, including cardiorespiratory fitness (CRF), muscular strength and endurance, body composition, flexibility, balance, agility, coordination, reaction time, and power (Caspersen, 1985). Previous studies have demonstrated the benefits of PF in children, adolescents and adults (Kvaavik, 2009; Zagout, 2016), such as the association between physical fitness, academic performance (Chomitz, 2009;

Bass, 2013; Coe, 2013; Santana, 2017; Van Dusen, 2011; McLoughlin, 2020) and mental functioning (Donnelly, 2016). In children and adolescents, favourable associations have been reported linking CRF and muscular fitness (MSF) to a low risk of cardiometabolic diseases, low adiposity levels, optimal mental health and cognition, as well as good bone health (Ortega, 2011; Ruiz, 2009; Smith, 2014). As a measure of perceived health, HRQoL is highly related to physical and psychosocial health outcomes that are positively impacted by physical activity. An important factor that contributes to a high awareness of HRQoL is physical fitness. A high level of physical fitness is linked to various health benefits such as reduced depression, mood stability, or self-esteem, among others (Ortega, 2008). There may even be indications that it influences cognitive performance (Ruiz, 2010). Physical and mental well-being is related to better cardiorespiratory fitness and muscular fitness among school-aged children (Gu, 2016). Moreover, some dimensions of HRQoL such as physical well-being and performance in school were associated with higher cardiorespiratory fitness and levels of muscular strength in children (Redondo-Tebar, 2019). Thus, it seems that health-related physical fitness is a good health marker shown to be predictive of cardiovascular disease, morbidities, and mortality (Hainer, 2009). It is important to consider this outcome in evaluating health-care interventions in youth (Ravens-Sieberer, 2006; Solans, 2008). If more impact is desired in school-based intervention programs, the focus of the program should be PA and, as far as possible, physical activities should be implemented directly. To prevent obesity and promote PA and PF, the characteristics of more effective programs should be examined in detail, and appropriate intervention programs should be designed. Such programs should be multicomponent and longitudinal to foster children's lifelong PA habits (Yuksel, 2020).

Effective school-based intervention for promoting physical activity

As has been described above, the school context offers several opportunities to promote healthy habits from early life. Accordingly, many school-based intervention studies promoting PA and a healthy lifestyle have been performed in recent decades. The most is known about upper-elementary-aged students, including the first multicenter randomized trial to report significant results for increasing MVPA in Physical Education and increasing vigorous PA outside of school (Stone, McKenzie, Welk, & Booth, 1998). In accordance, the school has proven to be an ideal setting for the development of these interventions to promote PA (Larouche et al.,2018; Pang, Kubacki, & Rundle-Thiele, 2017; Villa-Gonzalez, Barranco-Ruiz, Evenson, & Chillon, 2018) for two main reasons: (a) the age of the students is key for changing habits, and young people with high levels of PA are more likely to be active

adults (Telama et al., 2014); and (b) schools have access to a wide range of the population (Anderson et al., 2016). Consistent with this fact, the International Society for Physical Activity and Health (2020) has proposed a total of eight investments to ensure the health of young people through the practice of PA. These investments can support the achievement of the global target for all countries to reduce physical inactivity by 10% by 2025 and 15% by 2030. The "whole-of-school programme" is one of the essential proposals to invest in intervention programmes for the promotion of PA in children and young people. So far, it continues to be shown that school-based interventions can have important potential in the health promotion of children in terms of obesity, PA level and PF. There is increasing evidence for the effectiveness of individual components of Physical Education programmes (Lonsdale et al., 2013) and active classrooms (Emma Norris, van Steen, Direito, & Stamatakis, 2020).

However, the quality, duration, and priority of PA intervention in comprehensive school-based programs and teacher capacity are some of the most important factors to improve for preventing obesity and promoting PA and PF (Yuksel, Şahin, Maksimovic, Drid, & Bianco, 2020). Therefore, successful and attractive interventions are necessary to encourage increased levels of PA during childhood and adolescence.

Games and Gamification

There is a wide variety of definitions for the term *game*. As defined by Huizinga (1938) it is "a free, playful and essential activity for the human that is generally carried out for enjoyment or entertainment". This term is a basic behaviour from a young age, and play has been found to be an increasingly common method of health promotion among children. There is evidence that games can be a tool for health promotion (Read & Shortell, 2011).

In the educational field, when teachers design or adapt a game (especially a board game) for promoting learning in students, they are using a methodology called Game-Based Learning (GBL)—that is, "Serious Games or applied games"(Djaouti, Alvarez, & Jessel, 2011). Another is the *exergame*, also known as an *active videogame* (AVG). It requires PA in contrast to passive games (Lieberman, 2006) (e.g., conventional handheld games). To homogenize the term, *AVG* will be used to refer to both AVG and exergames. In addition, AVG refers to the use of technology to capture the body movement necessary to advance the activity (LeBlanc et al., 2013). Serious games and AVGs have been implemented in the educational context for the promotion of PA in both children and adolescents (Bossen et al., 2020; Merino-Campos & del Castillo Fernández, 2016; Norris, Hamer, & Stamatakis, 2016).

On the other hand, the concept of *gamification* is often confused with GBL.

Gamification is understood as the use of game elements in non-game contexts. (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011; Fleming et al., 2017). Gamification uses game dynamics and mechanics to increase motivation through positive experiences. In this way, both engagement and involvement are increased and desired behaviours can be promoted. Essential features of this term that should be taken into account are, for example: the narrative that is carried out, the story that is created for which the whole proposal is articulated, the continuous feedback to the learners and the decision making processes to address different challenges. Moreover, compared to other strategies, gamification requires longer implementation times, as it is mainly oriented toward ambitious objectives that require a process of adaptation, such as the development of certain competencies, habits or values in the learner (Pérez-López & Navarro Mateos, 2019). In contrast, GBL takes place only in specific periods of time because it usually focuses on the game designed with the primary objective of learning rather than entertainment (Noemí & Máximo, 2014). Gamification has been a trending topic in different domains of knowledge such as health promotion (Edwards et al., 2016; Johnson et al., 2016; Sardi, & Fernández-Alemán, 2017), online programs (Looyestyn et al., 2017), internet intervention (Floryan, Ritterband, & Chow, 2019) or education (Attali & Arieli-Attali, 2015; Beemer,. Ajibewa, DellaVecchia, &Hasson, 2019; Coombes & Jones, 2016; Mora-Gonzalez, Perez-Lopez, & Delgado-Fernandez, 2020; Mora-Gonzalez, Perez-Lopez, Esteban-Cornejo, & Delgado-Fernandez, 2020; Pérez-López, Tercedor Sánchez, & Delgado-Fernández, 2015; Uechi, Tan, & Honda, 2018).

It is therefore important to understand that all these terms defined above are not synonymous, and that they describe different approaches in the educational context. Therefore, they should not be confused as they have different procedures and purposes. (Deterding, Khaled, Nacke, & Dixon, 2011; Prince, 2013). Thus, games and/or gamification seem to be a promising area for educational and health research (Argiles, Jurado, & Junyent, 2020; Hamari, Koivisto, & Sarsa, 2014), and they are starting to be used in educational contexts for different purposes, such as promoting PA. However, the scientific literature lacks studies on how games and/or gamification-based interventions are implemented in the school setting to increase PA, and their effects on the young population are unknown. Thus, promoting PA habits in young people such as active commuting to school through new and attractive strategies based on the implementation of games and/or gamification could be interesting options to test.

What is active commuting to school?

According to Sallis al. (2006), one of the four active living domains in PA practice is active transport. Increasing the time of this domain during the day would be relevant to

reach an active living style. In this sense, one active transport opportunity for young people is active commuting to and from school (ACS). ACS is defined as the use of physically active modes of transportation such as walking, cycling, skateboarding, or other non-motorised modes of transport that imply energy expenditure for commuting to and/or from school (Ruiz-Hermosa et al., 2019). This daily behaviour has several benefits, but one of the main benefits is the contribution to increasing total PA (Chillón et al., 2017). ACS is a daily behaviour that could contribute to up to 10 possible moments during the week where young people could perform PA. During a habitual school week, young students could perform a total of 10 active trips—five weekly trips from home to school and five weekly trips from school to home or other locations. In fact, in a systematic review and meta-analysis by Martin, Boyle, Corlett, Kelly, & Reilly (2016), concluded that walking to or from school makes a significant contribution to individual schoolday MVPA for active commuters with a total of seven minutes per day (23%) for primary school students and 13 minutes per day (36%) for high school students. Moreover, ACS also facilitates greater PA outside the school trip, as well as positive associations between school transport and PA in the afternoon and evening (Alexander et al., 2005; Chillón et al., 2011; Loucaides & Jago, 2008). Additionally, ACS should contribute to other individual and social benefits.

Benefits associated to active commuting to school.

ACS is a potential opportunity to accumulate daily PA levels for health (Chillon et al., 2010), and reach several environmental goals (Huertas-Delgado et al., 2017), as well as other collateral benefits related to physical fitness, body composition, cardiometabolic health, and psychological and psychosocial health, as summarized below. In addition, ACS could improve mental well-being (Janssen & LeBlanc, 2010; Larouche, Saunders, Faulkner, Colley, & Tremblay, 2014; Lubans, Boreham, Kelly, & Foster, 2011) and more favourable body composition (Landsberg et al., 2008; Mendoza et al., 2011), whereas other studies have found no association (Cooper, Page, Foster, & Qahwaji, 2003; Kong et al., 2010; Saksvig et al., 2012). Children and adolescents who choose an active mode are more physically active than those who travel in motorised vehicles (Larouche et al., 2014). The use of active modes of commuting to and from school could improve several individual outcomes such as physical fitness, well-being (Larouche, Mammen, Rowe, & Faulkner, 2018), cardiorespiratory capacity (Saucedo-Araujo et al., 2021; Villa-González, Ruiz, & Chillón, 2015), and psychosocial variables (Herrador-Colmenero, Villa-Gonzalez, & Chillon, 2017). In addition, research has demonstrated that ACS improves children's and adolescents' autonomy and independence (i.e., better psychological health and self-efficacy) (Herrador-

Colmenero et al., 2017). Accordingly, a cross-sectional study of secondary education showed that adolescents who spent more than 15 minutes daily on active commuting had higher levels of subjective happiness and psychological well-being (Ruiz-Ariza, Torre-Cruz, Redecillas-Peiró, & Martínez-López, 2015). Data from previous studies confirm that regular cycling to school is associated with higher levels of CRF in young people (Cooper et al., 2008; Chillón et al., 2010; Jurak et al., 2021) and were almost five times more likely to be fit than those who cycled passively (Cooper et al., 2006). On the other hand, Henrique-Nieto et al. (2020) conducted a systematic review focusing on children and adolescents, where seven studies showed a positive association between PF levels and active commuting by bicycle. However, this systematic review showed inconsistency related to benefits in health-related physical fitness.

Trends and prevalence of active commuting to school

Although scientific evidence points to various benefits of ACS as described in the previous section, it would be interesting to know what prevalence and what patterns of ACS there are in the young population, in order to implement effective interventions.

According to Pabayo, Gauvin, & Barnett (2011) the prevalence of students using ACS increases from the age of 6 and decreases throughout adolescence. The ACS rates among preschool children (5 years old) were less than 40% in New Zealand (Hinckson, Garrett, & Duncan, 2011), whereas 28% of preschool children commuted actively from home to school in Brazil (Melo et al., 2013). In Europe, the IDEFICS study (Santaliestra-Pasías et al., 2014) analysed ACS in preschool children (2 to 6 years old) in 8 countries between September 2007 and June 2008. Countries such as Italy, Estonia, Belgium, and Cyprus reported less than 20%. On the other hand, higher percentages were reported—around 35% in Germany—and Sweden and Spain reported an ACS rate of 54%. In Spain, a MOVI-KIDS study reported in 2013 that almost 50% of pre-school children walked to school (Ruiz-Hermosa & Martínez-Vizcaíno, 2019), and Terrón-Perez et al. showed that almost 70% of Spanish preschool children presented ACS behaviours between 2015 and 2016 (Terrón-Pérez, Molina-García, Martínez-Bello, & Queralt, 2018). However, evidence for ACS trends in preschool children around the world is deficient. The MoMo Study developed in Germany (Reimers et al., 2020) analysed trends in ACS up to adolescence (ages 4-17) between 2003 and 2017. It was observed that in boys as in girls aged 4-5, the rate of ACS decreased significantly from 2003 to 2017—boys from 85% to 78% and girls from 84% to 77%. However, additional evidence exists for ACS trends in children and adolescents. Health Behaviour in School-Aged Children (Haug et al., 2021) analysed data from 88,212 students aged 11, 13, and 15 years and indicated that ACS has decreased in the Czech Republic, Norway, Scotland, and Wales. In general, the trends

in active commuting appear to have remained the same or decreased over the last decades. In a recent trend study in Spain (Gálvez-Fernández et al., 2021), the rates of ACS in Spanish children and adolescents were analyzed. It appears that ACS has not changed significantly during the period of 2010-2017, except for a sporadic increase in the rate of ACS in adolescents in 2012 to 2013. Nevertheless, for the time being, there are no studies that analyse the trend of ACS in Spanish preschoolers. Therefore, interventions which encourage children and adolescents to increase their ACS behaviour are necessary to promoting more active and healthier living (Dinu et al., 2019; Henriques-Neto et al., 2020; Ruiz-Hermosa et al., 2019).

Active commuting interventions focus on children and adolescents.

It is important to include school-based interventions for promoting PA from an early age (O'Dwyer et al., 2013; Pate, Brown, Saunders, Pfeiffer, & Dowda, 2013; Pate et al., 2016; Sääkslahti et al., 2004). Effective intervention programs could generate considerable cost savings to the public health service (Abu-Omar et al., 2017). In this sense, ACS is a novel school based-intervention strategy considered to be a low-cost solution with high feasibility for increasing daily PA (Berglund, Lytsy, & Westerling, 2016; Owen, Pennington, Fischer, & Jeong, 2018).

According to a systematic review (Larouche et al., 2018), the population where most ACS interventions have taken place has been in primary schools, and the least in secondary schools. In addition, the main types of interventions were observed to be provision of safe routes to school, school travel plan projects, pedestrian school bus schemes and training focused on the effects of bicycling. To note, the studies included in this systematic review evaluated ACS in a variety of ways from practical classroom surveys to child/parent diaries to accelerometer step counting. In addition, there was substantial heterogeneity in how the mode of commuting on a normal day and the frequency of ACS were classified. Another systematic review (Villa-Gonzalez, Barranco-Ruiz, Evenson, & Chillon, 2018) agrees with the above and mentions the countries where the interventions took place, notably in the United States, Belgium, Denmark, Spain, and the United Kingdom. Several interventions resulted in a statistically significant increase in ACS while others reported no change in ACS. Furthermore, it was concluded that studies with longer follow-up periods may achieve greater change. The main problems encountered were the lack of resources or unequal access to resources for interventions and high heterogeneity in measurement. The development of a standardised measurement protocol and interventions using more robust study designs were therefore identified as the main need (Larouche et al., 2018; Villa-Gonzalez et al., 2018).

In conclusion, interventions to promote PA in the educational context are an effective

opportunity for the creation of healthy lifestyle habits. These types of interventions should focus on the acquisition of habits that improve PA levels from an early age, as well as other related health outcomes such as quality of life and physical fitness. In that sense, ACS is described as a daily habit that can increase PA levels, as well as improve other individual, social and environmental health variables. However, the trends of this habit have remained stable or have decreased in the recent decades, so new, attractive strategies in intervention focused on the promotion of this habit are recommended. Thus, creating adherence in children and young people, such as through games and gamification, could help. In addition, it is necessary to analyse the trends of this habit in the preschool population and to analyse the association of ACS with other health outcomes such as quality of life and health-related physical fitness.

AIMS

AIMS

The porpouse of this doctoral thesis are: to analyse the rates of ACS in preschool children; a systematic review of games and gamification with its previous protocol; the design and development of an application called "Mystic School"; an educational proposal in Physical Education lessons in adolescents and to examine the association between quality of life, physical fitness and travel mode in children.

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

The objectives of this study were: 1) to describe the rates of ACS and 2) to examine the changes in the rates of ACS between 2013 and 2017 among Spanish preschool children.

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

The objectives of this study were: 1) to identify and examine school-based interventions using games and/or gamification to promote PA in pre-schoolers (3–5.99 years old), children (6–11.99 years old), and adolescents (12–18 years old) (non-university students) and 2) to analyse their quality and effectiveness on the PA levels; accordingly, future recommendations will be provided to design and implement successful game and/or gamification interventions to promote PA in this population.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

The objectives of this study were: 1) to identify and examine school-based intervention studies focused on game and/or gamification strategies to promote PA and 2) to analyse their quality and 3) effectiveness on the PA levels.

Study IV. Designing the Mystic School mobile app to promote active commuting to school in Spanish adolescents: the PACO study.

The objective of this study was to design a mobile application based on active video games (AVG) called "Mystic School" to promote active commuting to/from school in Spanish adolescents.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

The objective of this study was to implement and evaluate a school-based intervention integrated into Physical Education lessons to promote ACS using additionally in the leisure time the Mystic School application among adolescents.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

The objectives of this study were: 1) to examine the associations between self-reported health-related quality of life (HRQoL), health-related physical fitness (cardiorespiratory fitness, muscular strength, and speed-agility), and mode of commuting to and from school in Spanish children, and separately by gender and 2) to analyse the difference in cardiorespiratory fitness by mode of commuting to and from school by gender.

MATERIALS AND METHODS

MATERIALS AND METHODS

Data collection in this Doctoral Thesis was carried out by means of questionnaires, interviews and electronic databases. Measurements within each study were performed at different times, years, cities and following specific procedures depending on the research project. Each study was carried out in accordance with current Spanish legal regulations controlling research involving human subjects. The study design, objectives, and protocol were approved by the Ethics Committee of the University of Granada, Spain (reference: 162/CEIH/2016 and 57/CEIH/2015.

Each school involved in the present thesis, as well as their families, directors, and teachers at each school, were informed about the nature and purpose of the studies through an information letter. Informed consent was also completed by the parents and guardians of the students, for their participation in the studies. Below, the method of each study is presented separately to better understanding of the procedure followed.

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

a) **Study design, procedure, and participants**

This study analysed data on the modes of commuting to and/or from school from various cross-sectional studies conducted across Spain by research centres and local/regional public institutions, between 2013 and 2017, and it includes Spanish preschool children's data. This study is part of the PACO Study (Cycle and Walk to School Study) that aims to (a) describe the rates of ACS among Spanish children and adolescents and (b) promote ACS through school-based interventions (Chillón et al., 2021).

The design and methodology of the current study have already been described in detail elsewhere (Gálvez-Fernández et al., 2021). Briefly, those research centers and local/regional public institutions (hereafter, studies) that were invited to participate in this study provided the following data: the data collection date (month and year) and school location, as well as the participants' age, gender, mode of commuting to school, and socioeconomic status, if available. In addition, the research team of the current study collected information about the population density and income of the localities where schools were located. The

inclusion criteria for including these studies were as follows: (a) data were collected using a questionnaire, (b) data were available at the participant level, (c) studies provided data collected until the end of the recruitment period (e.g., 2017), and (d) studies provided data on the data collection date and school location, as well as preschool children's mode of commuting to school, age, and gender. Of the 34 initial studies that contributed data, 28 met the inclusion criteria. This study followed the ethical considerations of Research in Sports Science and Exercise (Harriss, Macsween, & Atkinson, 2017) according to the principles included in the Declaration of Helsinki(Association, 2013). The Medical Ethics Committee of University of Granada approved the PACO Study design, protocols, and informed consent procedure (case no. 162/CEIH/2016). Informed consent was obtained from all subjects involved in the study.

Data on 48 373 Spanish participants (preschool children (3.00 to 5.99 years old), children (6 to 11.99 years old), and adolescents (12 to 18 years old) from 28 cross-sectional original projects carried out between 2010 and 2017 were collected. To be included in the PACO Study, the general inclusion criteria required for participants (from preschool children to adolescents) were (a) to have completed information about gender and age, (b) to report the school location, and (c) to report the mode of commuting. Additionally, an additional inclusion criterion was required for inclusion in the current study—that is, whether the participant was between 3.00 and 5.99 years old. Participants who did not meet some of the inclusion criteria were removed from the database. This study's final sample included 4787 preschool children between 3.00 to 5.99 years old (males: 51.2%) from Spain (**Figure 1**), which was part of 5 separate studies that analysed preschool children from 27 different Spanish localities.

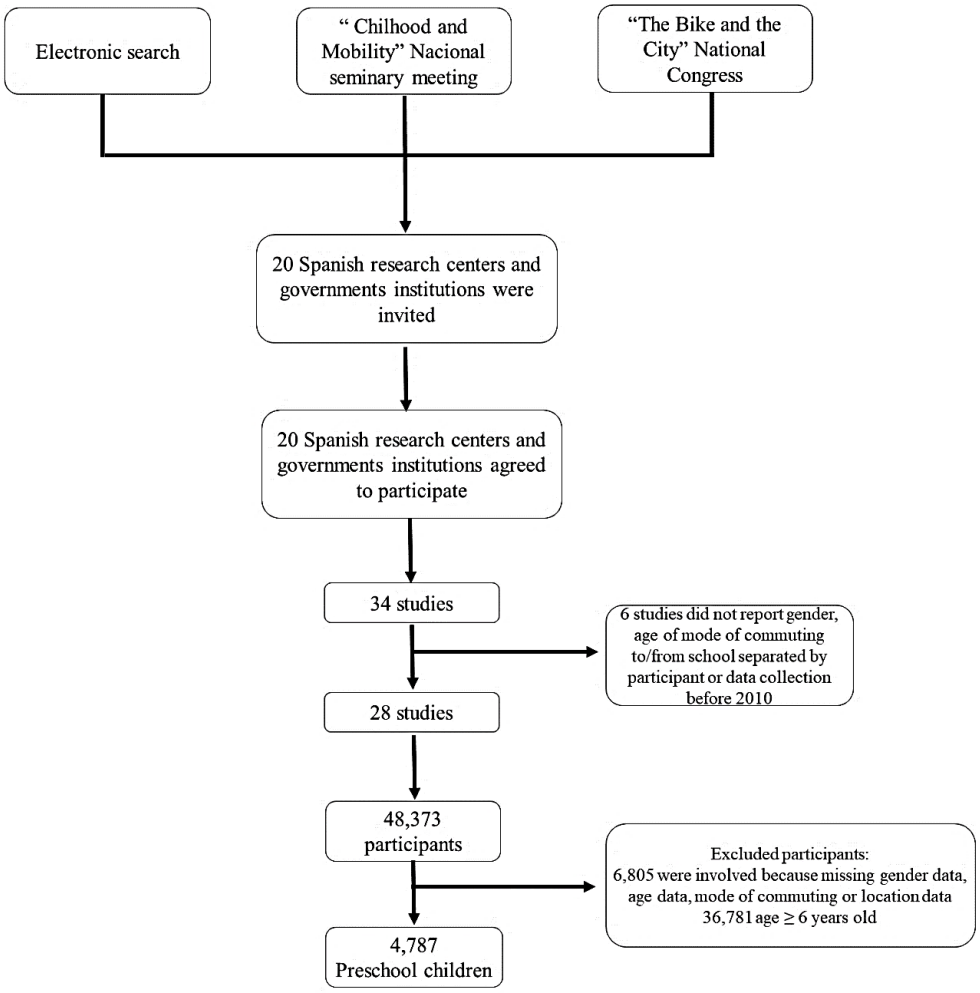

Figure 1. Flow chart of the study participants.

b) Measurements

The mode of commuting to and from school was assessed using 3 questions throughout the 5 studies (Figure 2). The questions used were as follows: (a) "How does your child usually go to school"; (b) "how do you take your child to school"; and (c) "what mode of commuting do you use to go to school?". This study only used the usual mode of commuting to school for analyses. Parents' preschool children answered the questions. Participants who reported walking (with the child by the hand), cycling, and/or using a nonmotorized scooter to travel to school were categorized as active commuters. Participants who reported travelling to school by foot with the child in a carriage, bike with a baby carrier, school bus, public bus, train/metro, taxi, motorbike, and/or car were categorized as passive commuters. Participants using multiple modes as part of their school journey (i.e., using 2 or more different modes of commuting for the same trip) were excluded in this study (Chillón et al., 2014). Several sociodemographic characteristics were assessed. Participants' gender and age were recorded as individual data. Characteristics of the school location

(i.e., population density and income) were calculated. Population density (number of inhabitants per locality area in km^2) was obtained from the Ministry of Finance and Public Administration of Spain using the available information closest to the data collection year in each locality. In addition, the localities' income of the data collection year was obtained from the Public Tax Agency from Spanish (https://www.agenciatributaria.es).

Each variable (population density and income) was categorized into a dichotomous variable (low vs. high) using the median.

In the current study, the survey year was defined as the specific year when data were collected. The survey year was collected in each individual study. The years of the studies finally included were from 2013 to 2017.

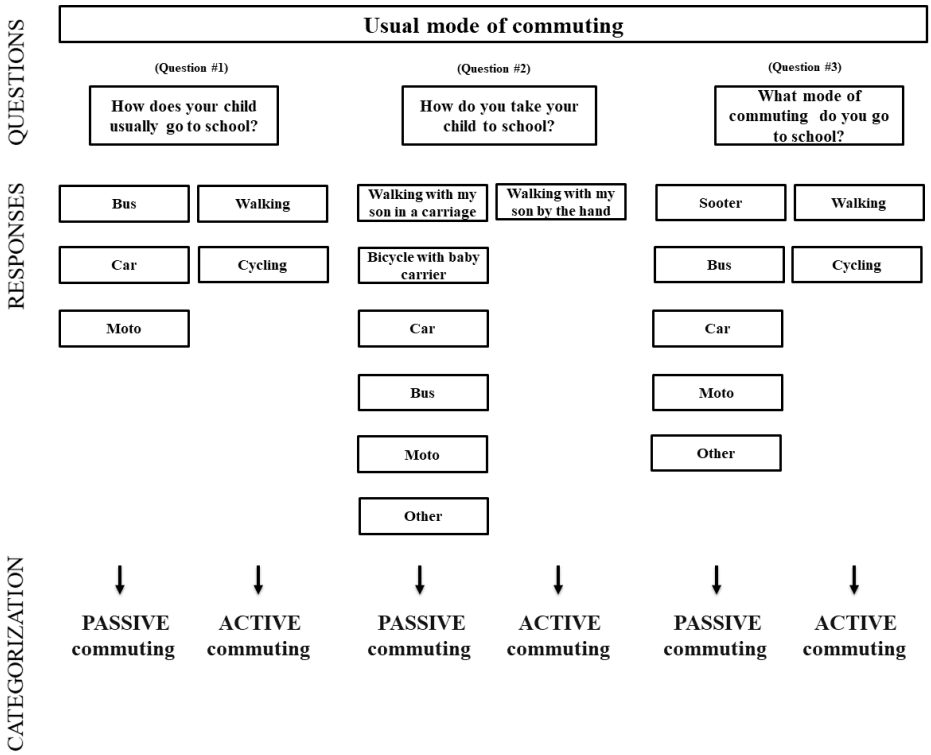

Figure 2. Questions to assess the mode of commuting.

c) Statistical Analysis

Descriptive statistics of the participants were reported for gender, age, population density, localities' income, and ACS; means and standard deviations were calculated for continuous variables; and percentages were reported for categorical variables. Additionally, ACS by survey year was analysed using chi-squared analyses for the whole sample, as well as for boys and girls, respectively. As the sampling frame of participants was based on localities (i.e., participants nested in localities), relationships between ACS and the survey

year were assessed using multilevel logistic regression, with 2 levels for analysis: participants (level 1) and localities (level 2). The goodness of fit of the empty model was studied, displaying an intraclass correlation of 0.20, which indicates that 20% of the variance in ACS was explained by between-localities differences.

Socioeconomic variables did not have an influence on the different localities ($p > 0.05$), as observed through the Wald test. The variable of ACS was entered into the models as the dependent variable and the survey year as the independent variable. Age and gender were included as covariates. The potential interactions between age, gender, and localities' income were analysed in the multilevel logistic regression analyses, and there were not significant differences ($p > 0.05$). Statistical analysis was performed using STATA v.13 (*Stata Corp: 110th edition College Station, TX: Stata Corp LP; 2009*, n.d.), and the statistical significance level was set at $p < 0.05$.

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

The protocol will be carried out strictly following the procedure of the PRISMA guidelines (Liberati et al., 2009). The systematic review protocol is in line with the items of the Preferred Networks for Systematic Review Initiatives and Meta-Analysis Protocols (PRISMA-P). The PRISMA statement provides an evidence-based 27-item checklist for reporting systematic reviews and meta-analyses (Moher, Liberati, Tetzlaff, & Altman, 2010). Following Cochrane's guidelines on the development of a systematic review, the research questions formed the base of a search strategy that was further developed using PICOS (Population, Interventions, Comparators, Outcomes, and Study design) tool components (**Table 1**).

Table 1. PICOS tool components.

POPULATION	Students from 3 to 18 years old.
INTERVENTION	School-based.
	Games and/or gamification to promote physical activity or exercise.
COMPARISONS	Pre-to post, pre- and post- treatment comparisons ±with /without controlled group.
OUTCOMES	Physical activity.
STUDY DESING	Experimental studies such as randomized clinical trials (RCTs), controlled clinical trial (CCT), Quasi-experimental non-randomized studies and pre-post intervention studies without control group.

The studies will be evaluated according to clearly defined criteria to determine their inclusion in or exclusion from the review, and the findings from included studies will be evaluated and reported (Higgins, 2008).

a) Eligibility

The inclusion criteria for the studies will be (a) to report PA as a primary or secondary outcome; (b) to implement a game and/or gamification intervention within the school; (c) intervention studies where a game and/or gamification were included with the learning objective; (d) to target pre-schoolers, children, and/or adolescent students (non-university students); and (e) to be written in English or Spanish. In the latter case, the abstract must also be written in English.

b) Outcomes

The outcome will be PA, which may be measured objectively (such as using an accelerometer or pedometer) or self-reported and/or through observation. Examples of potential PA outcomes would be minutes of moderate to vigorous PA, minutes or counts of total PA, total steps, or any other qualitative values (such as Likert scale).

c) Information Sources

For this purpose, the included databases will be PubMed, Web of Science, SPORTDiscus, Cochrane Library, ERIC, and PsycINFO, because there are previous review studies on this topic that have used some of these electronic databases (Chow et al., 2020; Lopes, Pereira, Magalhães, Oliveira, & Rosário, 2019; Sardi et al., 2017). In addition, one of the authors (I.J.P.-L.) is an expert and investigates the games and/or gamification field and will provide appropriate insights and potential studies to include. In addition, a manual search will be performed to identify studies that were not selected in the electronic research, and the references of these articles will be verified for the same purpose.

d) Search Strategy

The search will be conducted following the PRISMA guidelines (Moher et al., 2010). The electronic search will be conducted in July 2020. Five categories of search terms will be identified: (a) games (serious games and applied games and AVGs) and gamification, (b) physical activity, (c) school, (d) intervention, and (e) age. The terms for each category will be obtained by consulting other reviews, such as (a) serious games and AVG (Benzing & Schmidt, 2018; Biddiss & Irwin, 2010; Bossen et al., 2020; Foley & Maddison, 2010; Merino-Campos & Del-Castillo, 2016; Norris, Hamer, & Stamatakis, 2016; Peng, Crouse, & Lin, 2013; Williams & Ayres, 2020), gamification (Deterding et al., 2011; Hamari et al., 2014; Jackson, Waters, Promotion, & Taskforce, 2005; Sardi et al., 2017) (b) physical activity (Deeks et al., 2003; Esteban-Cornejo, Tejero-Gonzalez, Sallis, & Veiga, 2015) , and (c) intervention (Mura, Vellante, Nardi, Machado, & Carta, 2015;

Watson, Timperio, Brown, Best, & Hesketh, 2017). Regarding the high diversity of game-related terms used in the literature, the most used and standardized terms found in the scientific references will be included in the current review. For example, the electronic search will be conducted following these sequences of terms: "game * OR 'game based learning' OR 'GBL' OR video gam * OR mobile gam * OR exergam * OR 'AVG' OR active video gam * OR gamifi * OR gamification OR 'serious games' OR 'applied games' OR app gam * AND 'physical activity' OR walk OR steps OR 'physical fitness' OR 'leisure activity' OR 'motor activity' OR exercise OR training OR sport AND school OR kindergar * OR 'high school' OR 'nursery school' AND intervention * OR program * OR school-based AND preschool * OR child * OR adolescen * OR young * OR youth OR kid OR teenage". The search strategy will be carried out within each database, including PubMed [Title/Abstract], Web of Science [Topic], SportDiscus [Title], Cochrane Library [Title Abstract Keyword], ERIC [abstract], and PsycINFO [abstract].

e) Selection Process

After performing the search in the electronic databases, all the identified records will be uploaded through EndNote X7 -a reference management software- (Thomson Reuters, New York, NY, USA). Then, the authors will easily identify any duplicates and will delete them. After duplicates are removed, all titles and abstracts will be evaluated for eligibility by two reviewers (R.G.S.-A. and Y.B.-R.) using the established inclusion criteria, and for those that are not clear, full texts will be searched. After obtaining the first full texts of potentially eligible studies, two reviewers (R.G.S.-A. and Y.B.-R.) will independently review the full texts based on the eligibility criteria. They will perform the screening and agree by consensus, and any disagreement in the inclusion process will be resolved with the rest of the authors.

f) Extraction and Synthesis of the Data

Two reviewers (R.G.S.-A. and Y.B.-R.) will verify the data extraction to check its completeness and accuracy. The results will be organized in chronological order, and tables will be created to capture the information. The following data will be extracted: descriptive information such as the authors and country, sample size and age (years), intervention study design and duration, the games or gamification used, PA outcomes, results from PA outcomes, and results from other outcomes.

g) Quality Assessment

Two researchers will conduct a quality assessment of the identified studies. The quality assessment will be carried out using a standardized evaluation framework called "Effective Public Health Practice Project" (EPHPP) (Jackson et al., 2005) (http://www.ephpp.ca/tools.html). The EPHPP is a generic tool to evaluate a variety of study designs of intervention studies,

studies such as RCT, before and after studies, and case-control studies. This tool is suitable for use in systematic reviews to check the effectiveness of interventions (Deeks et al., 2003) and is used especially for health promotion and public health interventions (Jackson et al., 2005). This tool evaluates six methodological dimensions: selection bias, study design, confounding factors, blinding, data collection methods, withdrawals, and dropouts, all of which include a global rating. The EPHPP quality assessment tool includes a standardized dictionary developed to classify factors as weak, moderate, or strong. The individual grades of each study are used to calculate a global score that assigns a total grade: (a) weak (when two or more factors are rated as weak); (b) moderate (when one factor is rated as weak, and four factors are rated as strong); and (c) strong (when there are no weak ratings). Two researchers (R.G.S.-A. and Y.B.-R.) will read and evaluate the quality of the articles according to the "Quality articles" criteria. Disagreements will be resolved by discussing the different opinions with the rest of the authors until a common opinion is reached.

h) Risk of Bias

Following Gunnell et al. (Gunnell, Poitras, & Tod, 2020), we will assess the risk of bias through 'The Cochrane Risk of Bias Tool 2' for randomized studies and 'ROBINS-1' for non-randomized studies. The Cochrane Risk of Bias Tool 2 (Sterne et al., 2019) includes five items: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing data; (4) bias in measurement outcomes; and (5) bias in the selection of the reported result. In addition, the rating system for each domain is either 'low', 'high', or 'unclear' risk of bias, and the researcher makes a judgment with supporting statements about the risk of bias (Sterne et al., 2019). The ROBINS-I tool domains (Sterne et al., 2016) include bias due to (1) confounding, (2) selection of participants for the study, (3) classification of interventions, (4) deviations from intended interventions, (5) missing data, (6) measurement of outcomes, and (7) selection of the reported results, and risk of bias is assessed as 'low', 'moderate', 'serious', or 'critical'.

i) Effectiveness

Regarding data analysis and synthesis, if the data extracted are available, the researchers will conduct a meta-analysis to determine the effect of school-based interventions for promoting PA using games and gamification in comparison to the control groups. For studies that include different types of interventions for comparison, not including control group, data will be also examined separately to the previous comparison analysis. The effect size of each study will be calculated as standardized mean difference (post minus pre) expressed as Hedges' g to correct for possible small sample bias (Morris, 2003). Finally, the effect size of all studies included will be

combined to estimate an overall effect with a 95% confidence interval. Fixed- or random-effects models will be selected based on the heterogeneity of the studies examined. The heterogeneity will be evaluated using the I^2 statistics. Additionally, we will examine the one-leave-out analysis in order to check the robustness of the estimates. Finally, to detect publication bias, we will conduct a visual inspection of funnel plots and the Egger test (Egger, Davey Smith, Schneider, & Minder, 1997) All the analysis will be performed using STATA 13 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP) software.

j) Data Reporting

In accordance with the PRISMA-P recommendations, the protocol for this systematic review was developed and submitted by the authors for registration in PROSPERO (registration number: CRD42019123521) and is available online (http://cort.as/-GZHe). The systematic review will follow Cochrane's recommendations and will be reported based on the PRISMA guidelines.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review

The methodological procedure of this systematic review has been described in detail elsewhere (Saucedo-Araujo, Chillón, Pérez-López, & Barranco-Ruiz, 2020) and has been registered in Prospero (registration number: CRD42019123521). The protocol was carried out following the procedure of the PRISMA Guidelines (Alessandro Liberati et al., 2009). The research question to develop this systematic review were created using PICOS (Population, Interventions, Comparators, Outcomes, and Study design) strategy components (Higgins, 2008).

a) Inclusion criteria

This systematic review has included experimental studies such as randomized clinical trials (RCTs), controlled clinical trial (CCT), quasi-experimental non-randomized studies, and pre-post intervention studies without control group. The population of the included studies were from pre-schooler to secondary stage (3 to 18 years, no university students) who participated in school-based interventions for promotion PA through games or gamification strategy.

Specific considerations to differentiate between games and gamification interventions were taken into account through the previously published protocol (Romina Gisele Saucedo-Araujo et al., 2020). Furthermore, only studies that reported PA as a primary or secondary outcome were included. Different units of PA were considered as PA outcomes ((kcal/kg/minute), oxygen uptake (VO_2), metabolic equivalent of task (MET) value, minutes or counts of total PA, or total steps, physical fitness (cardiorespiratory fitness)

and heart rate. In addition, intensities were considered as light (< 3 METs), moderate (3–6 METs), or vigorous (>6METs)(Ainsworth, Montoye, & Leon, 1994). Moreover, only peer-reviewed studies with the tittle and abstract written in English from 2008 to 2021 were included. This fraction of years is due to the relevance of the games and gamification topic at school context. The games term relation with school-based intervention was in 2008 (Mellecker & McManus, 2008). Although the "Gamification" term was originated in the digital media industry, this term gained widespread acceptance in school context after late 2010 (Deterding, Dixon, Khaled, & Nacke, 2011).

b) Search strategy

Following Cochrane's guidelines, the search strategy was also developed using the PICOS strategy. The terms for each category were: (a) Population (students from 3 to 18 years old), Interventions (school-based, games and/or gamification to promote PA or exercise; Comparator's outcomes (pre-to-post, pre- and post- treatment comparisons ± with/without controlled group) and Study design (experimental studies such as randomized clinical trials (RCTs), controlled clinical trial (CCT), quasi-experimental non-randomized studies, and pre-post intervention studies without control group). The literature search was conducted on December 10th, 2020 and was updated on January 2nd, 2022, in eight electronic databases (PubMed, Web of Science, SPORTDiscus, Cochrane Library, ERIC, and PsycINFO (search terms and search strategy included were published in the protocol Saucedo-Araujo et al. (2020).

c) Study selection

The identified records were uploaded and further managed through EndNote X7 (Thomson Reuters, New York, NY, USA). After remove the duplicated studies, the studies selection was carried out mainly by two authors (R.G.S.-A. and P.C.-G.). Any disagreement between these authors in the inclusion process was resolved by consensus among the reviewers, and in case of disagreement the other authors intervened (Y.B.-R. and P.C.). The studies selection was carried out through the following steps: 1) screening of title and abstracts, 2) screening of full-text articles, and 3) revised the references of included studied to detect possible studies ignored during search strategy.

d) Data extraction

The extracted data from every study was identified by 2 reviewers (R.G.S.-A. and P.C.-G.) and organized in chronological order. The following descriptive categories were extracted from each of the identified studies: 1) authors and country, 2) sample size and age (years), 3) intervention study design and duration, 4) description of the intervention, 5) PA assessment and 6) main findings regarding PA outcomes. The reviewers were not blinded to authors and journals while extracting study information.

e) Risk of bias and quality assessment

Risk of bias and quality assessment of the included studies were evaluated. In accordance with Gunnell et al. (2020), risk of bias and quality assessment are different constructs and should, therefore, be assessed separately.

Risk of Bias

The risk of bias was assessed using 'The Cochrane Risk of Bias Tool 2-for randomised studies" (Sterne et al., 2019). This tool considers five domains: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing data; (4) bias in measurement outcomes; and (5) bias in the selection of the reported results. In addition, the rating system for each domain is either 'low', 'high', or 'unclear' risk of bias, and the researcher makes a judgment with supporting statements about the risk of bias. For non-randomised studies, the ROBINS-I was used (Sterne et al., 2016). In addition, the signaling questions are broadly factual in nature and aim to facilitate judgements about the risk of bias. The categories for risk of bias judgements are "Low risk", "Moderate risk", "Serious risk" and "Critical risk" of bias. Importantly, "Low risk" corresponds to the risk of bias in a high-quality randomised trial. Finally, the overall score was as follows: studies were rated as "high risk" if most of the items were rated as having some concerns or one of the items was rated as "high risk"; studies were rated as "some concerns" if one of the items was rated as having "some concerns"; and studies were rated as "low risk" if most of the items were rated as having "low risk".

Quality Assessment

The methodological quality of each study reviewed was scored using the Effective Public Health Practice Project quality assessment tool (EPHPP) (Jackson & Waters, 2005). The factors assessed and rated were: (A) selection bias; (B) study design; (C) confounders;(D) blinding; (E) data collection method; (F) withdrawals/drop-outs; (G) intervention integrity, and (H) analyses. These items were rated as ***= strong, **= moderate, or *=weak. Each study was then assessed as a) weak: when 2 or more factors were rated as weak; b) Moderate: there was one weak and 4 factors were rated strong; c) strong: there were weak ratings, and the factors were rated strong. The risk of bias and quality assessment were identified by two reviewers (R.G. S-A and P.C.-G). In case of disagreement with the interpretation of the results, reviewers resolved through discussion among the rest of authors until a common agreement was reached.

f) Effectiveness assessment

The effects of interventions in PA (comparison between groups or across time) were examined. The effect size using Cohen's d was included if the study calculated it to determine the efficacy of

each intervention on PA-related outcomes. Effect sizes were conducted between the experimental and control groups, or between baseline and follow-up of the experimental group. It was calculated according to the type of study and the data provided by each study (i.e., standardized mean or proportion differences, t-statistics, or p values). Studies included steps and PA time as the main outcome: PA levels, steps during the activities at the school, sedentary time, and METS. Cohen's d was classified into five levels: trivial (Cohen's d≤0.2), small (> 0.2), moderate (> 0.5), large (> 0.8), and very large (> 1.3) (Cohen, 2013).

g) Data synthesis

A narrative synthesis of the findings reported were included in this systematic review. The included studies were classified into studies with games intervention and studies with gamification intervention. A priori, the authors intention was analysed the studies according to the different scholar stage (pre-schoolers, primary education, and secondary), however, the included articles were mainly carried out in children belonged to primary education. Thus, the authors decided not to split the data synthesis by this condition. Additionally, information regarding main strategies for implementing the interventions in the included studies was extracted and analysed: 1) teacher's implementation; 2) research team implementation; 3) incentives to participate and 4) parents' participation. Moreover, to analyse the effectiveness of the includes studies, the effect sizes (ES) like Cohen's d and interventions p-values (significant: $p \leq 0.05$) were reported if the study had previously calculated it.

Study IV. Designing the Mystic School mobile app to promote active commuting to school in Spanish adolescents: the PACO study.

a) Study design

This study adopted a qualitative research method based on focus groups. This type of qualitative methodology consists of a group of individuals selected and assembled by researchers to discuss and comment on, from their personal experience. Specifically, in the present study, an AVG called Mystic School was the product analysed and improved by focus groups considering the user experience.

b) Description of the Mystic School application

The Mystic School is an application based on AVG whose main purpose is to encourage walking as a mode of commuting to increase the levels of daily PA in young people. The Mystic School software was designed for Android from version 4.0 (Ice Cream Sandwich) Operation System in advance in the mobile phone and Spanish version. For its functioning, the Mystic School application includes GPS and accelerometery to record the steps and the distance. Real steps while adolescents walk is transformed into virtual steps to be able to

play. These virtual steps allow the players to move an avatar through the different Mystic School scenes (different levels inside a maze).

The video game is placed in a school setting. The first scene (level 1) starts when the player finished a Physical Education lesson, and the teacher asks the player and his/her classmates for help to pick the material up. From here, it is when the players need to accumulate real steps to be able to move the avatar into the game to collect the materials that the Physical Education teacher had requested. In the storage room, they find a strange ball that transports them to a school in ruins, located in a parallel universe "Mystic School" **(Figure 1)**, and the game continues in a ruins school maze. Every task completed allow to obtain rewards to continue advancing in the different levels of the game through different screens.

Figure 1. Registration in the video game and first explanation screen (Spanish language).

c) Participants and recruitment

Participants of this qualitative study belong to the "Pedalea y Anda al COle: PACO" (Cycling and Walk to School) project. PACO project has been designed to encourage ACS among Spanish students within the Physical Education curriculum for secondary education (14-15 years old). The PACO study has been approved by the Review Committee for Research Involving. Human Subjects at the University of Granada (Reference: 162/CEIH/2016).

For this qualitative study, participants were recruited in two phases from four public school of the cities of Granada, Jaén, and Toledo. In the phase 1, the sample was

selected via-convenience from Granada (non-randomised sampling) academic course 2016-2017, where in phase 2 a random sampling was used (academic course 2018-1029). The following inclusion criteria were applied to participate in any of the study phases: 1) attend to 3rd grade of secondary education (14-15 years old), 2) have an Android Operation System mobile phone, 3) access to internet and, 4) play the Mystic School application during the intervention.

An initial contact was made with the Physical Education teacher and the school staff at secondary schools to explain the study. Then, according to the study selection criteria, two informed consents were sent: 1) to the secondary school staff and 2) to the students' legally authorized representative (parents/legal guardians). A meeting was held with secondary school students to present the subject of the study by the researcher team and Physical Education teacher. Informed consents were collected by the Physical Education teachers. The main researcher went to the secondary school to carry out each meeting.

d) Procedure

Phase 1

Adolescents from 2 high schools located in Granada (Spain) were invited to take part in the study. The phase 1 included one presentation session, two weeks for testing the application, and finally, one focus group session (see **Table 2**).

Table 2. Schedule in PE lesson.

SCHEDULE	
Personal resources	
One researcher	
Facilities	**Material resources**
Classroom	Computer projector and internet connection

PHASE 1 (play for two weeks)

Title	Description	Duration
Session I. Mystic school presentation	Deeply explanation on how the active application is used	20 minutes
Session II. Focus group	Questions about the perception and experience to play Mystic School.	15 minutes

PHASE 2 (play for one month)

Title	Description	Duration
Session I. Application presentation	Deeply explanation on how the active application is used.	25 minutes
Session II. First impressions	General usage questions and whether they have had any difficulties or failures.	10 minutes
Session III. Knowing failures and progress in the application	Questions about it is use. Hhow many steps they recorded and the level they are in the active application.	15 minutes
Session IV. Progress in application and daily habits	To know the general opinion about the application.	20 minutes
Session V. Focus group	Different questions about the perception, habits, and implementation to play Mystic School.	10 minutes

The contents in the presentation session were: 1) an introductory presentation of the Mystic School app; 2) sharing the link to download the Mystic School application; 3) showing the steps to download the application; and 4) once the Mystic School application was installed, the research team explained the characteristics of the game. The Mystic School application can be played individually or up to 3 players (in the same group). Each adolescent must choose an avatar. The mission of the application is to find the way out of the maze through the different trials. The virtual steps will help you to get different objects and prizes until you reach the last level. In addition, in the application you can choose a "special skill" (See Figure 2). Each skill is an advantage for each player (two players cannot have the same skill in the same group).

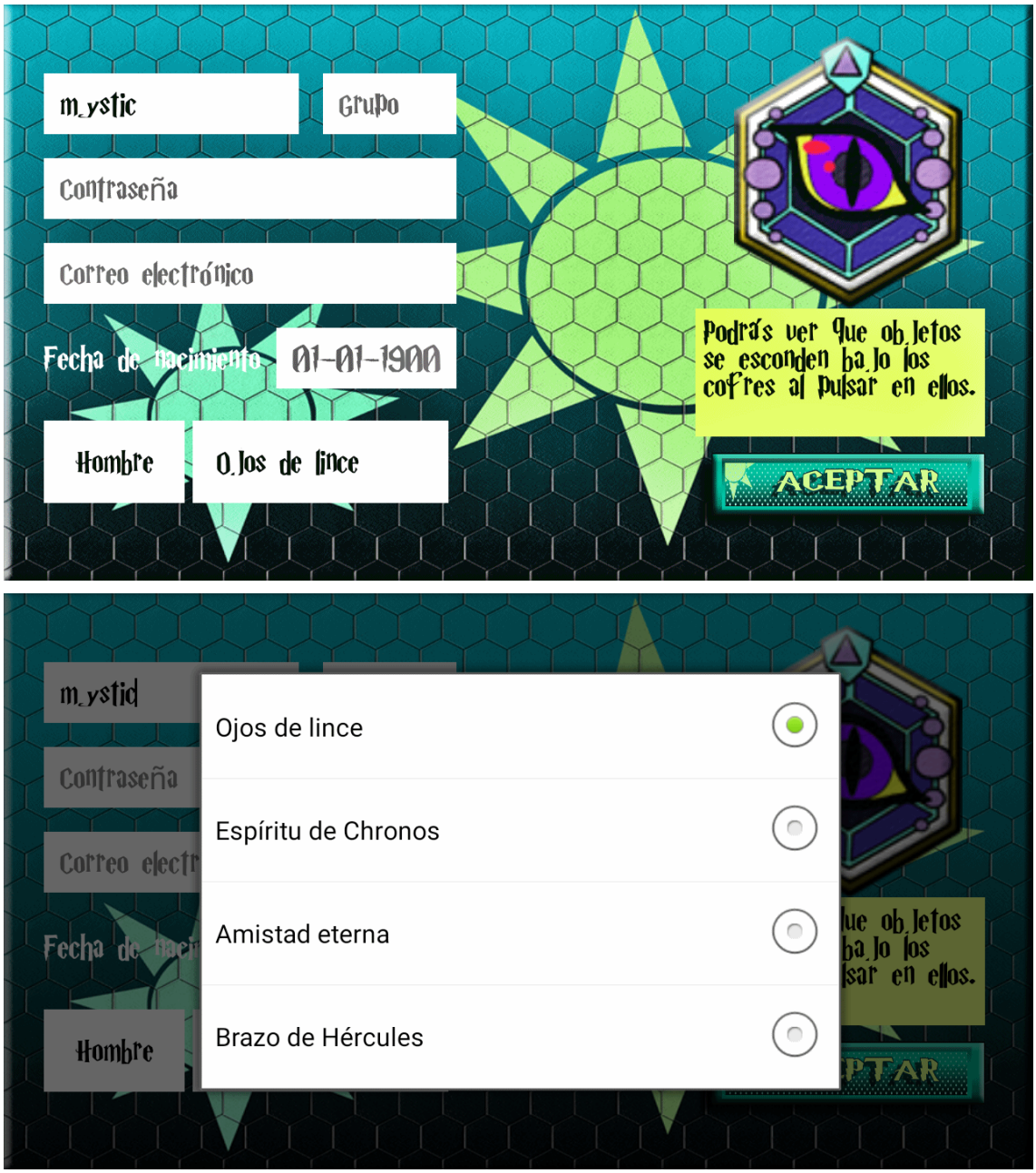

Figure 2. User registration and special skill selection (Spanish version).

The four skills are:

- "Eyes of Lynx": Allows students to see the contents of treasure chest (in each level of play there are different coffers with hidden objects).
- "Spirit of Chronos": Recorded steps are worth twice as much when collected during a 30-minute period per day (e.g., from 12:00 to 12:30).
- "Eternal Friendship": Share steps with another avatar in the same group.
- "Arm of Hercules": The students can approach another avatar in the same group to share an item.

Therefore, not all the adolescents could participate because adolescents had limited access to internet on their mobile phones. Another reason was that some adolescents were in exams period or not being able to use their mobile phone during the week. The Physical Education teachers at both schools supported us all the way to get the students to participate. A total sample of 14 participants played the Mystic School application (6 boys and 8 girls) during the testing period (two weeks).

Focus group: Two weeks after experiencing and playing to Mystic School, a focus group was carried out. The 20 questions (additional file 1) used in the focus group were divided into seven categories: 1) usability of the application, 2) assessment of the design, 3) usefulness of social networks in the game, 4) understanding the degree to which the application is useful in the game, 5) understanding of the game and the design, 6) usability of social networks in the game, 7) overall user satisfaction and impact on your overall user satisfaction and impact on your daily habits. The questions were designed by the research team. In addition, qualitative analytical experts from outside the research reviewed the questions. Only the participants that played during the two weeks were invited to join to the focus group. Four participants did not attend the focus group because one had a broken phone and the others had lack of time to play. Afterwards, the same researcher who led the meetings with the students and the full process, acted as moderator (who guided the group). The focus group had an average duration of approximately 30 minutes. The questions were mainly focused on exploring the perception of adolescents about the application, aspects to improve on the design, operation, and satisfaction in general. The topics discussed in the group were anonymous and confidential. Those contributions made by participants were discussed by the research team. The most relevant proposals (i.e., we improved the software and avatar movement) were incorporated into the new version of the application, and thus retested as explained in phase 2 below.

Phase 2

The Mystic school application was applied in 4 sessions over 1 month (one session per week) in the Physical Education lessons:

Session I. Application presentation. It contains a detailed explanation of how to download and play to Mystic School (25 minutes).

Session II. First impressions. It deals with general questions such as how many days they have used Mystic School, what level they are at or if they have had some difficulties or problems with Mystic School (10 minutes).

Session III. Knowing failures and progress in the Application. Questions about the use of game were asked (for example: failures, recorded steps, and the current level 15 minutes).

Session IV. Progress in Application and daily habits. In addition to repeating some of the questions of the previous weeks, the research team sought to know the general opinion about Mystic School and identify those who finished playing the entire game (20 minutes).

After the 4 sessions, the participants from the class-groups located in Toledo (n=20) did not meet the criteria to use one month the Application and they were excluded. Therefore, they were not invited to take part in the focus group for not meeting the criteria of continued participation. A total of 34 students participated in the study. A focus group of 4 participants was held in Granada and a second focus group of 4 participants was held in Jaén.

Focus group: When the testing period for the Mystic School ended, a focus group of 4 participants per secondary school was held in Granada and Jaén schools. The mean duration of the focus group was approximately 10 minutes. As a reward for participating, the focus group received a healthy breakfast. All adolescents who participated in the study were given a bracelet, and 3 backpacks per school were raffled.

e) Data Analysis

The text of both focus groups was inserted into the qualitative analysis, the software NVivo 11 plus. The aim was to deliver the intervention to participants and obtain feedback on specific aspects of it. The following phases were carried out:

1) Transcriptions were read several times to obtain a sense of the overall data.

2) The text was divided into meaning units.

3) The meaning units were coded, and these codes were compared, contrasted, and sorted into themes while maintaining fidelity with the text.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

a) Study design

This study adopted a qualitative research method based on focus groups. Specifically, in the present study, an educational proposal

using the AVG Application called Mystic School was the product analysed by adolescent's students focus groups considering their experience as user.

b) Participants and recruitment

The participants of this study are part of "The PACO (Pedalea y Anda al COle; Cycling and Walk to School) study", which has been designed to promote ACS to and from school and PA in adolescents (Chillón et al., 2021). The PACO study has been approved by the Review Committee for Research Involving. Human Subjects at the University of Granada (Reference: 162/CEIH/2016).

Two groups per secondary school were invited to participate in the cities of Valencia (n= 34) and Almería (n= 58). A total of 62 adolescents gave consent to participate in the study from two public secondary schools in Valencia (n = 18) and Almería (n = 44). The inclusion criteria applied to participate were the following: 1) attend 3rd grade of secondary education and 2) have an Android Operation System mobile phone.

c) Procedure

Initial contact was made with the Physical Education teacher and school staff at secondary schools to explain the study. Two informed consents were sent: 1) to the secondary school and 2) to legally authorized representatives (parents/legal guardians). Participants' informed consent was collected by the Physical Education teachers. The teachers responsible for each group accepted to give their perception after the end of the intervention.

The period of the intervention was one month in both schools (4 sessions). One session per week was conducted in each group in Valencia. In contrast, due to COVID-19, health recommendations reduced the class groups into smaller groups in Almería. Two groups in Almería were divided by two. The duration of the sessions was between 30-45 minutes. The didactic proposal using Mystic School was applied during January-February 2020 in Valencia and March-April 2021 in Almería. The sessions were based on overcoming challenges and obtaining points as a reward. In addition, during this implementation period, in each session, students were recommended to use the Mystic School application during their school trips as an option to obtain extra points and thus have group rewards. After the intervention, focus groups were conducted with those students who had actively participated in the sessions.

d) Description of the educational intervention

An education proposal based on a Physical Education didactic unit with four sessions was design to implement the Mystic School Application. The Physical Education lessons were designed based on the minimum Physical Education contents for adolescents from the 3rd grade of secondary education.

This proposal was presented based on four sessions with the minimum contents established in Real Decreto 1105/2014, 26th December, curriculum of Compulsory and Upper Secondary Education (BOE no. 3, 3rd January 2015). The curriculum established, five content blocks. The proposal was focused on physical activities in the natural environment which includes: 1) performance of physical activities in the natural environment to improve health and quality of life and active occupation of leisure and free time; 2) progression techniques in unstable environments. Basic orientation techniques. Route choice, continuous reading, relocation, and 3) study of the range of activities on offer and use of the possibilities offered by the immediate environment for physical activities. The main objectives of the proposal were: 1) to increase the practice of PA; 2) to improve the capacity for orientation based on knowledge of the immediate environment; 3) to become familiar with and know how to use maps and 4) to develop teamwork skills for problem solving.

Based on the general characteristics of the adolescents for whom this proposal is intended, the use of teaching styles of homework assignment and discovery learning is proposed. The proposal called "alien invasion" was set in the plot of an alien invasion that will take over planet earth unless the students collaborate. The students (who composed the group "the resistance") had to perform some activities in each Physical Education lesson to develop different skills. To gain advantages and overcome established challenges, adolescents must use the Mystic School application. If they meet the process, the aliens will not invade the earth and the humans could continue to live on earth. Teams of 4 to 6 components maximum (depending on the total number of students in the class's group) were formed by a randomized assignment. In addition, each team (called in the proposal "resistance group" to match with the proposed amination) choose a team leader and a name for the group.

Session I: The main objective was to collect and place different Physical Education materials where each coordinate indicates in the map legend. Each group received a map of the outdoor courts of the school. Each the resistance group read the map to correctly place all the materials according to the instructions. In addition, the leader of each group carried a mobile phone with an application that records total steps and distance covered (mobile phone native application for health or fitness were suggested to be used). To carry out the activity, the teacher had a record sheet with requirements to be carried out by each team.

Session II: The aim of this activity was to recognise the environment through clues (images with different descriptions). An orienteering race through clues in QR codes based on very specific images of the school (i.e., landmarks) were carried out. Each team used a mobile phone of any of the members

of the group to show the clue. Students discovered progressively a question about PA and commuting those students had to answer in each clue). Thus, once answered correctly, students went to the next QR.

Session III: The aim was to follow a different route within school's facilities. In addition, teams received a map, which they used in one of the tracks to continue the route. The students had to find a clue, and, to get it they must complete an activity. When the activity was completed, they could move to the next clue. the activity consisted of a tour of the school's facilities. activities to solve such as an equation, a drawing or a riddle that will tell them about the next station on the route that can be in or around the school.

Session IV: The aims were to improve the capacity for orientation and to develop teamwork skills for problem solving. In the park closest to the school, different stations with different tests were organised. The teacher gave a map to each team before leaving the school to guide them to the park and follow the instructions. In this case, all teams moved as a group to the nearest park. Each map of the park contains 4 locations (stations) called alpha, beta, gamma, and delta with a test to pass at each location. When each team managed to locate the area, the teacher gave them a situation, problem, or physical test that they had to solve as a team. At each of the stations, each team was given a piece of Morse code that they (each team) had to keep and decipher at the end of all the tests. With all the Morse code clues, they had to access a platform to prevent the extermination of the aliens and thus prevent their invasion. A brief explanation of the main activities, objectives, duration, facilities material resources for each Physical Education lessons of the present educational intervention was shown in **Table 3.**

Table 3. Schedule in Physical Education lessons.

Intervention			
Description of sessions	**Duration**	**Facilities**	**Material resources**
I. To know the nearby environment. Move different elements according to a school map.	25 minutes	Outdoor tracks.	Group registration sheet and, mats, balls, and hoops. Map of the outer tracks and one student per group must have their phone and internet connection.
II. To recognize different facilities through QR codes.	25 minutes	School gym / Outdoor tracks.	Group registration sheet, mobile phone with internet and QR.
III. To use map with different requirements.	25 minutes	School gym / Outdoor Courts. Surroundings of the educational secondary school.	Group registration sheet, mobile phone with internet access.
IV. Overcome different games in relation with the orientation and localization.	45 minutes	Space outside the educational secondary school (e.g., park, square, etc.).	Group registration sheet, cones (10) and internet access.

e) The AVG "Mystic School

The AVG called "Mystic School" (**Figure 1**) is a new mobile application which purpose is to promote ACS by walking in adolescents, focusing on motivation, awards, and group collaboration. The Mystic School software was designed only for Android Operation System in the mobile phone (minimum version 4.0). Mystic School transforms the steps of the real route into virtual steps to be able to play. Mystic school counts real steps, accumulating them virtually and allowing the user to move his avatar through a labyrinth and obtain certain objects. To overcome the different levels, the game has different objects to obtain steps and continue overcoming challenges.

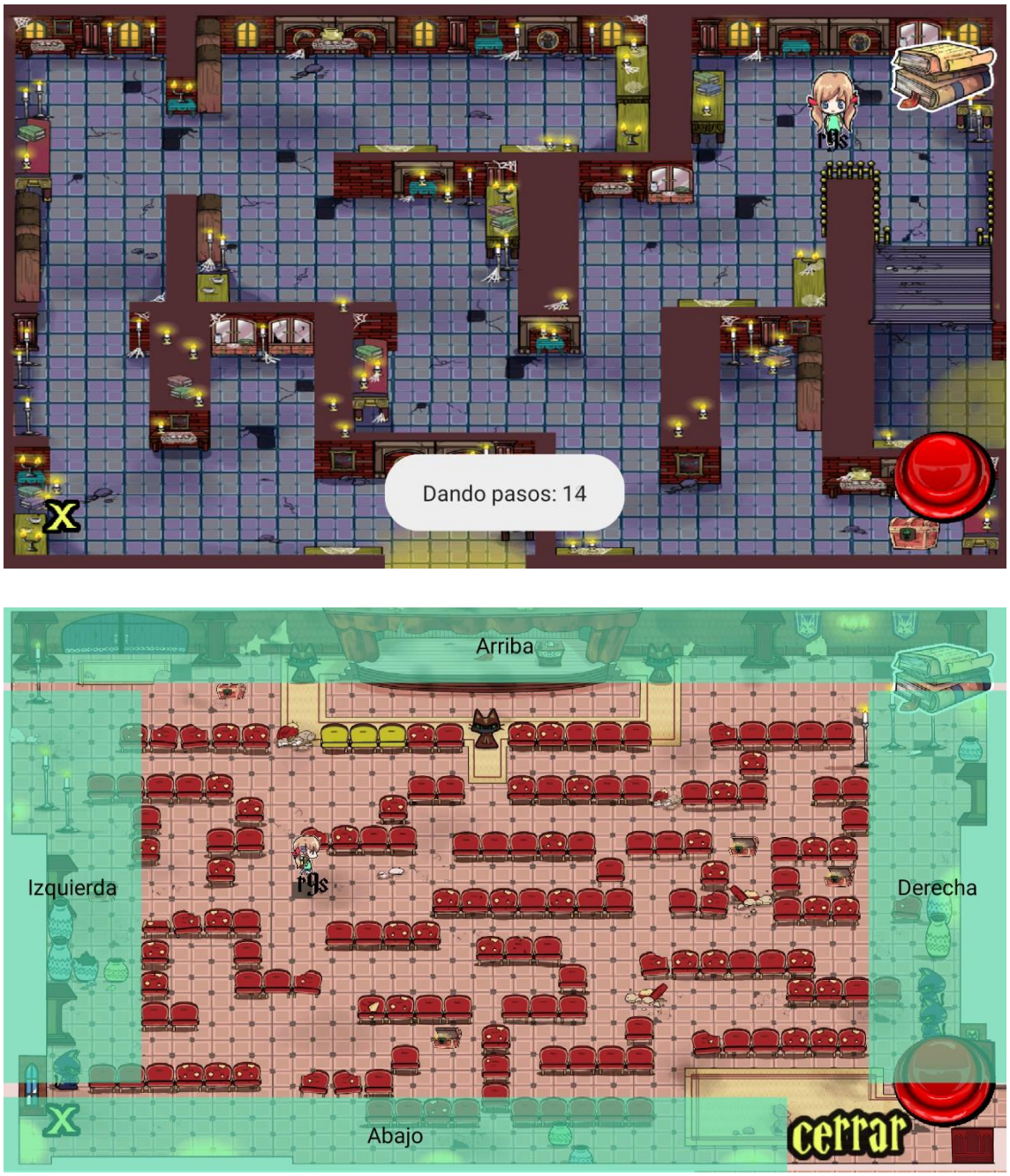

Figure 1. Different levels of the Mystic School (Spanish version).

f) Focus Group

One month after experiencing the proposal with different activities about Physical activities in the natural environment and playing the Mystic School, a focus group was carried out in Valencia. Four questions were asked about the Physical Education sessions. 1) what did you think of the sessions? 2) which session did you like the most? 3) which session did you like the least? and 4) how can the sessions be improved? or what would you modify to have a better time? Regarding the AVG Mystic School, four questions were performed: 1) what did you think about active the video game; 2) what would you

improve to play more? and 3) if you were a teacher, do you see the active video game applicable in Physical Education lessons?. In addition, qualitative analytical experts from outside the research reviewed the questions. Only the participants that assisted to Physical Education lessons and played during the weeks were invited to join the focus group. Afterward, the same researcher who led the meetings with the students and the full process acted as moderator (who guided the group). The focus group had an average duration of approximately 10 minutes. The topics discussed in the group were anonymous and confidential. Those contributions made by participants were discussed by the research team. However, due to COVID-19 it was not possible to carry out the focus group in Almería. Therefore, the same questions from the focus group were sent online (google form). Both the opinions of the focus group and the responses to the form were grouped together.

g) Teacher individual interview

At the end of the intervention, the teachers were asked about the proposal and Mystic School. The questions that were asked were: 1) what did you think of the sessions?; 2) how would you apply Mystic School with your students?; 3) do you think it could be useful? And 4) what aspects have you seen that should be worked on more?.

h) Data Analysis

The text of both focus groups was analysed through qualitative methods, using the software NVivo 11 plus. The aim was to deliver the intervention to participants and obtain feedback on specific aspects. The following phases were carried out: 1) transcriptions were read several times to obtain a sense of the overall data; 2) the text was divided into meaning units and, 3) it was compared, contrasted, and sorted into themes while maintaining fidelity with the text.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

a) Participants and Study Design

The data of this study were obtained as part of the PREVIENE Project (Promoting Healthy Lifestyles for the School Environment). Further details of the PREVIENE Project can be found elsewhere (Tercedor et al., 2017). The study protocol was approved by the Ethics Committee on Human Research of the University of Granada (Reference: 57/CEIH/2015).

The data were collected in two stages. First, during January–March 2017, and second, during the same period in 2018. During the first stage, the schools were selected using non-randomized sampling, and in the second stage, they were selected using randomized sampling.

The schools in Granada (Spain) were invited by phone call and email. The research team conducted an initial meeting with the teachers to explain the objectives and evaluation process of the study. Finally, 14 schools (nine public and five private) participated in the study. All the schools were of a medium socioeconomic level. After participation approval from the schools, students' families received an invitation to an initial meeting to collect information and to encourage their participation. Parents signed an informed consent form for the inclusion of their children in the study. Of the initial 596 children who agreed to participate, 181 were excluded due to missing data. Reasons for exclusion were 1) they did not provide their age (n = 50); 2) some questions on the valid and reliable KINDL-R questionnaire were incompleted (n = 15); 3) children did not answer the commuting questions "How do you usually get to school?" and/or "How do you usually get home from school?" (n = 48); or 4) they did not complete the whole fitness test battery (n = 68). Finally, a total of 415 children aged 8.47 ± 0.36 (53.5% boys) were included in the study. The response rate of the schools was 100% due to this was a convenience study, where the response rate of the students was 69.6% for the total sample.

b) Instruments

Health-Related Quality of Life

Children's HRQoL was measured using the valid and reliable RevidierterKINDer Lebensqualitätsfragebogen (KINDL-R), validated for Spanish children from 8 to 16 years old (Fernández-López, et al., 2004). The KINDL-R assesses HRQoL through 24 questions about children's experiences during the past week. The 24 items are answered according to a Likert scale (1-5) and are equally distributed into 6 subscale scores/dimensions: physical well-being, emotional well-being, self-esteem, family, friends, and school. The scores achieved on the individual KINDL-R subscales and the KINDL-R total score represent a quantification of the subject's HRQoL from the respondent's point of view. The raw subscale scores were transformed into a 0–100 scale, with higher scores indicating better quality of life. The reliability of this questionnaire was measured by Cronbach's α coefficient and showed good reliability (> 0.70) in a previous study with a similar sample (Fernández-López et al., 2004).

Health-Related Physical Fitness

Fitness level was measured with the ALPHA battery for children and adolescents (Ruiz et al., 2011). Cardiorespiratory fitness, muscular strength, and speed-agility were evaluated. The research team applied the ALPHA battery test during the Physical Education lesson.

Cardiorespiratory fitness was measured using the 20-meter shuttle run test. The children ran from one line to another line placed 20 meters away. The initial speed was 8.5 km/h, which increased at a rate of 0.5 km/h in each stage (1 stage equals

1 min), announced by a sound signal (Ruiz et al., 2011). The test ended when the children were not be able to reach the lines twice before the sound signal. The results were obtained by recording the last stage children reached. By means of the results of this test, the VO2 max can be determined as the physiological variable that best defines aerobic capacity. To estimate the maximal oxygen consumption (VO_2 max), Leger's equation was used for children aged 6 to 17.9 years: [VO2 max = 31.025 + (3.238 × Speed) − (3.248 × Age) + (0.1536 × Speed) × Age)](Leger, Mercier, Gadoury, & Lambert, 1988). The CRF level of the children was categorized as "Fit" or "Unfit". For being considered Fit in children from 8 to 8.5 years old, separated by boys (50.8 ml/kg/min) and girls (47.9 ml/kg/min). In children from 8.5 to 9 years old, a different cut-off point was classified for boys (50.9 ml/kg/min) and girls (47.7 ml/kg/min).(De Miguel-Etayo et al., 2014).

Muscular strength: Lower body muscular fitness was evaluated through the standing board jump test. Children were asked to jump horizontally to reach the maximum distance and position immediately behind a line with feet spaced at hip width apart (Ruiz et al., 2011). The result was recorded in centimetres as the best value of the two attempts made. Upper body fitness was assessed by means of handgrip strength using a hand dynamometer with adjustable grip (TKK 5401 Grip D; Takey, Tokyo, Japan). The dynamometer was adjusted according to the child's hand size. The test was done in the standing position with the wrist in the neutral position and the elbow extended; children were given verbal encouragement to "squeeze as hard as possible" and apply maximal effort for at least two seconds (s). Two attempts per hand were made, and the best score was used. The average of the best scores achieved by each hand was used in the analysis (Ruiz et al., 2011).

Speed-agility was obtained through the 4 × 10 meters test (4 × 10 shuttle run). The children ran as fast as possible between two lines 10 meters apart to pick up small blocks. There was a small block at the starting line and two blocks at the opposite line, so that when the start was indicated, the students had to run as fast as possible towards the other line, returning to the starting point with the first block and exchanging it for a second, then running to the other line and exchanging the block for another again, and finally returning to the starting line (Ruiz et al., 2011). The test was measured twice. Two attempts were made, and the best score was retained (in seconds).

Anthropometric Measures

The children's weight and height were assessed with them wearing shorts, a short sleeve shirt, and bare feet. For weight, a Seca 876 weighing system (Seca, Ltd., Hamburg, Germany) was used, with an accuracy of 0.1 kg. Height was measured in the Frankfort plane, with an approximation of 0.1 cm, using a Seca 213 stadiometer (Seca, Ltd., Hamburg, Germany). Both weight and

height were measured twice, and the average of both measurements was taken. Body mass index (BMI) was calculated from the mean of the two weight and height records, that is, weight in kilograms divided by the square of the height in meters (kg/m2). To determine the weight status of children, the age and gender BMI cut-off points proposed by the International Obesity Task Force were used (Cole, Bellizzi, Flegal, & Dietz, 2000).

Mode of Commuting to and from School

We analysed the *mode* of commuting to and from school of the children during the latest week. The children completed the valid, reliable and feasible "*Mode and Frequency of Commuting To and From School Questionnaire*". The questionnaire shows an almost perfect kappa coefficients for children, revealing between light and almost perfect reliability (k = 0.19–0.88). The questionnaire is a feasible and reliable for Spanish children and adolescents.(Segura-Díaz et al., 2020) Specifically, we selected two questions to evaluate the mode of commuting to and from school: (1) How do you usually get to school? (2) How do you usually get home from school?. The possible answers were walk, bike, car, motorcycle, school bus, and public bus. Children were categorized as "active commuters" if they walked or cycled to and/or from school almost ≥ 1 active travel per day out of 2 daily school trips and "passive commuters" if they commuted to and from school by car, motorcycle, school bus, or public bus (Chillón et al., 2009). Children completed the questionnaire with the help of the teacher and the research team.

c) Statistical Analyses

The sociodemographic characteristics were analysed using descriptive statistics. The data are presented as mean and standard deviation with medians. Normal distribution of the data was tested using the Kolmogorov–Smirnov test. Pearson correlations were calculated between HRQoL dimensions (physical well-being, emotional well-being, self-esteem, family, friends, school, and total score) and PF components (CRF, muscular strength, and speed-agility) by gender. Correlation coefficients between HRQoL scores and physical fitness values were categorized as weak (0.1–0.29), moderate (0.30–0.49), or large (≥ 0.5)(Cohen, 1988). Analysis of covariance (ANCOVA) models were used to assess mean differences in HRQoL with PF components (CRF, muscular strength, and speed-agility) by gender, and to analyse mean differences in CRF by mode of commuting to and from school (active or passive mode) adjusted by age and BMI. Another ANCOVA model analysed the association between HRQoL and CRF level (fit or unfit) in children who actively commuted to school. In the models, CRF and ACS were included separately as dependent variables, and HRQoL as an independent variable. All the analyses were adjusted by gender, age, and BMI, and the level of statistical significance was set at $p < 0.05$.

All statistical analyses were performed using SPSS (version 23.0; SPSS, Chicago, IL, USA).

RESULTS

RESULTS

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

Descriptive characteristics of the participants and localities are displayed in **Table 4**. Boys were 52% of the total sample, with a mean age of 4.59 years old. Population density was 2913.33 (hab/km2), and the localities' income median was 27 881 euros. The ACS rates in Spanish preschool children by survey years in the period 2013-2017, controlled for age, are shown in **Figure 3.** Overall, around 52% of the preschool children actively commuted to school between 2013 and 2017. The ACS rate was around 51% in 2013 and 2014, around 58% in 2015 and 2016, and 67% in 2017. ACS differences by survey year were found for both boys and girls separately. In boys, a higher percentage of ACS was found in 2015 vs. 2013 and 2014, as well as in 2017 vs. 2013, 2014, and 2015 (all, $p < 0.05$). Regarding girls, a higher percentage of ACS was found in 2015 vs. 2013 and 2014, in 2016 vs. 2014, and in 2017 vs. 2013 and 2014 (all, $p < 0.05$). Moreover, ACS differences by gender in the same survey year were studied, and significant differences were not found.

Associations between ACS and survey years, adjusted for age and gender, are shown in **Table 5**. It was noted that there were no changes in ACS behaviour during the period 2013-2017 (all, $p > 0.05$).

Table 4. Descriptive characteristics of the study participants and cities by survey year.

Preschool children	All n= 4,787	2013 n= 735	2014 n=2,867	2015 n=634	2016 n=198	2017 n= 353	P
Age ($\bar{X}$±SD)	4.59 ± 0.77	4.88 ± 0.33	4.53 ± 0.84	4.72±0.62	4.16±0.84	4.5±0.81	**<0.001**
Gender							0.264
Boy [n (%)]	2,498 (52.2)	403 (54.83)	1,503 (52.42)	323 (50.95)	94 (47.47)	175 (49.58)	
Girl [n (%)]	2,289 (47.8)	332 (45.17)	1,364 (47.58)	311 (49.05)	104 (52.53)	178 (50.42)	
Population density (median) (hab/km2)	2913.33	1048.367	2724.802	4320.324	11505.59	3093.23	**<0.001**
Localities´ Income (median) (euros)	27,881	20,520	31,820	23,197	23,104	21,751	**<0.001**

$\bar{X}$, mean; SD, standard deviation

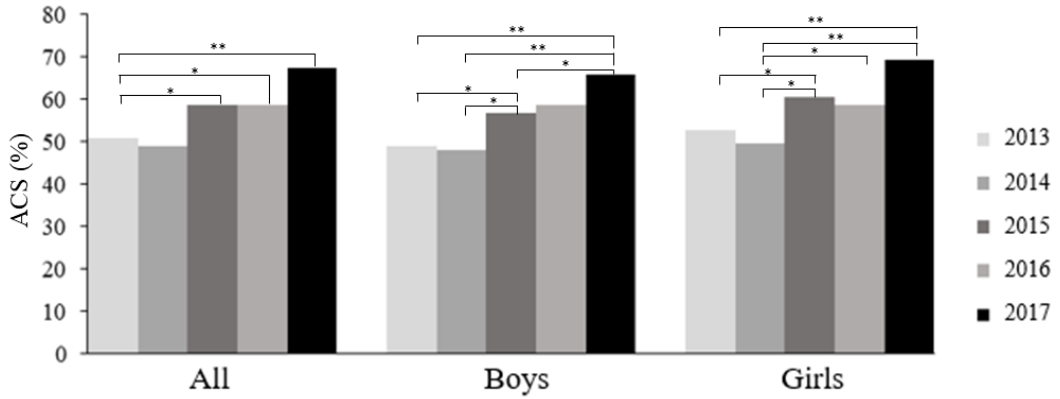

Figure 3. Active commuting to school in Spanish preschool children by years in the period 2013-2017 and by gender.

*p<0.05

**p <0.01

Significant differences were not found in the same year by gender.

Table 5. Associations of active commuting to school with survey years for preschool children adjusting by age and gender.

Preschool children	n=4,787	OR	95% CI	P
Survey year				
2017	353	1	Reference	
2016	198	0.47	0.72 - 3.05	0.428
2015	634	0.58	0.92 - 3.63	0.559
2014	2,867	0.53	0.83 - 3.36	0.498
2013	735	0.40	0.63 - 2.52	0.329
Age		1.10	1.02 -1.20	**0.019**
Gender (Girl)		1.07	0.95 - 1.21	0.249

OR, Odds Ratio; CI, Confidence Interval

II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

This protocol intends to present the specific methodology that will be used in a systematic review to identify and examine school-based intervention studies focused on game and/or gamification strategies to promote PA. The included studies will provide preliminary evidence regarding games or gamification as novel and attractive strategies to improve PA levels in the youth population in a school setting.

PA patterns are developed from childhood to adulthood (Sallis et al., 1992; Summerbell et al., 2005). Along these stages, most children and adolescents spend the majority of the day at school. Thus, the school becomes an ideal and appropriate environment to promote PA in children and adolescents (Naylor & McKay, 2009). Moreover, school has an influence on children during the transition from childhood to youth (Story, Nanney, & Schwartz, 2009).

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

a) Search strategy

The flow of studies through the selection process was reported in **Figure 7**. A total of 2,105 titles and abstracts were identified. After abstract and title screening 2,012 studies were excluded. Therefore, 35 were reviewed in full text and there was any exclusion. Thus, 35 intervention studies were included in the present review.

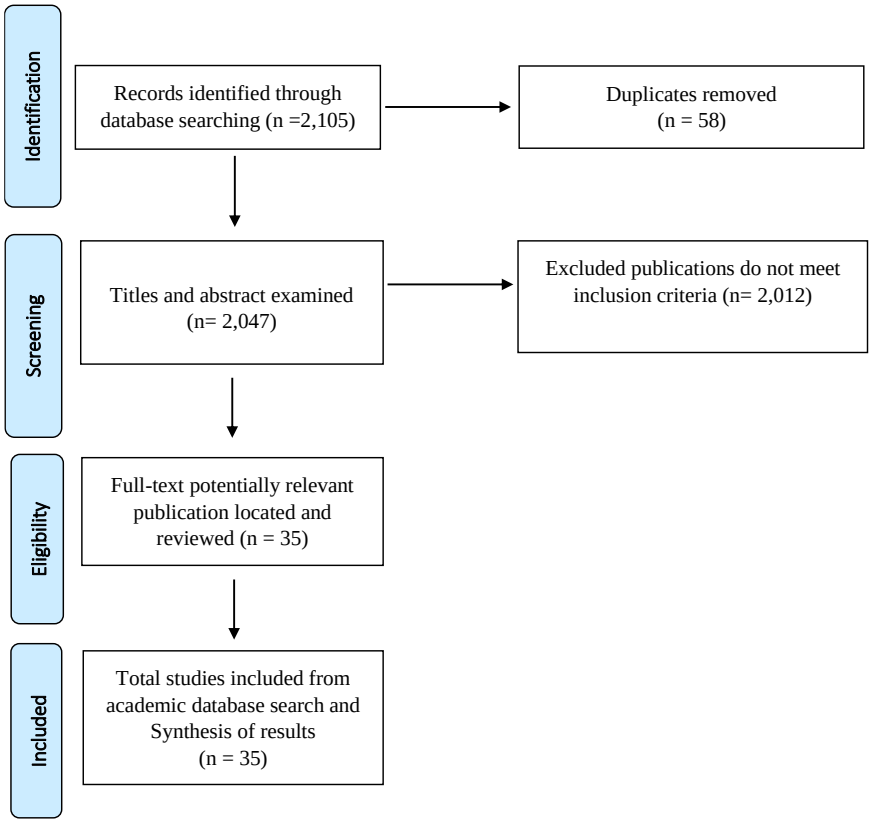

Figure. 7. Flow chart about the procedure of the study selection.

b) Characteristics of the included studies

A total of 35 relevant studies were included from electronic database search. The search strategy was carried out between 2008 and 2022. The characteristics of different kind of interventions were presented in **Table 6.** A total of 4165 (75,2%) participants of the included studies were conducted in children, 1250 (22,6%) participants were adolescents, and only 111 (2,6%) participants were pre-schoolers. The age of participants was from 4 to 18 years: pre-schoolers (Fu et al., 2018; Gao et al., 2019) ; children (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Joyner et al., 2019; Lau et al., 2016; Mellecker & McManus, 2008; Miller et al., 2015; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018) and adolescents(Cui et al., 2012; Direito et al., 2015; Maloney et al., 2012; Melero-Cañas et al., 2020; Pope et al., 2018). Primary schools were the most chosen settings 27/35 (77,1%) (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Joyner et al., 2019; Lau et al., 2016; Mellecker & McManus, 2008; Miller et al., 2015; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018), followed by high school 5/35 (14,4%) (Cui et al., 2012;Direito et al., 2015; Maloney et al., 2012; Melero-Cañas et al., 2020; Pope et al., 2018), and kindergartens 3/35(8,6%) (Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2019).

Interventions were predominantly carried out in USA 18/35 (51,4%), (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gaoet al., 2019; Gao et al., 2013; Joyner et al., 2019; Maloney et al., 2012; Pope et al., 2018; Rincker & Misner, 2017; Sharma et al., 2015), Europe 6/35 (17,1%) (Coombes & Jones, 2016; D'Egidio et al., 2019; Duncan & Staples, 2010; Melero-Cañas et al., 2020; Robertson et al., 2018; Viggiano et al., 2018), Canada 3/35 (8,6%)(Garde et al., 2018; Garde et al., 2016; Garde et al., 2015), Australia 2/35 (5,7%)(Cui et al., 2012; Miller et al., 2015) , China 3/35(8,6%)(Lau et al., 2016; Wang et al., 2017; Ye et al., 2018), Japan 1/35 (2,9%) (Mellecker & McManus, 2008), Georgia 1/35 (2,9%) (Chen & Sun, 2017), and New Zealand 1/35 (2,9%) (Direito et al., 2015).

Regarding study design, 17/35 (48,6%) interventions were RCTs (Baranowski et al., 2011; Cui et al., 2012; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2019; Gao & Podlog, 2012;Garde et al., 2018; Lau et al., 2016; Maloney et al., 2012; Melero-Cañas et al., 2020; Miller et al., 2015; Pope et al., 2018; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Ye, Pope, Lee, & Gao, 2019) , 9/35 (25,7%) studies (Beemer et al., 2019; Coombes & Jones, 2016; Chen & Sun, 2017; Fu & Burns, 2018; Gao et al., 2013; Gao et al., 2019; Gaoet al., 2019; Garde et al., 2015; Wang et al., 2017) were NRCTs and 9/35 (25,7%) studies were pre-post intervention studies without control group (Bailey & McInnis, 2011; Fu & Burns, 2019; Gao et al., 2012; Gao et al., 2017; Garde et al., 2016; Joyner et al., 2019; Mellecker & McManus, 2008; Rincker & Misner, 2017; Ye et al., 2018). Moreover, only 7/35 (20%) studies did not report the gender (Coombes & Jones, 2016; Gao et al., 2013; Mellecker & McManus, 2008; Miller et al., 2015; Rincker & Misner, 2017; Robertson et al., 2018; Viggiano et al., 2018).

Table 6. Intervention characteristics and strategies.

Author (year), Country	Participant´s age group (sample and age)	Study design and intervention duration	Description of intervention	PA assessment	PA results
Games					
Mellecker & McManus (2008), Japan	18 children (mean [SD] age, 9.6 [1.7] years).	Study design: Quasi-experimental. Only one group: (i) Traditional seated computer gaming; ii) Active gaming using the XaviX bowling, and iii) XaviX J-Mat gaming systems. Duration: After a 5-minute familiarization period to habituate the children to the gaming systems, each child completed a 25-minute gaming protocol. This consisted of the 5-minute seated baseline measure, 5 minutes of seated computer bowling, 5 minutes of XaviX bowling, 5 minutes of seated rest, and 5 minutes of XaviX J-Mat gaming (1 day).	All the children were familiar with traditional seated computer gaming; however, the XaviX active gaming system was not commercially available at the time of this study, and none of the children had any experience playing the XaviX active games. A computer-generated 10-pin bowling game was used for the seated gaming format. This game requires the mouse to be held down for a predetermined time and then released to complete a successful bowl. This game was played for 5 minutes seated at a computer desk. Two active games formats were chosen from the XaviX gaming system—XaviX bowling and XaviX J-Mat Jackie's Action Run. Game strategy: active video games	Outcomes: Energy expenditure (kcal/day). Resting energy expenditure and heart rate measured Instrument: Indirect calorimeter (Oxycon Pro; Viasys Healthcare, Warwick, England). Heart rate monitor (Polar Inc, Lake Success, New York). Measurement period: before/during/end intervention.	The energy expenditure was significantly higher during seated gaming compared with rest. The energy expended above rest was significantly higher for the 2 active gaming formats compared with seated gaming. The heart rate was significantly higher during XaviX bowling and XaviX J-Mat gaming compared with rest. Heart rate during the XaviX J-Mat gaming was significantly higher than during seated gaming.
Duncan & Staples (2010), United Kingdom	30 children (60% girls). Mean age (SD) 10.4 (0.5) years	Study design: Quasi-experimental - Experimental group. - Control group.	The intervention group undertook twice weekly active video game play sessions instead of their regular recess activity. Active video game play sessions used the Nintendo Wii	Outcome: Steps/min. Instrument:	Significant increase in the number of step/min steps was observed in first week for intervention group. However, the number of steps was higher in the

		Duration: 6-weeks. Twice weekly sessions of active video gaming during school lunch breaks with 15 children acting as controls.	console and employed 3 game titles, Wii Sports (Tennis), Sonic and Mario at the Olympics (100 m, 110 m hurdles) and Celebrity Sports Showdown (Horse Racing). Game titles were rotated during each session to avoid children becoming bored by playing the same game. Game strategy: active video games	Piezoelectric pedometer (New Lifestyles, NL2000, Montana, USA). Measurement period: at baseline, third, and sixth week.	control group in the middle and at the end of the 6-week period.
Bailey & McInnis, (2011), USA	39 children (51% girls): (mean [SD] age, 11.5 [2.0] years)	Study design: Quasi-experimental - Experimental group. - No control group. Duration: 8- weeks. Twice a week for 90 minutes and rotated through each of the exergaming systems being evaluated. Every participant spent 10 to 15 minutes on each system per day. In addition, participants were given 5 minutes of seated rest between each activity.	Children played the different gaming systems and levels to determine which were the most aerobically challenging (using a rating of perceived exertion scale), while still maintaining the gaming experience. Gaming systems came with multiple games as well as multiple levels within each game. Six exergaming systems were evaluated. These systems included Playstation (Dance Dance Revolution [DDR], Konami, Redwood City, California, using Sony Playstation, Nintendo Wii (Redmond, Washington), Xavix (SSD Company Ltd, Shiga, Japan), Cybex Trazer (Medway, Massachusetts), LightSpace (Light-Space Corp, Boston, Massachusetts), and Sportwall (Rolling Meadows, Illinois). Game strategy: active video games	Outcome: energy expenditure. Instrument: indirect calorimetry during PA and by means of a CosMed K4B2 portable metabolic cart (Rome, Italy). Measurement period: Following the measurement of seated energy expenditure, energy expended during 7 activities (6 exergames and treadmill walking).	Energy expenditure was elevated to a moderate to vigorous intensity level for all the activities evaluated. All forms of interactive gaming evaluated significantly increased energy expenditure above rest. The energy cost was highest for Xavix Jackie Chan Alley Run and Sportwall, followed by LightSpace Bug Invasion, Cybex Trazer Goalie Wars, DDR, and Nintendo Wii Boxing.

Baranowski et al., (2011), USA	153 children (56.2% boys) aged 10–12 years	Study design: Quasi-experimental - Experimental group: Diab and Nano adventures. - Control Group. Duration: 5-weeks. Each game had nine sessions and a minimum of approximately 40 minutes of gameplay per session. 6 hours of new gameplay per game.	Diab and Nano were designed as epic video game adventures. Each session had a knowledge mini game designed to provide practical knowledge related to change goals. Treatment group participants were loaned 24 inch iMac computers Game strategy: computer game - interactive game	Outcome: MTVPA Instrument: Actigraph AM-7164 accelerometers (Manufacturing Technology Inc. Health Services Division, Ft. Walton Beach FL). Measurement period: at baseline and post intervention.	Children playing video games "Diab and Nano adventures) did not increase MVPA levels. PA were below the minimum recommendations. There were no significant effects for PA.
Gao, Huang, Liu, & Xiong, (2012), USA	101 children (51.5% boys). (Mean age =10.36; SD = 0.98).	Study design: Quasi-experimental - Experimental group: Dance Dance Revolution (DDR) - Control group. Duration: 9– weeks (three 30-minute DDR sessions/week during recess)	DDR was offered and monitored during recess periods every weekday. When playing DDR, a player must move his or her feet to a set pattern, stepping in time to the general rhythm or beat of a song. While the game is in play, there are four stationary, transparent arrows at the top of the screen. Game strategy: interactive game	Outcome: MVPA Instrument: Physical Activity Questionnaire for Older Children (PAQ-C). Measurement period: at baseline and post intervention.	Follow-up tests indicated that children in the intervention group also displayed significantly higher 1-week daily PA levels than those in the control group. There was no significant difference on the change of outcome expectancy between the two groups.
Cui et al. (2012), Australia	682 adolescents (51.8 % boys) mean [SD] age, 12.7 [0.48] years).	Study design: Quasi-experimental - Experimental group. - Control group.	Four components: food choice, PA and sedentary behaviour, carbonated drinks, and goal setting, which directly aimed at behaviour change. Learning activities were designed to be conducted in a variety of ways, including presentation, video	Outcome: MVPA and sedentary behaviour in the previous week. Instrument: 7-day youth physical activity questionnaire.	There was no significant difference between groups in total MVPA, in-school and out-of-school MVPA and active commuting to school at 3 and 7 months.

		Duration: 8- weeks. Each component was designed to be taught at a 40-min	watching, group discussion, games experiments, lifestyle practice, skit playing, and quiz show. Each component was designed to be taught at a 40- min lesson. A peer leader's manual was developed to describe these structured activities. Game strategy: games-based learning	Measurement period: At baseline, 3 months, and 7 months.	
Gao & Podlog, (2012), USA	98 children (52% girls) mean [SD] age, 8.46 [1.26] years).	Study design: Experimental - Experimental group. - No control group. The participants were randomly assigned into 1 of the following 3 goal-setting conditions: (1) easy, (2) difficult, and (3) best effort (hereinafter referred to as do-your-best goal). Duration: 8- weeks. 45-minute after-school PA program 4 times per week.	Each school was furnished two sets of Playstation 2, the software ''In the Groove'' (Red Octane, Sunnyvale, CA), and two padded dance mats with an 8 MB memory card. Like with a jukebox, youth could pick their own songs from ''In the Groove,'' with some having more complicated foot patterns or faster tempos to challenge the subjects over the semester. Game strategy: active video games based on dance PA	Outcome: steps per minute were used as the outcome variable. PA levels were measured using piezoelectric pedometers, and steps per minute Instrument: Piezoelectric pedometer (New Lifestyles Inc, NL1000, Montana, USA). Measurement period: The students were advised to reset the pedometers to 0 at the beginning of the warm-up and turned in the pedometers at the end of the program.	Children's increased PA levels in the easy-goal (mean increase, 10.34 [95% CI for mean difference, 4.32-16.34] steps per minute(SPM)) and difficult-goal groups (22.45 [16.43-28.48] SPM) were significantly higher than those in the do-your-best group (0.83 [−5.30 to 6.96] SPM). In addition, children who were provided with difficult goals displayed greater increased PA levels than those in the easy-goal group (95% CI for mean difference, 3.6-20.63).
Maloney et al. (2012), USA	58 children: the average age of the sample was 13.7 years	Study design: Quasi-experimental	PlayStation 2 (Sony Corporation of America, New York, NY) hardware, the software ''In the Groove'' (Red	Outcome: Sedentary, light PA, moderate PA, vigorous PA, and MVPA.	They did not measure exergame intensity at baseline.

	(SD = 0.6), approximately half of the participants were girls.	- Experimental group: Generation Fit (GenFit) - Control group. Duration: 40 minutes per 10 weeks in Physical Education lessons. .	Octane, Sunnyvale, CA), and two padded dance mats with an 8MB memory card. The game is designed to be danced in rounds of three songs totalling approximately 5 minutes for a round. Participants were encouraged to set a goal of about 10 minutes per day on 4-5 days per week. Game strategy: active video games based on dance PA	Instrument: GT1M ActiGraph accelerometers (Fort Walton Beach, FL). Measurement period: Three time points during a single second school semester. Drawing names randomly from the 17 study completers at Week 20 from one school, four participants were selected to wear a hip-worn accelerometer to measure the intensity of the bouts of activity. in real-time?	However, during bouts of dance, on average, youth obtained 2.1 minutes (SD = 0.6) of light PA, 2.8 minutes (SD = 0.5) of MVPA, and 1.6 minutes (SD = 0.3) of vigorous PA while dancing one full exergame cycle of three songs at the study end point.
Gao et al., (2013), USA	208 Latino school children. Grade-4 to Grade-6 students	Study design: Quasi-experimental - Experimental group = Dance Dance Revolution (DDR). - Control group. In Year 1 and 2 Year, experimental group (Grade-4 students) offered 30 minutes of exercise (DDR, aerobic dance) three times per week. Control group (Grade-3 and Grade-5) were offered no structured exercise at school.	DDR requires full body movement, which serves as an important bridge that catches children's interest and gets them up to a health-enhancing level of fitness. DDR combines real physical dancing requiring fast foot movement with energetic music and visuals. Total of eight DDR stations were set up in the gym, with each DDR station accommodating two children. Game strategy: active video games based on dance PA	Outcome: Cardiorespiratory fitness. Instrument: Cardiorespiratory endurance assessment (1-mile run). Measurement period: At baseline f in (August 2009). Each cohort was then tracked to the second year and higher grade after a 2-month washout period (Summer 2010). The participants completed follow-up fitness assessments in May 2010 (Year 1), and again in	Data yielded significant differences between the intervention and comparison groups in differences in 1-mile run and math scores in Year 1 and Year 2.

		In Year 2, intervention (Grade-4), whereas Grade-5 and Grade-6 students were in the control group. Duration: two academics courses. With the school's support, the two recesses were combined into a 30-minute PA program within the Grade-4 curriculum		August 2010, and May 2011 (Year 2).	
Gao & Stodden (2013), USA	53 students -children (54.7% girls) Mean age: 10.3 years	Study design: Quasi-experimental - Experimental group: Dance Revolution - Experimental group: Aerobic dance group. - Control group. Duration: 9 months academic year. DDR-based program that was integrated in regular PE (three 30-min sessions per week).	DDR and aerobic dance, PE classes included other sports and fitness activities, such as jumping rope, volleyball, soccer, etc. Eight DDR station were set up next to the walls of the school gym with each DDR station can accommodating two children. For the aerobic dance, research assistant led the children to dance in the centre of the gym. Game strategy: active video games based on dance PA	Outcome: steps/min and MVPA. Instrument: NL-1000 piezoelectric pedometers Measurement period: Research assistants recorded the steps and MVPA at the end of the 15-min session, after resetting the pedometers to zero before the DDR/aerobic dance.	Children spent 21% of time in MVPA time in DDR and 31% of time in the MVPA time in aerobic dance. Children demonstrated significantly higher MVPA time in aerobic dance than they did in DDR.

Miller et al., (2015), Australia	168 children; mean age=11.2 years, SD=0.95)	Study design: Experimental - Experimental group: Professional Learning for Understanding Games Education (PLUNGE). - Control group. Duration: 7- weeks.	Children were exposed to the PLUNGE intervention for the development of practical instruction skills, promotion of a mastery climate and use of game focussed on curriculum delivered via an in-class. Game strategy: games-based learning – active game -	Outcome: steps/min. Instrument Pedometer (Yamax Digi-walker CW700). Measurement period: prior to the intervention period and during weeks 6 and 7 of the intervention period to compare PA of the developed curriculum relative to the control group.	Significant group-by-time intervention effects (all $p < 0.05$) and in-class pedometer steps/min ($d = 1.0$). No significant intervention effects ($p > 0.05$) were observed for perceived sporting competence.
Direito et al. (2015), New Zealand	51 adolescents (57% girls): age 15.7 years (SD 1.2)	Study design: Experimental - Experimental group: immersive app Zombies run. - Experimental group: nonimmersive app -Get Running. - Control group. Duration: 8-weeks.	The 2 intervention groups allowed comparison of an identical delivery approach (i.e., stand-alone app), but with distinct design features: (1) use of an immersive app or (2) use of a non-immersive app. Both apps consisted of a fully automated 8-week training program designed to improve fitness and ability to run 5 km; however, the immersive app featured a game-themed design whereby the training program was embedded with a story where the user is trained to collect supplies and protect a town from zombies.	Outcome: Estimate VO_2peak (CRF). Mean daily time (min) spent in sedentary and light-to-vigorous PA. Instrument: - CRF= 1-mile run/walk test. -Accelerometer (Actigraph GT1M). -Physical Activity Questionnaire for Adolescents (PAQ-A)	Time to complete the fitness test decreased in both app groups, but there were no statistically significant differences observed between the intervention groups and the control. Group assignment did not have a significant effect on overall activity or mean daily time spent in MVPA. In addition, no intervention effects were found for self-reported PA.

			Game strategy: active video games by mobile app	Measurement period: at baseline and final the intervention	
Garde et al. (2015), Canada	47 children (66% girls): age 10.2 (SD:1.2) years.	Study design: Experimental - Experimental group: game group MobileKids Monster Manor (MKMM) - Experimental group: "feedback" group (activity feedback through tractivity online software. - Duration: 2-weeks.	The mobile phone game ("MobileKids Monster Manor") has activity monitor to transfer steps to an in-game currency that can be redeemed for additional playtime. For the game group, subjects were divided into three in-game teams that competed remotely against individual players. The feedback group had access to online tractivity and received quantitative PA through the web. Game strategy: active video game by app	Outcomes: PA steps and PA minutes Instruments: Tractivity activity monitor accelerometer (Kineteks Corporation, Vancouver, Canada). Measurement period: first week at baseline data collection and second week.	A significant increase PA during the intervention period compared with the baseline. Steps and active minutes during both interventions were increased.
Sharma et al. (2015), USA	94 children (57% girls): age 9-11 years.	Study design: Experimental - Experimental group. - Control group. Duration: 6- weeks. Implemented as part of the in-school or afterschool program. Recommended game exposure duration was 90 min/week.	Quest to Lava Mountain (QTLM) Computer Game is a web-based game of approximately 10 hours' duration. The game starts with easy levels and progress to increasingly challenging and more complex levels. Game components include mazes, interactive activities, and simulations to integrate nutrition and PA concepts.	Outcome: PA behaviours: frequency (day per week) and outdoor play. Instrument: Nutrition and Physical Activity Habits and Related Psychosocial Mediators (questionnaire). Measurement period: at baseline and post intervention.	Compared with the comparison group, children in the intervention group reported higher physical activity attitudes (P=0.041) pre- to postintervention. There were no significant effects of QTLM on physical activity.

			Game strategy: web-based game (Computer-based educational games)		
Garde et al. (2016), Canada	42 children (61.9% boys): age 11.3 (SD: 1.2) age.	Study design: Experimental - Baseline - Experimental group: MobileKids Monster Manor (MKMM) - Washout and control/interventi on phase Duration: 4-weeks (one session each week).	MKMM has activity monitor to transfer steps to an in-game currency that can be redeemed for additional playtime. For the game group, subjects were divided into three in-game teams that competed remotely against individual players. Incorporates behavioral psychology and positive peer. In addition, offers gold as a within-game prize to players to encourage then to venture through the gamers ascending levels. Game strategy: Active video game: app	Outcome: Steps and active minutes Instrument: Tracktivity activity monitor accelerometer (Kineteks Corporation, Vancouver, Canada). Measurement period: at baseline and post intervention.	When children were exposed to the game, an increase compared with the control phase of 2,934 steps per day and 46 active minutes per day from baseline (12,299 steps/day and 190 active minutes/day) was observed. MKMM yielded a greater increase in steps and active minutes per day among children
Lau et al. (2016), China	80 children (68.8% boys): age 8–11 years	Experimental study design. - Experimental group: Active video game (AVG). - Control group. Duration: twice per week during after-school hours, each for 60 minutes over 12 weeks	The Kinect for Microsoft Xbox 360 was used to deliver the AVG intervention. Children shared one play station. The Kinect sensor is compatible with all the Xbox 360 models and this technology uses a webcam style sensor device, allowing participants to play the game without any joystick or hand controller in a large function room. The sensor recognizes the user's gestures and voice commands.	Outcome: Vo2max., light PA, moderate PA, vigorous PA, and MVPA. Instrument: Aerobic fitness. Participants' levels of aerobic fitness were assessed using the Progressive Aerobic Cardiovascular Endurance Run (PACER) 20-m	Compared with the control group, children in the intervention group had higher VO2max at post-test. For the effect of the 12 weeks of PA, significant difference was found for VO2max in the intervention group compared with the control group. No significant differences were detected for total PA and MVPA at baseline. Significant increases in total PA and MVPA were observed at post-test within the intervention group (total

			The two Seasons feature both team-based and individual sports, including 10-pin bowling, boxing, track and field, table tennis, beach volleyball, and association football in Season 1 and golf, darts, baseball, skiing, tennis, and American football in Season 2 Game strategy: active video games	shuttle run performance test. Participants' PA was measured using the ActiGraph GT3X+ accelerometer. Measurement period: baseline and at the end of intervention period	PA: t=-5.40, P < 0.001; MVPA: P < 0.001). Compared with the control group, children in the intervention group had higher total PA at post-test (t = 2.15, P = 0.035). No significant difference in MVPA was detected at post-test across groups.
Rincker & Misner (2017), USA	404 children (Grades 1 to 5).	Study design: A quasi-experimental - Experimental group 1. Exergaming/PE: Group 1 received AVG - Control group: Group 2 received face-to-face - Experimental group2 : Group 3 received both AVG and instructor-provided fitness lessons. Duration: 6- weeks. During their daily Physical Education lessons, students in each group received five	The AVG activity introduced students to cultural Irish dance with active exercise, as made popular in the well-known production of River Dance. This health education module introduced specific Irish dance steps for a beginner-level dance (the "reel") to encourage student participation in individualized exercise. Game strategy: active video games based on dance PA.	Outcome: activity heart rates Instrument: Microsoft Kinect, a full-body tracking device. Measurement period: pre- and post-activity heart rates.	The mean resting heart rate for Group 1 was 96.7 (*SD* = 12.1). The mean gaming heart rate was 25 points higher than the mean resting heart rate (121.6 vs. 96.7; p < .001). The mean peak heart rate was 132.9, 11 points higher than the mean gaming heart rate of 121.6. AVG students achieved comparable levels of mastery, significantly elevated heart rates.

		days of intervention exposure.			
Gao et al. (2017), USA	261 children (51.3% girls: age 8.27 (SD: 0.7) years.	Study design: quasi-experimental - Experimental group (Exergaming/PE) group (125 min weekly of exergaming-based PA program). - Control group (125 min weekly of PE). Duration: approximately 8 PE learning units in 2 semesters (125 min of weekly structured PA programs, with exergaming and PE alternating daily each week).	Several exergames were offered, including but not limited to Kinect Ultimate Sports, Just Dance, Wii Sports, and Wii Fit. A trained teacher supervised the participation of exergaming. Each station accommodated the gameplay of 2 children, who rotated stations twice during each session, allowing for a short-duration transition. All children in class had the opportunity to play exergaming simultaneously and were able to engage in different activities during the program. Game strategy active video games	Outcome: sedentary behaviour, light PA, moderate PA, vigorous PA, and MVPA. Instrument: ActiGraph GTX3 accelerometers (ActiGraph, Fort Walton Beach, FL, USA). Measurement period: entire 3-day period during school hours. Pre-test, post-test, and follow-up.	Children in the exergaming/PE intervention accumulated significantly greater light PA and MVPA time at school ($p < 0.01$) and nonsignificant yet higher EE at post-test than was seen during pre-testing. Exergaming PE could have the same positive effect on children's light PA, MVPA, and energy expenditure as regular PE.
Chen & Sun (2017), USA	65 children (61.53% girls); age 9.65-10 years	Study design: Quasi-experimental - Experimental group= active video game (AVG). - Experimental group= (SPARK). - Control group. Duration: 6- weeks. 40 minutes per 3times/ week.	Compared to traditional PE programs, the SPARK PE curriculum aims to help students accumulate greater in-class PA and enhance their health-related fitness. The two games used during the intervention were Zumba Kids (used for eight sessions) and Just Dance Kids 2014 (used for nine sessions). Most songs from both games feature three or four on-screen dancers with participants dancing at the same time	Outcome: time and percentage of time in sedentary behaviour, light PA, moderate PA, vigorous PA, and MVPA. Instrument: GT3X+ ActiGraph, accelerometers.	The comparisons of the objectively measured PA levels between the two intervention groups showed that Kinect AVG group generated higher light PA and lower sedentary time for three and two sessions, respectively. The results of MVPA comparisons, however, were inconclusive in the current study.

			to mimic the movements of the on-screen dancers. Game strategy: active video games based on dance PA.	Measurement period: first week, third week, and e fifth week.	
Wang et al. (2017), China	179 children aged 10.2 years (57.5% boys).	Study design: Quasi-experimental -Experimental group (Diab). -Control group. Duration: 8-10 weeks depending on the completion of game play. session: 2 sessions -40-minute morning sessions before classes or 1 session-90-minute afternoon session afterschool	Health video game embedded with story immersion. Diab tells the story of DeeJay, an athletic and healthy modern-day youth. He accidentally falls through the floor of an abandoned building into a world, named Diab, where fruit, vegetables, and PA are forbidden by evil King Etes. The game is based in Behavior change components, minigames with tailored knowledge, motivational statements, goal setting and review, feedback, problem solving, and behavioral inoculation. Diab gamed played in the school's multimedia classroom on single consoles at the scheduled sessions. Game strategy: videogame	Outcome: Self-reported PA. Objective PA. Sedentary behaviour, light PA, and MVPA. Instrument: Self-reported PA. The researchers used the Physical Activity Questionnaire for Older Children (PAQ-C). Objective PA. The ActiGraph GT3X (ActiGraph, Pensacola, FL). Measurement period: at baseline, immediately after the game (post 1: about 8–10 weeks after baseline), and 8–10 weeks after the game (post 2: 8–10 weeks after completion of game playing; follow-up times were kept the same as the duration of intervention for each participating school).	Children had increased intrinsic self-efficacy for PA, and self-reported PA scores at post 1 (all $P < .05$). However, these were not significant at post 2 ($p>0.05$). Whereas these measures decreased in the control group. The objective PA level did not demonstrate a positive change in the study.

Viggiano et al. (2018), Italy	1313 children (7–11 years old).	Study design: Experimental - Experimental group (Kaledo). - Control group. Duration: 15– 30 min every week for 20 weeks.	Kaledo is a board game that can be played by up to four people at a time and is composed of the following materials: -One play board with 59 boxes (+1 start box) marked on it. -100 cards (80 cards related to nutrition and 20 cards related to activity). -Four pawns or play pieces -40 Kaledo chips. -One dice with six sides. -Four "kaleidoscopes," by which the player can add energy (for food intake) or subtract energy expenditure (for physical activity) to the basal metabolic rate (BMR). -One guide explaining the rules of the game. Game strategy: board game	Outcome: self-reported frequency and duration of PA. Instrument: WHO Health Behaviour in School-aged Children (HBSC) PA questionnaire. Measurement period: at baseline and at two post-assessments (8 and 18 months).	Both groups significantly increased ($p < 0.01$) the frequency and duration of PA at 8 months compared to baseline. However, the treated group showed an increase in frequency and duration of PA compared to the control group. At 18 months, there was a significant increase in frequency and duration on PA for the control group and the experimental group compared to baseline. Experimental group also showed a significant increase in frequency and duration of PA compared to the control group.
Robertson et al. (2018), Scotland	215; 10-11 years old.	Study design: Quasi-experimental - Experimental group (FitQuest). - Control group. Duration: 5 weeks.	FitQuest is a suite of separate mini-games, consistent themes and an overarching points system tie the games together in Physical Education. A player can earn up to 10 points from each mini-game, which is accumulated as a session	Outcome: step count, minutes spent on MVPA and exercise self-efficacy. Instrument: Piezoelectric pedometer (New	Step counts, and minutes spent on MVPA were lower (no significant result) in the FitQuest group compared with the control group.

		During at least one hour of mandated Physical Education lessons per week	total, and running total over multiple sessions. Control arm took part in standard mandated Physical Education lessons. The children could match their game choices to their energy levels, and the short nature of the mini-games fit enable flexibility to fit around school timetabling constraints. Game strategy: serious game/exergame	Lifestyles Inc, NL1000, Montana, USA). Measurement period: one week before the intervention and one week after the end of the intervention	
Fu (2018), USA	65 preschools (52.3 % boys); age 4.9 (SD 0.7) years.	Study design: Experimental - Experimental group: exergaming. - Control group (free-play), Duration: 12 weeks. AVG curriculum for 30 minutes per day, 5 days per week by the trained classroom teacher and 1 trained graduate assistant.	One exergaming station included a computer, a projector, and a screen, and was set up in a spacious classroom for all the children to play at the same time. Children played "GoNoodle" for 15 minutes, followed by 10 minutes playing "Adventure to Fitness," followed by 5 minutes allocated in the "Cosmic Kids Yoga," which was used as the cool-down activity. "Adventure to Fitness" included more than 40 video episodes with each episode providing an estimated 30 minutes of MVPA while taking students on a fun adventure to a fascinating part of the world or time in history. Game strategy: active video game/exergame	Outcome: School-day step counts. Instrument: Yamax Digi Walker CW600 pedometers (Warminister, PA). Measurement period: for one preschool week (Monday–Friday) and during the final week of the intervention	Exergaming group demonstrated higher school-day step counts. The exergaming group displaying higher mean scores compared with the free-play group. Significant differences between groups on average step counts (Mean difference = 785 steps, P = 0.003, d = 0.68).
Garde et al. (2018), Canada	A total of 37 children (61% girls): age 10-11 years.	Study design: Experimental	Players' steps are redeemed for rewards such as in-game items and the unlocking of new characters.	Outcome: steps and active minutes.	Game group averaged 1,758 more steps/day and 31.3 more active minutes/day relative to their baseline

		- Experimental group: The Mobile kids Monster Manor (MKMM) game uses a monster character theme. - Control group. Duration: 4 - weeks.	MKMM leverages behavioural psychology in the form of positive peer pressure. Players are assigned to three teams and team members work together to achieve a higher total score. The game allows players within teams to encourage and congratulate their teammates' efforts using present messages. Players completing PA challenges add to their teams' total score, in addition to unlocking items and characters for themselves. Game strategy: active video game	Instrument: Tractivity activity monitor accelerometer (Kineteks Corporation, Vancouver, Canada). Measurement period: At baseline, during intervention and follow up.	than the Control group. These results showed that MKMM successfully increased PA during the first intervention week, but this activity boost was not maintained during the second intervention week and follow-up.
Pope et al. (2018), USA	75 adolescents (71% girls): age 16-18 years.	Study design: Quasi-experimental - Experimental group: electronic gaming application. - Control group. Duration: 12- weeks. Each week , investigators would send out email reminders to participants to wear their FitBits	Camp Conquer was developed to motivate high school students to meet PA goals. Camp Conquer is a capture the flag-style game, where students are divided into two teams, and each day a water balloon battle is waged between the two teams. The water balloon battle took place each weekday; games did not take place on weekends. Game strategy: game based learning	Outcome: Number of steps/days and active minutes. Instrument: FitBit Flex. Measurement period: during the whole/entire intervention	The present intervention was not successful in increasing PA in high school students. There were non-significant differences in steps number and active minutes between the intervention group and control group.
Fu You & Burns Ryan D. (2018), USA	65; age 11-12 years (55.4% girls)	Study design: Quasi-experimental - Experimental group (AVG curriculum). - Control group	Children had three 30-minute AVG sessions in the classroom per week, supervised by the trained classroom teacher and 1 trained graduate assistant. One AVG station was installed in the classroom that	Outcome: daily step counts. Instrument: Yamax DigiWalker CW600 pedometers (Warminister, PA).	At baseline, there were no differences between the AVG group and control group on school day step counts P>0.05 There was no group × time interaction for step counts (P = .03); however, there was a trend of decreasing steps counts in the comparison group (mean

		Duration: 30 min/day, 5 days/week for 18 weeks.	included a computer, a projector, and a screen. Throughout the duration of the entire 30-minute AVG session, several video games were provided to increase students' motivation and interest. Game strategy: active videogame	Measurement period: for 1 school week (Monday to Friday). At baseline, post intervention, and 18-week post-test.	difference = −1178 steps, P < .001) but not in the AVG group (mean difference = −534 steps, P = .20).
Fu et al. (2019), USA	16 children: age 7.1 (SD:0.7) years (62.5% boys).	Study design: Quasi-experimental Experimental group (AVG) Duration: 12-weeks. AVG for 30 minutes per school day (10 minutes per session).	Children played a series of AVGs (e.g., Adventure to Fitness, GoNoodle, and Cosmic Kids Yoga) in their classroom, supervised by their full-time classroom teacher. In each 10-minute AVG session, children played 5 minutes of "GoNoodle", then 2–3 minutes of "Adventure to Fitness," and ended with 2–3 minutes allocated to "Cosmic Kids Yoga," which was used as a cool-down activity. Game strategy: active video games	Outcome: light PA, moderate PA, vigorous PA, and step counts. Instrument: ActiGraphGT3X+ accelerometers (ActiGraph Ltd., Pensacola, FL, USA). ActiGrap. Measurement period: weekly over 12 consecutive weeks.	There were significant time trends for SB, light PA, vigorous PA, step counts, (p < 0.001). Specifically, SB tended to decrease, and time spent in light PA, vigorous PA, and step counts tended to increase. Moderate PA did not significantly change across the 12 weeks.
Gao et al. (2019), USA	81 children: age 9.23 (SD:0.62) years (52.25% boys).	Study design: Quasi-experimental - Experimental group (AVG). - Control group. Duration: 9 months academic year (a once-weekly 50 min AVG during recess).	The program was integrated into the intervention school's curriculum, with a full-time PE teacher supervising the program. Eight AVG stations in a fitness room, with each station equipped with one of two AVG systems (Xbox 360 (Microsoft; Redmond, WA, USA) or Nintendo Wii (Nintendo; Kyoto, Japan)), a TV, and necessary ancillary supplies. It offered several developmentally-appropriate AVGs including Just	Outcome: Energy Expenditure. (EE) kilocalories/day Instrument: ActiGraphGT3X+ accelerometers (ActiGraph Ltd., Pensacola, FL, USA). ActiGrap.	Children in the intervention group had increased METs/day whereas children in the control group demonstrated decreased METs/day over time. Both groups' daily caloric expenditure increased markedly across time, but the intervention children demonstrated significantly greater increases in this outcome.

			Dance, Wii Fit, Gold's Gym Cardio Workout, and Kinect Sports (children rotating from one station to another station every 10 min—allowing for a 45 s transition). Game strategy: active video games based on fitness	Measurement period: 3 days to capture their regular PA behavior at baseline and at the 4th and 9th months.	
Gao et al. (2019), USA	56 preschool children age 4.45 (SD:0.46) years (55.4% girls).	Study design: Quasi-experimental - Experimental group: Exergaming. - Control group. Duration: 8- weeks.100 min of exergaming/week (5 days x 20 min) at school.	Research team set up 8 exergaming stations in a large room separate from the main classroom. Each station was equipped with 1 exergaming system (Wii or Xbox Kinect), a television, and necessary ancillary supplies. Exergaming play occurred individually, in pairs, or as a group, with the supervising teacher or research assistant assisting children in gameplay throughout to ensure continuous gameplay and, thus, PA. Game strategy: active video games based on fitness	Outcome: light PA and MVPA time. Instrument: accelerometers ActiGraph GT9X LINK acelerometers (ActiGraph Corp., Pensacola, FL USA) Measurement period: during the school day for 3 school days during the first week baseline and after the 8th week of the study.	Intervention children had significantly greater increased on the time in MVPA than those in the control group.
D'Egidio et al. (2019), Italy	150 students aged 6-8 years (55% boys).	Study design: Quasi-experimental Unique Experimental group= GiochiAMO Duration: 1 academic year.	The first phase, including an informative session about the food pyramid and PA by experts of public health and preventive medicine (oral presentation). The second phase, including only the experimental groups, involved games focusing on the main concepts of the food pyramid and PA.	Outcome: MVPA (self-reported). Instrument: validated questionnaire PAQ-C. Measurement period: five months after the beginning of the intervention/the	Behaviour score was 27.4 (SD: 9.6) before PA intervention and 30.5 (SD: 10.7) after it. A total of 35 students (70%) improved their PA behaviour. Thus, there were significant differences before and after the intervention concerning PA behaviour score (P = 0.003).

			It included educational seminars/sessions and interactive games to promote healthy nutrition and PA and to prevent smoking and alcohol abuse among elementary school students. Different board and card games were created for the intervention. All games aimed at teaching the principles of the food pyramid and PA pyramid. Each class received a kit-game with cards, board games and an instruction manual. Game strategy: interactive Games (board and card games)	post-intervention and follow- up.	
Ye et al. (2019), China	81 children (51.9% boys): age 9.23 (SD:0.62)	Study design: Quasi-experimental - Experimental group. - Control group. Duration: 8 months. Once weekly. 50min in recess. The intervention was during recess throughout the school year, while the children in control group continued regular recess activities.	Nine exergaming stations were set up in classroom (Xbox 360 or Nintendo Wii). Children rotating stations every 10 minutes each session. Game strategy: active video games based on fitness	Outcomes: PA time CRF Instrument: ActiGraph GT3X accelerometers. CRF: half-mile run Measurement period: at baseline, mid-intervention (four months), and post-intervention (eight months)	PA significant time increase by group intervention were found for LPA and MVPA. LPA increased among the control group. MVPA increased in the intervention group. CRF demonstrated lower over time for both groups.
Gamification					

Coombes et al. (2016), United Kingdom	80 children: age 8-10 years	Study design: Quasi-experimental - Experimental group. - Control group. Duration: 8 weeks.	In total 40 Beat Boxes were installed in the street environment; 38 were placed on lampposts in the three intervention neighbourhoods and an additional 2 were placed in the city centre approximately 3 km away. Participants were awarded a point each time they touched their smartcard on a sensor, allowing children to compete against other pupils at their school to see who could achieve the most points. Gamification elements: researcher motivated children though via competitions and weekly spot prizes.	Outcome: Sedentary behaviour, light PA, moderate PA, vigorous PA, and MVPA. Instrument: ActiGraph GT3X+ accelerometer. Measurement period: at baseline, during the intervention, post-intervention, and 20 weeks post-intervention.	PA overall was not higher at follow-up among intervention children compared to controls. However, there was a positive association between MVPA during school commute times and the number of days on which children touched a Beat the Street sensor.
Joyner et al. (2019), USA	29 children: age 12 years (59% girls).	Study design: A single-case experimental. An ABAB reversal design was used (with "A" referring to pre/post intervention baseline phases and "B," to the FIT Game phases). - Baseline 1 (Days 1-10, 2 School Weeks) - FIT Game Phase 1 (Days 11-20) - Baseline 2 (Days 21-30) - FIT Game Phase 2 (Days 31-40) Duration: 8-weeks. Episodes were displayed on a screen 108 approx. 15 minutes before recess.	The FIT Game is a science-fiction narrative in which the Field Intensive Trainees (the FITs). The comic book–formatted FIT Game narrative was presented in slideshow episodes, with a different episode presented each day when PA goals were met the previous day.	Outcome: step count. Instrument: Fitbit Flex, (San Francisco, CA). Measurement period: during pre/ post intervention for 5 days.	Children met their PA goals on 16 of the 20 days (80%) of the FIT Game phases, increasing their median step counts from 3,331 per day during baseline to 4,102 per day during the FIT Game phases (X2=39.0; P<.001). From Baseline 1 to FIT Game phase 1, PA increased significantly by a median of 1,073 steps per child per day (W=425; P<.001; r= 0.603). During Baseline 2, the average number of steps significantly decreased from levels observed in FIT Game phase 1 (W=399; P<.001; r= 0.566), thereby demonstrating experimental control over PA.

			Gamification elements: narrative history and awards.		When the game resumed in FIT Game phase 2, the PA increased significantly above Baseline 2 levels by a median of 658 steps Step counts during FIT Game Phase 2 were also significantly higher than Baseline 1 by a median of 1204 steps (W=335; P=.001; r= 0.476).
Beemer et al. (2019), USA	292 students age 8–13 years (51% boys).	Study design: Quasi-experimental Implementation consisted of three phases: - Ramp-up. - Standard intervention. - Gamified intervention. Duration: 20-weeks.	Ramp-up: During weeks 1–4, students completed a 1x 4 min activity break per day during the first week and then to add a 1x4 min activity break each successive week until reaching 5x4 min activity breaks per day. Standard intervention: During weeks 5–11, teachers implemented standard 5 x 4 min activity breaks per day without gamification components. Gamification of activity breaks occurred during weeks 13–20 of the intervention and included the use of game design elements and classroom goals for activity break intensity. Gamification elements: Each classroom received challenging weekly goals, the daily,weekly, and post-intervention incentives, reinforce positive behavior among students with daily reward and included an opportunity to win a	Outcome: Sedentary time, light PA and MVPA (as 60%–85% of heart rate maximum) and PA participation (intensity of activity breaks performed). Instrument: Direct observation via the System for Observing Play and Leisure Activity in Youth (SOPLAY). Measurement period: At baseline, during and post intervention.	There was a significant effect of intervention with a 27% increase in student MVPA participation during the gamified intervention weeks compared with the standard intervention weeks (p = 0.03). During the gamified intervention, there was a 4.9% - 0.04% increase in MVPA participation per week, however, this change was insignificant (p > 0.05) in the end of intervention.

			personalized t-shirt, trophies and stickers as weekly rewards.		
Melero-Cañas et al. (2021), Spain	150 adolescents (60% boys): age 14.63 (SD: 1.38) years.	Study design: Quasi-experimental - Experimental group. - Control group. Duration: 9 months.	Each group received two PE lesson per week, lasting 55 minutes. Experimental group participated in a PE program based on the Hybridization of TPSR and gamification strategies considering game-based learning. And control group was carried out traditional learning methods. Gamification elements: Powerful narrative, challenges: Class climate, Immediate feedback badges for achievement and final status and game-based learning.	Outcomes: Physical fitness (CRF) Time spent practicing PA (in school and after school). Instrument: Cardiorespiratory fitness by the 20m shuttle run test lifestyle habits. YAP-S questionnaire Measurement period: At baseline and post intervention.	Significant differences were observed concerning to the CG in APA-weekend ($p = 0.044$), speed-agility ($p = 0.005$) and agility ($p = 0.008$) Regarding the intervention, cardiorespiratory fitness ($p = 0.000$), speedagility ($p = 0.000$), strength ($p = 0.000$), flexibility ($p = 0.000$), agility ($p = 0.000$), PA in school ($p = 0.011$), APA-weekday ($p = 0.001$), APA-weekend ($p = 0.000$), APAweek ($p = 0.000$), increased significantly in the EG.

Foot notes:
Physical Education (PE)
Cardiorespiratory fitness (CRF)
Youth Activity Profile questionnaire (YAP)
Teaching Personal and Social Responsibility (TPSR)
maximal oxygen uptake (Vo2max)
Dance Dance Revolution (DDR)
sedentary behaviour (SB)
Energy Expenditure (EE)
Sports, Play and Active Recreation for Kids (SPARK)
Ligh physical activity (LPA)
"A" referring to pre/postintervention baseline phases and "B," to the FIT Game phases (ABAB)

c) Intervention's characteristics

Interventions

This review identified 35 interventions studies, where 31 used games (Bailey & McInnis, 2011; Baranowski et al., 2011; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gaoet al., 2019; Gao et al., 2013; Garde et al., 2018;Garde et al., 2016; Garde et al., 2015; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018) and 4 studies used the strategies' gamification (Beemer et al., 2019; Coombes & Jones, 2016; Joyner et al., 2019; Melero-Cañas et al., 2020). The games named "active video games" 13/35 (37,1%) used the technology such as the PlayStation (Xbox 360 or Nintendo Wii) (Bailey & McInnis, 2011; Chen & Sun, 2017; Duncan & Staples, 2010; Fu & Burns, 2019; Gao et al., 2017; Gao et al., 2019; Gao et al., 2019; Lau et al., 2016; Maloney et al., 2012; Ye et al., 2018) to promote PA through dance, sports or adventures games, and web-based game (Baranowski et al., 2011; Fu & Burns, 2018; Robertson et al., 2018). As for gamification, it employed different strategies such as the creation of a narrative (Joyner et al., 2019), challenging goals, providing incentives, and reinforcing positive behaviour among with daily reward (Beemer et al., 2019; Coombes & Jones, 2016; Melero-Cañas et al., 2020).

Intervention duration and frequency

The intervention duration was different in each study and diverse results were obtained regardless of the intervention period from one day (Mellecker & McManus, 2008) to academic course (D'Egidio et al., 2019; Gao et al., 2013). Interventions of the following durations predominated;8-weeks(Bailey & McInnis, 2011; Coombes & Jones, 2016; Cui et al., 2012;Direito et al., 2015; Gao & Podlog, 2012; Gao et al., 2019; Joyner et al., 2019) 7/35 (20%); 6-weeks (Chen & Sun, 2017; Duncan & Staples, 2010; Rincker & Misner, 2017; Sharma et al., 2015) 4/35 (11,4%) and 12-weeks (Fu & Burns, 2019; Fu et al., 2018; Lau et al., 2016; Pope et al., 2018) 4/35 (11,4%).

Secondly, predominated 4-weeks (Garde et al., 2018; Garde et al., 2016); 5-weeks (Baranowski et al., 2011; Robertson et al., 2018); 20 weeks (Beemer et al., 2019; Viggiano et al., 2018); 9 months (Gao et al., 2019; Melero-Cañas et al., 2020) and one academic course (D'Egidio et al., 2019; Gao et al., 2013). There were reported shorter intervention periods such as 2- weeks (Garde et al., 2015); 7- weeks (Miller et al., 2015); 8-10 weeks (Wang et al., 2017); 9– weeks (Gao et al., 2012); 10 weeks (Maloney et al., 2012); 18 weeks (Fu & Burns, 2018); 2 semesters (Gao et al., 2017); 8 months (Ye et al., 2018). In relation to frequency, it is very difficult to group due to the great

variety between each study. Sessions are usually held one session each week (Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2016; Pope et al., 2018; Robertson et al., 2018; Viggiano et al., 2018; Ye et al., 2018) (11/35 (31,4%)) and twice weekly sessions (Bailey & McInnis, 2011; Duncan & Staples, 2010; Lau et al., 2016) (3/35 (8,6%)).

Strategies for implementing the interventions

In the current review, the most common included strategies were: 1) teacher's implementation; 2) research team implementation; 3) incentives to participate; and 4) parents' participation (**table 7**).

Intervention by teachers' implementation

A total of 11/35 (31,4%) studies (Beemer et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2018; Fu et al., 2018; Gaoet al., 2019; Gao et al., 2013; Garde et al., 2018; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Miller et al., 2015; Robertson et al., 2018; Viggiano et al., 2018) were carried out mainly focusing on the role of the "teacher". The teacher implemented the intervention. Some examples are in the study by Gao et al. (2013) the video game - based exercise-was implemented by classroom teachers and centre activities were monitored by research assistants. Moreover, Fu & Burns (2018) incorporated AVG into the curriculum as part of school class time. In contrast, Fu & Burns (2019) incorporated the AVG program into the students' daily classroom routine with the support of the classroom teacher.

Research team's implementation

In this case, 10/35 (28,6%) studies were developed by a member of the research team or a monitor external to the educational centre (Bailey & McInnis, 2011; Cui et al., 2012; Chen & Sun, 2017; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2013; Rincker & Misner, 2017; Ye et al., 2018) (D'Egidio et al., 2019; Garde et al., 2018). Specifically, in the study of Millet et al. (2015) the content of the lessons was developed by the research team; both the presentation of the game and the feedback was carried out by a member of the research team. Moreover, in the study of Bailey & McInnis (2011), the interactive games were carried out under the supervision of the research staff. In the study Rincker & Misner (2017), several treatments by certified Irish dance teacher and a fitness instructor were implemented.

Incentives to participate

In this section, 13/ 35 (37,1%) studies received incentives to participate (Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Direito et al., 2015; Gao et al., 2017; Garde et al., 2018; Joyner et al., 2019; Melero-Cañas et al., 2020; Pope et al., 2018; Sharma et al., 2015; Wang et al., 2017), complete measurements or as a reward for compelling the intervention. Some examples are reported:

Financial reward: In the study designed by Baranowski et al. (2011), incentives were provided for child participation in different steps of the data collection: $25 for baseline assessment, $30 for between-game assessments, $35 for immediate postgame assessment, and $40 for 2-moth follow-up. The authors Wang et al. (2017), after playing, a game controller worth $50 and a game CD were offered to participants in the treatment group as incentives.

Gift cards: In the study by Sharma et al.(2015), children were given a $10 gift card to local retail store for their participation in measurement. In the same line, Pope et al. (2018), incentivized students in both groups to wear their FitBits, participants were entered into a weekly lottery to win one of three $10 Amazon gift cards for each day they FitBit. Additionally, the Game Group participants could win one of two weekly $10 Amazon Gift Cards. Participants received a NZ $10 gift card to a local shopping centre for each visit to complete study measures (i.e., maximum NZ $30 for 3 visits) in the study by Direito et al. (2015).

Parents' participation

Only 1 /35 (2,9%) study focused on parents' participation. The intervention design by Cui et al. (2012) consisted in three-step process, including peer leaders' recruitment and training, peer-led education, and student action. Basic knowledge in healthy lifestyles was distributed to students and their parents.

Table 7. Predominate characteristic in the intervention.

	Author (year)	Teacher's implementation	Research team's implementation	Incentives to participate	Parents'to participation
Games					
1	Mellecker & McManus (2008)	x			
2	Duncan & Staples (2010)	x			
3	Bailey & McInnis (2011)		x		
4	Baranowski et al. (2011)			x	
5	Gao et al. (2012)			x	
6	Cui et al. (2012)				x
7	Gao, Z & Podlog, L. (2012)		x		
8	Maloney et al. (2012)		x		
9	Gao et al.(2013)			x	
10	Gao & Stodden (2013)		x		
11	Miller A et al. (2015)	x			
12	Direito et al. (2015)			x	
13	Garde et al. (2015)			x	
14	Sharma et al. (2015)			x	
15	Garde et al. (2016)		x		
16	Lau et al. (2016)	x			
17	Rincker & Misner (2017)		x		
18	Gao et al. (2017)	x			
19	Chen & Sun (2017)		x		
20	Wang et al. (2017)			x	
21	Viggiano et al. (2018)	x			
22	Robertson et al. (2018)	x			
23	Fu et al. (2018)	x			
24	Garde et al. (2018)		x		
25	Pope et al. (2018)			x	
26	Fu & Burns (2018)	x			
27	Fu & al. (2019)	x			
28	Gao et al. (2019)			x	
29	Gao et al. (2019)b		x		
30	D'Egidio et al.(2019)			x	
31	Ye et al. (2019)		x		
Gamification					
32	Coombes & Jones (2016)			x	
33	Joyner et al. (2019)			x	
34	Beemer et al. (2019)	x			
35	Melero-Cañas et al. (2021)			x	

d) Assessment the PA

The prevalent instruments to assess PA were accelerometer (13 studies/37,1%) (Baranowski et al., 2011; Coombes & Jones, 2016; Chen & Sun, 2017; Duncan & Staples, 2010; Fu & Burns, 2019; Gao et al., 2017; Gao et al., 2019; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Maloney et al., 2012; Wang et al., 2017; Ye et al., 2018) questionnaires (7 studies/ 20%) (Cui et al., 2012; D'Egidio et al., 2019; Gao et al., 2012; Melero-Cañas et al., 2020; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017), and pedometer (6 studies/ 17,1%) (Fu & Burns, 2018; Fu et al., 2018; Gao & Podlog, 2012; Gao et al., 2013; Miller et al., 2015; Robertson et al., 2018).

e) Risk of bias and quality assessment

Risk of bias assessment

All intervention studies (RCT) were rated as high risk of bias (Baranowski et al., 2011; Cui et al., 2012; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2019; Gao & Podlog, 2012; Garde et al., 2018; Lau et al., 2016; Maloney et al., 2012; Melero-Cañas et al., 2020; Miller et al., 2015; Pope et al., 2018; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Ye et al., 2019) 17/35 (48,6%)(**Figure 8).**

Regarding the risk of bias of the NRCT intervention studies (Beemer et al., 2019; Coombes & Jones, 2016; Chen & Sun, 2017; Fu & Burns, 2018; Gao et al., 2013; Gao et al., 2019; Gao et al., 2019; Garde et al., 2015; Wang et al., 2017), a total of 6/9 (66,7%) studies were rated moderate risk of bias and 3/9 (33,3%) of the studies had serious risk of bias (**table 8**).

	Risk of bias						
	D1a	**D1b**	**D2**	**D3**	**D4**	**D5**	**Overall**
Duncan, M & Slapes, V (2010)	+	-	+	+	-	!	-
Baranowski et al. (2011)	+	+	!	+	-	-	-
Cui et al. (2012)	+	+	!	+	-	-	-
Gao, Z., & Podlog, L. (2012)	+	+	!	+	-	-	-
Maloney et al. (2012)	+	+	-	+	-	-	-
Direito et al. (2015)	+	+	!	+	+	-	-
Miller et al. (2015)	+	+	-	+	-	-	-
Sharma et al. (2015)	+	+	+	+	-	-	-
Lau et al. (2017)	+	+	!	+	-	-	-
Fu You (2018)	+	+	!	+	-	!	-
Garde et al. (2018)	+	+	-	+	-	-	-
Pope et al. (2018)	+	+	!	+	-	+	-
Robertson et al. (2018)	+	+	!	+	-	-	-
Viggiano et al. (2018)	-	+	!	+	-	-	-
Ye et al. (2019)	+	+	-	+	-	-	-
D'Egidio et al. (2019)	+	+	!	+	-	-	-
Melero-Cañas et al. (2021)	+	+	!	+	-	-	-

D1a: Randomisation process
D1b: Timing of identification or recruitment of participants
D2: Deviations from the intended interventions
D3: Missing outcome data
D4: Measurement of the outcome
D5: Selection of the reported result

Judgement
+ Low risk
! Some concerns
- High risk

Figure 8. Risk of bias for RCT.

Table 8. Risk of bias for NRCT.

Studies	Confounding	Selection of participants into the study	Classification of interventions	Deviations from intended interventions	Missing data	Measurement of outcomes	Selection of the reported result	Overall Bias
Garde et al. (2015)	Low	Moderate	Low	Moderate	Moderate	Low	Low	Moderate
Gao et al. (2013)	Serious	Low	Low	Moderate	Moderate	Low	Moderate	Serious
Coombes et al. (2016)	Low	Low	Low	Moderate	Moderate	Low	Moderate	Moderate
Chen & Sun et al. (2017)	Low	Low	Low	Low	Low	Low	Moderate	Moderate
Wang et al. (2017)	Low	Low	Low	Low	Moderate	Low	Serious	Serious
Fu & Burns (2018)	Moderate	Low	Low	Low	Low	Low	Low	Moderate
Beemer et al. (2019)	Serious	Low	Low	Moderate	Serious	Low	Low	Serious
Gao et al. (2019)	Moderate	Low	Low	Low	Moderate	Low	Low	Moderate
Gao et al. (2019)	Low	Low	Low	Low	Moderate	Low	Moderate	Moderate

Quality assessment

The quality assessment was carried out (see **table 9**). A total of 25/35 (71,4%) studies were assessed as weak (Bailey & McInnis, 2011; Baranowski et al., 2011; Coombes & Jones, 2016; Cui et al., 2012; D'Egidio et al., 2019; Direito et al., 2015; Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao, Pope, et al., 2019; Gao et al., 2019; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Ye et al., 2018) in the global rating and 10/35 (28,6%) studies were rated moderate (Beemer et al., 2019; Chen & Sun, 2017; Duncan & Staples, 2010; Fu & Burns, 2018; Gao et al., 2017; Gao et al., 2013; Garde et al., 2016; Garde et al., 2015; Melero-Cañas et al., 2020; Wang et al., 2017). In the section "study design", a total of 29/35 (82,9%) studies (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao & Podlog, 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao, Zeng, et al., 2019; Gao et al., 2013; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017) rated as stronger. In the section "withdrawals and dropouts " a total of 22/35(62,8%) studies (Bailey & McInnis, 2011; Coombes & Jones, 2016; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2012; Gao, Pope, et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Mellecker & McManus, 2008; Miller et al., 2015; Rincker & Misner, 2017; Sharma et al., 2015; Wang et al., 2017; Ye et al., 2018) and "data collection" with 18/35 (51,4%) studies (Beemer et al., 2019; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017) rated as strong. Referring to the section "blinding", 29/35 (82,9%) studies were rated as moderate (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gao et al., 2013; Garde et al., 2016; Joyner et al., 2019; Lau et al., 2016; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Pope et al., 2018; Rincker & Misner, 2017; Robertson et

al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018). In the section "confounders", a total of 25/35 (71,4%) studies were rated as weak (Bailey & McInnis, 2011; Beemer et al., 2019; Coombes & Jones, 2016; Cui et al., 2012; D'Egidio et al., 2019; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2019; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018). Lastly, in the section "selection bias", 24/35 (68,6%) studies were rated as weak (Bailey & McInnis, 2011; Baranowski et al., 2011; Coombes & Jones, 2016; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2013; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018). When the required information on any item was not reported, because it was not the objective of the study, the item was rated as "not applicable". In case of any data were not reported or provided unclear information, the item was rated as "not clear".

Table 9. Quality Assessment Tool for Quantitative Studies.

Author (year), country	Quality assessment							
	Effectiveness Cohen's d	**Selection bias**	**Study design**	**Confounders**	**Blinding**	**Data collection**	**Withdrawals and dropouts**	**Global Rating**
Games								
Mellecker & McManus (2008), Japan	n/a	*	*	*	**	*	***	*
Duncan et al. (2010), United Kingdom	n/a	**	***	***	**	*	***	**
Bailey & McInnis (2011), USA	n/a	*	***	*	**	*	***	*
Baranowski T et al. (2011), USA	0.25	*	***	***	**	**	*	*
Gao et al. (2012), USA	n/a	*	*	*	**	***	***	*
Cui, Z., et al. (2012), Australia	n/a	*	***	*	**	**	***	*
Gao, Z., & Podlog, L. (2012), USA	n/a	*	***	*	**	**	*	*
Maloney et al. (2012), USA	n/a	*	***	*	*	*	**	*
Gao, Z. et al. (2013), USA	n/a	*	***	*	**	*	**	*
Gao & Stodden (2013), USA	n/a	*	***	**	**	***	***	**
Garde et al. (2015), Canada	n/a	***	**	**	*	*	*	**
Miller A et al. (2015), Australia	1.02	**	***	**	*	*	***	*

Direito et al. (2015), New Zealand	80% power and α=.05	*	***	***	*	***	**	*
Sharma et al. (2015), USA	n/a	*	***	*	**	***	***	*
Garde et al. (2016), Canada	n/a	***	*	**	**	*	*	**
Lau et al. (2016), China	n/a	*	***	*	*	***	***	*
Rincker & Misner (2017), USA	1.02	*	***	*	**	*	***	*
Gao et al. (2017), USA	n/a	*	***	**	**	***	**	**
Chen & Sun (2017), USA	n/a	*	***	***	**	***	***	**
Wang et al. (2017), China	n/a	***	***	*	**	***	***	**
Viggiano et al. (2018), Italy	n/a	*	***	*	**	***	*	*
Robertson et al. (2018), Scotland	(80% power (α =0.05, effect size= 0.018)	*	***	*	**	*	**	*
Fu You (2018), USA	n/a	*	***	*	**	***	***	*
Garde et al. (2018), Canada	n/a	*	***	*	*	***	***	*
Pope et al. (2018), USA	80% power (α =0.05, effect size =0.15)	***	***	*	**	**	*	*
Fu & Burns (2018), USA	n/a	***	***	*	**	***	***	**
Fu et al. (2019), USA	n/a	*	***	*	**	***	***	*

Gao et al. (2019), USA	80% power (α = 0.05, effect size = 0.30)	***	***	*	*	***	***	*
Gao et al. (2019), USA	80% power (α = 0.05, effect size = 0.30)	***	***	*	**	***	***	*
D'Egidio et al. (2019), Italy	n/a	*	***	*	**	***	***	*
Ye et al. (2019), China	n/a	**	*	*	**	*	***	*
Gamification								
Coombes & Jones. (2016), United Kingdom	n/a	*	***	*	**	**	***	*
Joyner et al. (2019), USA	n/a	*	***	*	**	***	***	*
Beemer et al. (2019), USA	n/a	***	***	*	**	***	**	**
Melero-Cañas et al. (2021), Murcia, Spain	n/a	*	*	**	*	*	*	**

Quality assessment tool for quantitative studies (McMaster University): Effective public health practice project (EPHPP) the assessment of a component was: *=weak; **=moderate; ***=strong.

f) Effectiveness

A total of 23/35 (65,7%) studies reported an increase in the PA following the interventions (Beemer et al., 2019; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Joyner et al., 2019; Lau et al., 2016; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Rincker & Misner, 2017; Viggiano et al., 2018; Ye et al., 2018) using outcomes such us step counts and minutes, PA levels, METS and energy expenditure (kcal/day). However, 12/35 (34,3%) studies did not report significant improvements in PA (Bailey & McInnis, 2011; Baranowski et al., 2011; Coombes & Jones, 2016; Cui et al., 2012; Direito et al., 2015; Fu & Burns, 2018; Maloney et al., 2012; Miller et al., 2015; Pope et al., 2018; Robertson et al., 2018; Sharma et al., 2015; Wang et al., 2017). In addition, only 8/35 (22,6%) studies incorporated the Cohen's (Baranowski et al., 2011; Direito et al., 2015; Gao et al., 2019; Gao et al., 2019; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018). Based on Cohen's d effect size, 5/8 studies had effect sizes small (0.2) (Baranowski et al., 2011; Gao et al., 2019; Gao et al., 2019; Pope et al., 2018; Robertson et al., 2018), 1/8 study had size medium (0.5) (Direito et al., 2015) and 2/8 studies had a size large (0.8) (Miller et al., 2015; Rincker & Misner, 2017).

Study IV. Designing the Mystic School mobile app to promote active commuting to school in Spanish adolescents: the PACO study.

The results obtained from the focus group questions mainly aimed at finding out the adolescents' perception of the application, and aspects to improve in terms of design, operation, and general satisfaction.

Phase 1

The comments in both groups were: a) the game did not record correctly the steps or there were more steps without having moved from the site; (b) sometimes it did not work; c) personalization of the avatar. Many comments were a consequence of the fact that the game did not record the steps, which was a main technical problem (**Table 10**):

Table 10. Adolescents' perceptions in phase 1.

Content	Phase 1
Design	*"The movement of the avatar is a bit strange because you hit it and it gets stuck with different objects"* *"The movement is a bit uncomfortable. You spend more time trying to make the avatar walk than you do walking in real life"*
Active videogame failures	*"It's a bit weird, because sometimes I gain a lot of steps when I walk and sometimes, I gain almost no steps at all"* *"The steps magically appear"* *"My screen has locked up and won't even let me move my avatar"* *"My GPS is working properly, and it does not let me move the avatar* *"I walked from my house to the school, and I didn't move from where I was in the video game. I did the same route again and I didn't move either"*
Difficulties	*"The video game closed by itself, and I had to open it again "* *"In some places the avatar gets stuck and can't move forward "* *"I advance a level and I don't really know how I got there"*
Suggestions for improvement	*"Instead of pressing a few seconds to move the avatar, it would be better to move the avatar with the arrows like in other games "* *"There should be a story section and a multiplayer section "* *"We are made for competition. An application to play against others is better than alone"*

Although the degree of satisfaction was positive, students indicated that they would return to play if it the avatar's movement in the maze is improved. Therefore, they found several software bugs that difficult the daily use of the application. The most relevant comments were that the application did not work correctly, and it did not count the steps as the player expected. On the other hand, the students suggested improvements such as changing the avatar being customisable, more competitive game, and being able to play single and multiplayer. The adolescents played an average of 4 out of 10 levels. Because of the previous reasons, the adolescents provided a low use of the application and consequently, few opinions.

The computer developers focused on correcting application errors such as not recording the steps correctly, leaving the screen unexpectedly or technical issues (i.e., brightness of the animation). In addition, the computer experts improved the functioning

of the GPS Therefore, the avatar's way of movement was changed as mentioned by the students prior to second section.

Phase 2

The participants highlighted aspects to improve in terms of the design of the application, the time they spent playing and what they liked most about the application (**Table 11**).

Table 11. Adolescents' perceptions in phase 2.

Content	Phase 2
Suggestions for improvement	*"I would like to get in the app and that it loads quicker"* *"It would be nice that there is prize that allows you to get into another secret map"* *"Put in the app that enemy players can steal 1000 steps"* *"More achievements, collect more steps and you get a prize because there were levels where you didn't have to do anything"* *"I would like an offline mode to play when I don't have internet connection"*
Playing time	*"My partner wasn't walking and couldn't move forward, so I wanted to pass steps to her, but it didn't work"* *"I put the application in the background and when I opened it again, my avatar appeared in a different place"* *"I have not been able to play because we have a lot of exams and other activities"*
Active videogames - positive aspects-	*"It's an original idea"* *"The graphics are good to begin"* *"The concept was well thought out"* *"It's an entertaining and fun application to promote Physical Activity"*

In relation to the content "suggestions for improvement", students answered a first question: "What aspects would improve the app?". They stressed about using the app without an internet connection since some of them did not have a service that provide internet. They also commented that more prizes will be provided during the game as a reward for reaching a certain number of steps. In addition, they proposed an increment in competitiveness and difficulty during the different levels of the game.

In the content "playing time" (second question), "How much time have you spent playing?", it was observed that some of the participants have not played enough. There were different reasons: a) the software did

not work; b) they had many extracurricular activities; and c) many exams. And finally, the participants were asked what they liked most about the game? About the content "positive aspects" participants said on, that the application is an original idea and that the design is good.

The computer experts focused on correcting application errors such as not recording all the steps, 50 steps were included to start to play and a maximum of 6km/h by walking was estimated to register steps.

Study V. Active methodologies in Physical Education lessons: a school-based intervention"

A total of 62 adolescents (age =14 ± 0.45, 54.8% girls) were part of the intervention and, participants of Valencia carried out the focus group (n=5) and in Almería filled out a form (n=4). The main adolescents' perceptions extracted of the focus group are presented in **table 12**.

Table 12. Characteristics of perceptions about the intervention.

Questions	**Point of view – adolescents' perception**
Questions about Physical Education sessions	
What did you think of the sessions?	- *I liked all the sessions* - *The sessions were fun and original* - *They were very entertaining and different*
Which session did you like the most?	- *The orientation session outside the school (last session)* - *When we had to look for the QR codes and take pictures where the instructions indicated*
Which session did you like the least?	- *None, all have been fun* - *All the sessions have been good* - *When we had to move the objects around the school yard*
How can the sessions be improved? or What would you modify to have a better time?	- *I would have liked to have had a gymkhana around the yard, looking for objects and clues* - *I would have liked to have played more sports* - *The truth is that I had a great time, I wouldn't have to improve anything*
Questions about AVG Mystic School	
What did you think about active the video game?	- *The app has been good, but it gave a lot of problems* - *Very interesting* - *Good, but needs a little more development* - *The application is entertaining*
What would you improve to play more?	- *That it will not waste so much battery power when you are walking* - *That it would not give so many failures when entering the application* - *That the steps are not spent so fast when you play* - *I would change having to have the application in the background and the messages of the speed and steps*
If you were a teacher, do you see the active video game applicable in Physical Education lessons?	- *Yes, it would be a voluntary activity outside of school* - *I would make teams with my students and see who would win* - *Giving rewards to those who accumulate the most steps*

In relation to the first question, "what did you think of the sessions?", the adolescents indicated positive comments such as "they have been fun and original", "entertaining

and different". They have also said that they would have liked the sessions to be for longer and they declared they enjoyed the sessions.

As for the question which session they liked the most, most agree that the last session was the most fun and because they had to perform the activities in a different context than usual. The question which session they liked least, some of the adolescents commented that the first session because the material weighed "having to transport Physical Education material through the yard".

Another question we asked the adolescents was "how can you improve the sessions?". Overall, the perception was good as most said they would not change anything. Although some adolescents said they would like the sessions to be longer and look for other activities that include sports.

The adolescents found the AVG Mystic School entertaining and interesting, but there were many problems in relation with the question "What did you think about active the video game?". In addition, some students did not play because they could not enter the AVG, and it did not work properly.

The next question was "What would you improve about the video game to play more?", the adolescents said that the steps would wear out too quickly, that it would not crash so much and even that there would be a version for iPhone Operating System (IOS). Another essential question was "If you were a teacher, do you see the active video game applicable in Physical Education lessons?". The majority answered positively in this regard. They reminded that some students have an IOS mobile phone, and that it would be necessary to find a way for everyone to participate and give more rewards for each achievement or final prize to do an extracurricular activity all together.

In addition, an individual interview was conducted with both teachers. The PE teacher 1 liked the sessions as the used different parts of the school's facilities, and activities that she does not usually carry out. She could easily use Mystic School for PA promotion as she already does with other apps. The idea of using the points and rewards system seemed novel to her but difficult to implement without a previous design with a lot of time in advance and without help she sees it as not very feasible to implement in the short term. Although she liked the sessions, she thinks that more time is needed because the Physical Education sessions have a very short duration. As for the AVG, teacher 1 said she thought it was fun but perhaps the design was not focused on today's adolescents. She would try the AVG with primary school children although she is aware that although it is more enjoy for children it is more complex to get permission from both the school and the parents to participate. The PE teacher 2 said that the adolescents participated more in the sessions and were more enthusiastic. In relation to Mystic School, teacher 2 said that

it should be improved a little more the AVG, due to several difficulties to use it. He believes that nowadays adolescents are used to having less patience and when they see that something doesn't work, they change to something else without knowing how to wait. Therefore, he believes that it could be applied in their lessons but only at a certain time because adolescents get bored quickly.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

The descriptive characteristics of the sample by gender are presented in **Table 13**. The prevalence of boys who actively commute to school was 54.5%, whereas girls displayed a lower percentage of 48.2%. Regarding CRF, the boys presented higher VO2 max ($p < 0.001$) and lower seconds (i.e., higher score) in the speed-agility test ($p = 0.033$) than girls.

Table 13. Descriptive characteristics of the participants by gender.

Variables	All n=415 Mean ±SD	Boys n=222 Mean ±SD	Girls n=193 Mean ± SD	*p*
Age (years)	8.47±0.36	8.49±0.37	8.44±0.34	0.843
Weight (kg)	31.34±7.14	31.85±7.37	30.74±85	0.737
Height (cm)	1.32±0.06	1.33±0.06	1.31±0.06	0.205
Waist circumference (cm)	58.95±7.81	59.44±7.34	58.38±7.88	0.251
BMI (Kg/m^2)	17.70±3.21	17.66±3.24	17.75±3.19	0.184
Normal (n (%))	228 (69.6)	158 (71.2)	131 (67.9)	
Overweight (n (%))	83 (20.0)	40 (18.0)	43 (22.3)	
Obesity (n (%))	43 (10.4)	24 (10.8)	19 (9.8)	0.551
Cardiorespiratory fitness (VO_2 max. (ml/kg/min))	47.79±3.38	**48.56±3.72**	**46.88±2.67**	**<0.001**
Standing broad jump	114.80±20.93	120.67±17.83	108.05±22.20	0.260
Handgrip strength	12.33±3.40	12.72±3.04	11.87±3.74	0.681
Speed-agility	14.68±6.39	**14.68±8.69**	**14.68±1.04**	**0.033**
Mode of commuting				0.199
Active (n (%))	214 (51.6)	121 (54.5)	93 (48.2)	
Passive (n (%))	201 (48.4)	101 (45.5)	100 (51.8)	
Health-related quality of life				
Physical well-being	78.07±17.18	78.94±16.27	77.07±18.16	0.237
Emotional well-being	85.57±15.38	85.25±15.59	85.95±15.18	0.935
Self-esteem	78.24±22.28	77.25±23.05	79.37±21.35	0.305
Family	83.87±15.06	83.36±15.30	84.46±14.81	0.552
Friends	82.89±16.13	81.53±16.33	84.46±15.74	0.858
School	67.94±17.74	66.36±16.70	69.75±18.74	0.116
Total score	77.64±9.83	77.10±9.84	78.26±9.81	0.807

The data are presented as means and standard deviations *(SD)*, body mass index *(BMI)* calculated as weight/height2 *(kg/m2)*. Higher scores indicate a better health-related quality of life.

The relationship between HRQoL and physical fitness (cardiorespiratory fitness, muscular strength, handgrip strength, and speed-agility) by gender is presented in **Table 14**. Cardiorespiratory fitness was weakly correlated with the emotional, school, and total score dimensions (ranging from 0.16 to 0.30). Cardiorespiratory fitness in boys was positively correlated with all dimensions of HRQoL (ranging from 0.16 to 0.30). Moreover, muscular strength was weakly correlated with higher physical well-being, emotional well-being, self-esteem, school, and total score (ranging from 0.14 to 0.22). Muscular strength was positively correlated with the emotional well-being dimension in girls.

Table 14. Correlation coefficients between health-related quality of life scores and physical fitness by gender.

		Physical well-being	Emotional well-being	Self-esteem	Family	Friends	School	Total score
Cardiorespiratory fitness	All	0.10*	**0.20***	0.10*	0.10	0.03	**0.12***	**0.15****
	Boys	**0.20****	**0.27****	**0.19****	**0.20****	**0.16***	**0.22****	**0.30****
	Girls	-0.06	0.12	0.01	0.05	-0.12	0.02	-0.03
Muscular strength	All	0.09	**0.16****	0.09	0.08	0.04	0.05	**0.11***
	Boys	**0.16***	**0.14***	**0.14***	0.13	**0.16***	**0.19****	**0.22****
	Girls	0.00	**0.22****	0.09	0.06	-0.00	-0.00	0.06
Handgrip strength	All	0.70	0.06	0.01	0.01	0.04	0.01	0.05
	Boys	0.02	0.07	0.02	0.01	0.10	0.13	0.09
	Girls	0.10	0.06	0.01	0.02	0.01	-0.07	0.02
Speed-agility	All	-0.02	-0.04	-0.05	0.02	-0.09	-0.05	-0.07
	Boys	-0.03	-0.04	-0.07	-0.02	-0.11	-0.08	-0.09
	Girls	0.01	-0.11	0.05	-0.02	-0.08	0.02	-0.02
Mode of commuting	All	0.02	0.00	0.04	0.06	0.02	-0.04	0.02
	Boys	-0.03	-0.01	0.02	0.09	-0.02	0.02	0.02
	Girls	0.06	0.02	0.06	0.03	0.08	-0.10	0.03

The value in bold indicate significant differences * p = < 0.05 and ** p= <0.001

Children with higher cardiorespiratory fitness presented better scores for physical well-being, emotional well-being, friends, school, and total score (all $p < 0.05$). These associations remained in boys but not in girls. In addition, boys with higher levels of muscular strength presented better scores in the emotional well-being, self-esteem, friends, and total score dimensions (all $p < 0.05$) than did boys with low levels of muscular strength. On the other hand, girls with higher muscular strength presented better emotional well-being ($p = 0.017$). Moreover, children with higher speed/agility presented higher scores for emotional well-being, self-esteem, family, friends, and total score (all $p < 0.05$) than did children with lower speed/agility. In addition, boys with higher speed/agility presented better scores for physical well-being, self-esteem, family, friends, school, and total score ($p < 0.05$) compared with boys with lower speed/agility.

The association between HRQoL, the group of fit/unfit children, and those who actively commute is shown in **Figure 9**. The active children who were categorized as fit presented better scores for the emotional well-being, family, and school dimensions, as well as total scores (all $p < 0.05$). Furthermore, boys who were fit and actively commuted to school presented higher levels of emotional well-being, self-esteem, family, school, and total scores (all $p < 0.05$) than did the boys who were not fit.

Figure 9. Association between HRQoL and fitness level in children who actively commuted to school children.

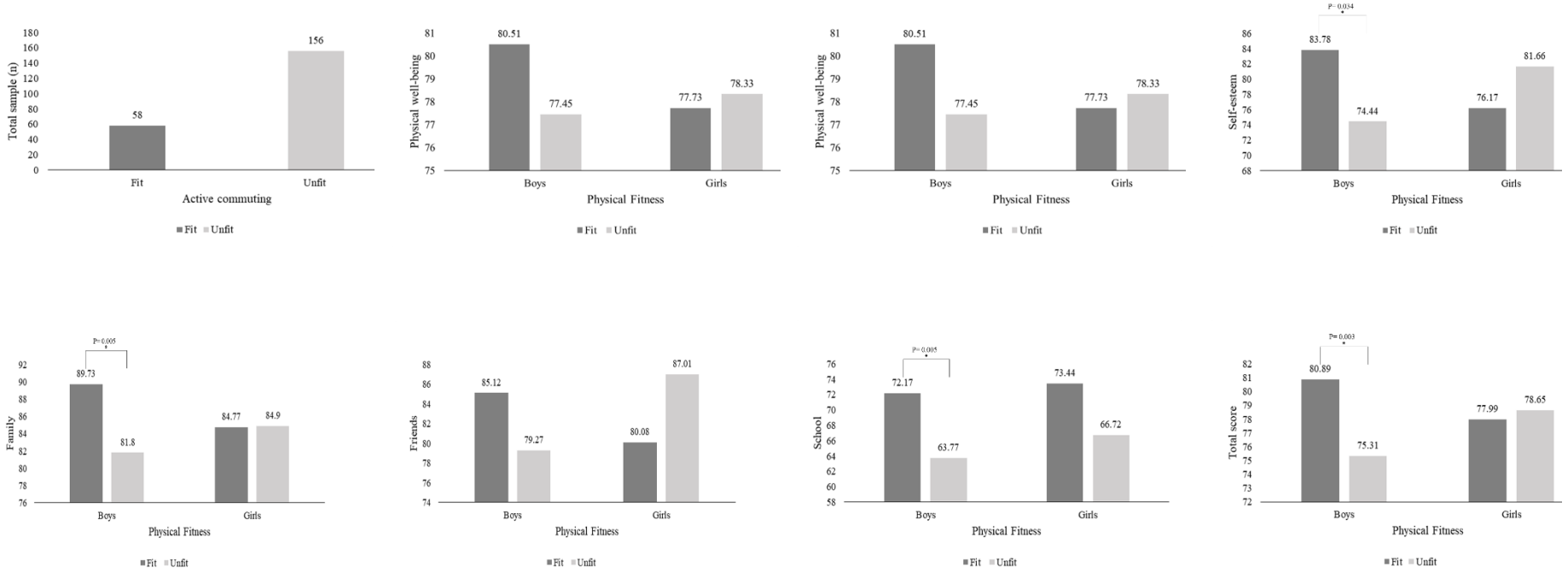

Table 15 shows the difference in physical fitness by mode of commuting to and from school by gender. Boys who actively commute to school presented better cardiorespiratory fitness than did boys who passively commute to school (p = 0.015).

Table 15. Analysis of covariance (ANCOVA) testing mean differences in physical fitness by mode of commuting to school.

		Passive	**Active**		**Active mode of commuting**		
		n= 201	n= 214		Time		
		n=♂101/♀100	n=♂121/♀93	*p*	≤ 15min (n= 164)	≥ 15min (n= 50)	*p*
Cardiorespiratory fitness	All	**47.48 ± 3.14**	**48.06 ± 3.57**	**0.059**	48.28± 3.74	47.36 ± 2.84	0.110
	Boys	**47.87 ± 3.51**	**49.13 ± 3.81**	**0.015**	49.34 ± 4.00	48.39 ± 3.00	0.266
	Girls	47.08± 2.68	47.67 ± 2.65	0.331	46.82 ± 2.79	46.23 ± 2.19	0.352
Muscular strength	All	114.64 ± 21.76	114.95 ± 20.17	0.842	115.70 ± 20.74	112.50 ±18.14	0.327
	Boys	120.96 ± 17.46	120.43 ± 18.19	0.599	121.09 ± 18.71	118.06 ± 16.30	0.454
	Girls	108.26 ± 23.80	107.82± 20.47	0.934	108.29 ± 21.24	106.48 ± 18.43	0.711
Handgrip strength	All	12.43 ± 2.65	12.24 ± 3.99	0.592	12.20 ± 4.34	12.37 ± 2.56	0.788
	Boys	13.14 ± 2.78	12. 38± 3.21	0.092	12.34 ± 3.41	12.53 ± 2.37	0.793
	Girls	11.71± 2.30	12.05 ± 4.84	0.425	12.00 ± 5.39	12.20 ± 2.80	0.863
Speed-agility	All	15.04 ± 9.09	14.34 ± 1.18	0.243	14.28 ± 1.22	14.53 ± 1.05	0.191
	Boys	14.19 ± 2.16	14.04 ± 1.22	0.630	13.99± 1.25	14.21 ± 1.09	0.426
	Girls	14.63± 1.06	14.73 ± 1.02	0.920	14.68 ± 1.05	14.88 ± 0.91	0.401

♂= boys
♀= girls

DISCUSSION

DISCUSSION

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

The current study analyses the ACS rates and changes among Spanish preschool children from 2013 to 2017 using data from 27 different localities. Around 52% of the participants commuted actively to school (from 48.8% to 67.4%) in the period studied, and differences in the ACS rate were found by survey year. In addition, the ACS rates in the Spanish preschool children did not change significantly between 2013 and 2017 using multilevel analysis, but an increasing ACS trend was observed throughout the years in the bivariate analysis.

The findings of the current study showed similar rates of ACS compared with previous studies carried out in Spain, such as the MOVI-KIDS study, which reported that 46% of preschool children walked to school (Ruiz-Hermosa & Martínez-Vizcaíno, 2019) or the IDEFICS study, in which almost 50% of preschool children actively commuted (Herrador-Colmenero et al., 2021). On the other hand, Terrón-Perez et al. (2018) reported a higher rate of ACS; that is, 70% of preschool children commuted actively to school In other countries, higher ACS rates were found in Germany, where more than 70% of preschool children aged 4-5 years old commuted actively (Reimers et al., 2020), or in the United Kingdom, where 70% of children aged 5-10 years old reported walking to and from school (Black, Collins, & Snell, 2001). However, in New Zealand, a lower rate of ACS (40%) was found among preschool children (5 years old)(Hinckson et al., 2011) compared with the current results.

The trend of ACS in Spanish preschool children did not change during the 2013-2017 period, as suggested by the current results. However, this study observed a promising increasing trend in the bivariate analysis. In a study with German boys and girls aged 4-5 years old, ACS significantly decreased from 2003 to 2017 (boys: from 84.5% to 78.3%; girls: from 84.4% to 77.4%) (Reimers et al., 2020). This study shows promising results as a decreasing trend was not observed, which might be a starting point in obtaining an increasing trend in the next upcoming years. The difference in the outcomes obtained in this study could be the result of an increase of German preschool children being chauffeured by parents in cars in this period (Reimers et al., 2020). Other trend studies focused on preschool children have not been found. Comparing the current results with previous studies focused on children (aged 6 to 12 years old), a decline in the ACS rate is observed in countries such as the United States (McDonald, 2007), China (Cui, Bauman, & Dibley, 2011), Australia (van der Ploeg, Merom, Corpuz, & Bauman, 2008), and Germany (Shaw et al., 2013). An

increased distance from home to school appears to be a key contributor to this decline (McDonald, Brown, Marchetti, & Pedroso, 2011), and the distance could be influenced by various barriers (Aranda-Balboa, Huertas-Delgado, Herrador-Colmenero, Cardon, & Chillon, 2020). On the other hand, it is unknown if this perceived barrier is similar in the families of preschool children. Among preschool children, the parents decide how they should go to school (Ahern, 2015; Henne, Tandon, Frank, & Saelens, 2014), but when they grow up, they can increase ACS for various reasons, such as walking to school with friends, going somewhere with friends after school, or travelling to the park to play. When children grow older, their parents perceive a decrease in control and supervision (Musitu & Cava, 2003) and an increase in autonomy (Yeung, Wearing, & Hills, 2008).

Another reason could be the time period of this study (i.e., between 2013 and 2017), which was different from the rest of the children studies, and it is related to the recovery process of the economic crisis (Hernández de Cos, 2018). On the other hand, the stability in the ACS rates observed in Spanish preschool children in the last years is a result of the findings from Gálvez-Fernandez et al. (2021), where there were not any changes in ACS in either Spanish children or adolescents. Therefore, in Spain, the rate of ACS remained stable from early ages up to the beginning of adolescence. The integration of preschool children and children into the same school might be one reason for the similarity of findings in these different age groups. Moreover, the establishment of active modes of commuting in preschool children could have a direct influence in the following ages. The stable trend in Spanish preschool children could also be due to the influence and impact of educational programmes on lifestyles (Rodríguez, Cordero, Villar, & Mur, 2017). In recent years, various proposals have been applied to promote ACS as a positive alternative to increase daily PA levels and other variables, from preschool children to adolescents, in Spain. In addition, the number of interventions in this area increased in the near age group (Chillon, Evenson, Vaughn, & Ward, 2011; Pang et al., 2017; Villa-Gonzalez et al., 2018) and could contribute to the importance of commuting actively. Consequently, promotion in young people fosters greater social awareness of the importance of promoting PA and its benefits. The promotion programmes to increase PA could have an influence on the ACS stability in this study; for example, “school path” and/or “pedibus” is carried out among preschool children and adolescents in many cities in Barcelona and Valencia within a different municipality, as well as San Sebastian or Madrid, among others (http://caminoescolarseguro.com/experiencias ces.html).

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

In recent years, evidence suggests that PA interventions at school can be effective for increasing PA in children and adolescents (Fu & Podlog, 2017; Dobbins, De Corby, Robeson, Husson, & Tirilis, 2009; Kriemler et al., 2011; Pérez-López, Tercedor, & Delgado-Fernández, 2015; Pozuelo-Carrascosa, García-Hermoso, Álvarez-Bueno, Sánchez-López, & Martinez-Vizcaino, 2018). In addition, there is evidence that PA in the classroom may have a positive impact on academic results (Watson et al., 2017), levels of concentration, memory, and classroom behaviors (Trudeau & Shephard, 2008).

A preliminary search found several studies based on game and/or gamification strategies that reported PA outcomes in a school context. For example, AVGs appear to hold promise as a method for increasing PA. This can improve health status and offer other social and academic benefits (Staiano & Calvert, 2011). Accordingly, the systematic review by Williams et al. (2020) concluded that AVGs can be an effective means of increasing adolescents' overall PA levels. Moreover, a 12-week school-based intervention (60 min/twice per week) based on AVGs improved Chinese children's PA levels (Lau, Wang, & Maddison, 2016). Likewise, students from a public elementary school who participated in an AVG intervention reported higher PA compared with those students who maintained their regular Physical Education lessons (Fogel, Miltenberger, Graves, & Koehler, 2010).

The use of the term gamification has been increasing, and it has been implemented for different age groups. In particular, one example of gamification strategy is the study by Coombes et al. (2016), which implemented "Beat the Street", a 9-week pilot intervention study in children from 8 to 10 years old. They evaluated the impact of touching smart cards with sensors to promote active travel to school and thus increase PA through competition, scores, and awards. The intervention did not significantly impact children's overall PA levels during school commute times, but there was evidence that the intervention had a positive impact on higher intensity PA during the commute to school. Another study carried out three types of interventions in a period of 20 weeks (Beemer et al., 2019) and one of the interventions was gamified. During the gamified weeks, students received challenging weekly objectives; when each class met its objective, a new objective was implemented. Therefore, daily, weekly, and post-intervention incentives were offered to reinforce positive behavior among students and even the possibility of earning badges, trophies, a personalized shirt, and a 2-h field day after the intervention. This study concluded that gamification is an important and promising strategy to increase PA in the classroom. A

secondary school in Northern Ireland carried out a gamified intervention (Corepal et al., 2018). The StepSmart Challenge was a 24-week intervention in adolescents to change behavior related to PA. The design of this intervention was based on team and individual competition using motivation and incentives. In addition, in the United Kingdom (Harris, 2018), a pilot evaluation of a community-wide gamification-based PA intervention was applied to the city/town and also called "Beat the Street". Participants recorded their walking and cycling tours by tapping "Beat Boxes" to record their PA levels. The participants received points and several incentives. This pilot study provides preliminary evidence that the intervention could increase PA levels.

Gamification strategies have also been implemented with university students. A gamification program using a mobile app at a university reported significant effects on cardiorespiratory fitness compared to the control group that followed a traditional teaching methodology (Mora-Gonzalez, Pérez-López, & Delgado-Fernández, 2020). Accordingly, another study about a gamification-based teaching program designed to increase PA levels in college students showed a significant effect on their cardiorespiratory fitness in comparison with peers of the control group (Mora-Gonzalez, Pérez-López, Esteban-Cornejo, & Delgado-Fernández, 2020).

Despite the recent studies based on games and gamification, there is no full review following a rigorous process to identify the overall school-based interventions focused on these strategies. In addition, research is needed to assess the impact of games and/or gamification strategies on the PA levels of young people. Regarding the importance of maintaining the effect of the intervention at the school level once the researchers are not present, as suggested by Sallis et al. (2006) it seems that gamification provides positive effects. However, the effects are highly dependent on the context in which gamification is implemented, as well as on the study participants and the effectiveness of the interventions (Hamari et al., 2014; Johnson et al., 2016). In addition, a recent systematic review protocol focused on the term 'gamification' has been published (Lopes et al., 2019). However, because there is great terminological and methodological confusion in the use of these strategies based on games to increase PA levels, it seems more appropriate to include all the terms mentioned in the current study. With this research, it is expected that more future school-based interventions using games or gamification may be implemented using appropriate methodologies to be effective in the classroom. Therefore, this review will help clarify the relationship between game and/or gamification strategies with PA improvements. Important guidelines will be provided for future research in the area of PA in order to optimize the educational value of games and/or gamification. Games and/or

gamification could be a promising strategy representing an excellent alternative, although regarding gamification, there is still a dearth of valid empirical evidence in this field.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

The aims of this systematic review were 1) to identify and examine school-based intervention studies focused on game and/or gamification strategies to promote PA in young people (children and adolescents) and 2) to analyse their quality and effectiveness.

In this review, 35 school-based interventions were identified (Bailey & McInnis, 2011; Baranowski et al., 2011; Beemer et al., 2019; Coombes & Jones, 2016; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018). The games (mainly exergames) were used as the main strategy of interventions (31/35, 88,6%) (Bailey & McInnis, 2011; Baranowski et al., 2011; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018) and only 4 studies used the gamification (Beemer et al., 2019; Coombes & Jones, 2016; Joyner et al., 2019; Melero-Cañas et al., 2020) . Approximately 65% of the studies (23/35), based on game all of them, had positive effects on PA variables post-intervention (Beemer et al., 2019; Chen & Sun, 2017; D'Egidio et al., 2019; Duncan & Staples, 2010; Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao, Pope, et al., 2019; Gao et al., 2019; Gao et al., 2013; Garde et al., 2018; Garde et al., 2016; Garde et al., 2015; Joyner et al., 2019; Lau et al., 2016; Melero-Cañas et al., 2020; Mellecker & McManus, 2008; Rincker & Misner, 2017; Viggiano et al., 2018; Ye et al., 2018). Interventions based on the gamification strategy obtained positive results in 3/4 studies (Beemer et al., 2019; Joyner et al., 2019; Melero-Cañas et al., 2020).

However, most studies 25/35 (71,4%) received a weak global rating in the quality

of the study (Bailey & McInnis, 2011; Baranowski et al., 2011; Coombes & Jones, 2016; Cui et al., 2012; D'Egidio et al., 2019; Direito et al., 2015; Fu & Burns, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2019; Gao et al., 2019; Garde et al., 2018; Joyner et al., 2019; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Ye et al., 2018) and only 8 included reported effect size (Baranowski et al., 2011; Direito et al., 2015; Gao et al., 2019; Gao et al., 2019; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018), where only 2/8 presented a large size (Miller et al., 2015; Rincker & Misner, 2017) . In recent years, the use of several strategies such as games and gamification at the school context to increase PA has become more widespread, trying to improve than only 20% meet the recommendations in this population (Guthold et al., 2020). Nevertheless, information about games and/or gamification as a school-based PA intervention is limited. Most studies based on game or gamification strategies have not been performed at school contexts and/or children and adolescent.

In this systematic review, most studies developed game-based interventions instead of gamification, which may be due to that the intervention's gamification strategy is still a novel approach (Cassar et al., 2019; Deterding et al., 2011). In addition, gamification requires a high degree of elaboration, commitment, and perseverance from the researcher-teachers for the intervention to progress properly (Deterding et al., 2011), as well as it needs to be extensive in the time to find long-term effects (Cassar et al., 2019). Contrarily, gamification is a good strategy to increase the commitment of its participants and it is concretized using technological applications (gamified application) (Edwards et al., 2016). The proposals of such gamified applications are including challenging tasks related to the adaptation of PA habits, food intake, or sedentary behaviours (Schoeppe et al., 2016). For this, the gamification must consist of proportionating enjoyable moments to users (Pereira, Duarte, Rebelo, & Noriega, 2014) through the inclusion of the game's elements along the tasks such as badges, points, challenges, rewards, leader boards, and different levels (Hamari et al., 2014). Several studies had positive results on some health-related habits in the adult population using gamification (Monguillot , González , Zurita & guitert catasús, 2015; Pérez-López, García, & Cervantes, 2017; Pérez-López, Rivera García, & Delgado-Fernández, 2017) but it seems that these positive effects are unclear in the young population (Díaz, Muñoz, & Santos-Pastor, 2019; Sardi, Idri, & Fernández-Alemán, 2017). The same happens in the gamification studies included in the present systematic review. A previous systematic review of school-based intervention programs to promote PA concluded that the content and

details of the school-based intervention program are the most important factors which determine the efficiency in the studies examined (Yuksel et al., 2020). Thus, it is necessary to deep into the specific content of the gamification interventions in the school context, choosing the successful gamification elements as well as, attractive and adaptable content for the age of the target scholar population. The intervention studies based on gamification in this systematic review were carried out in a population from 8 years old to adolescent population age. The interventions had a heterogeneous duration ranging from 8 weeks to 9 months.

In the same way, a recent systematic review and meta-analysis (Mazeas, Duclos, Pereira, & Chalabaev, 2022) concluded that there is a statistically significant effect (small to medium) of gamified interventions on total PA (mainly number of steps per day and no in MVPA) with an average of 12 weeks of intervention. However, not all studies were carried out in a school setting and on young people. Notwithstanding, a similar duration was presented in 3/4 included studies based on gamification in the present systematic review (Combes & Jones, 2016: Beemer et al.,2019; Joyner et al., 2019; Melero-Cañas et al., 2020).

Moreover, it seems that the effect of gamification may be efficient in any kind of population including young people (children and adolescents) (Mazeas et al., 2022). However, it seems recommendable to implement multiple gamification during or after the period of the treatment to acquire a more sustainable PA behaviour in time. Moreover, this organization in the gamification-based intervention could be affordable in the school context due to the different intervals of academic periods/recess and so provide an adequate duration which avoids the possible exhaustion and boredom in the participants with gamified interventions > 12 weeks.

Regarding the game-based interventions, 31 of the included studies implemented these types of strategies with the use of exergames or AVG as the main type of game (Bailey & McInnis, 2011; Baranowski et al., 2011; Cui et al., 2012; Chen & Sun, 2017; D'Egidio et al., 2019; Direito et al., 2015; Duncan & Staples, 2010; Fu & Burns, 2018, 2019; Fu et al., 2018; Gao et al., 2013; Gao et al., 2012; Gao & Podlog, 2012; Gao et al., 2017; Gao et al., 2019; Gaoet al., 2019; Gao et al., 2013; Garde et al., 2018;Garde et al., 2016; Garde et al., 2015; Lau et al., 2016; Maloney et al., 2012; Mellecker & McManus, 2008; Miller et al., 2015; Pope et al., 2018; Rincker & Misner, 2017; Robertson et al., 2018; Sharma et al., 2015; Viggiano et al., 2018; Wang et al., 2017; Ye et al., 2018). Some previous systematic reviews presented similar results about the prevalence of AVG-based interventions to improve health-related outcomes, but inconclusive evidence was found for the effect of games (AVGs) on PA (Biddiss & Jennifer , 2010; Gao, Zeng, McDonough, & Su, 2020; LeBlanc et al., 2013; Norris, Hamer, & Stamatakis, 2016). In contrast, other studies concluded that this

type of strategy can increase PA among overweight adults (Höchsmann, Schüpbach, & Schmidt-Trucksäss, 2016), children/adolescents (Ramírez-Granizo, Ubago-Jiménez, González-Valero, Puertas-Molero, & San Román-Mata, 2020), and improve on weight-related outcomes in obese children and adolescents (Valeriani et al., 2021). The greatest similarity between the effective games-based interventions in the present systematic review was that they all used the modality of "exergames" (i.e., AVG) using technological tools such as Wii, Xbox 360, or Play station focused on playing sport, dancing, or doing fitness circuit training). Maybe, the use of new technologies arouses a great interest of young people due they are very attractive, as well as generates motivational effects in a short period due to the stimulation that they provide when playing (Ramírez-Granizo et al., 2020). In addition, young people may be more likely to exercise longer because they have the AVG which distracts them thus maybe they could reach greater amounts of physical activity and energy and their perceived exertion could be attenuated (Sween et al., 2014). Additionally, the activities during AVG were carried out in the same space and by all pupils at the same time, which allowed the socialisation and encouraged participation in the games (Burke, Carron, Eys, Ntoumanis, & Estabrooks, 2006).

Related to the duration of the intervention, we cannot suggest a specific period since the games-based interventions that significantly increased PA included in this systematic review showed a wide time variability of at least 6 weeks up to one academic year or a wide variability in the weekly frequency (from 1 day to 5 days per week). In addition, it must be taken in account that the interventions that increased PA may be limited along the time.

Other important considerations for the implementation of interventions in the school context are those presented in table 2, such as if the intervention has been implemented by the teacher, if the research team has been involved in the implementation, incentives to participate or if the parents were involved in the intervention. Moreover, there was little process evaluation of AVG interventions, which did not report indications of session uptake, teacher, children/adolescents, and school feedback. Despite, previous study as the by Naylor et al. (2015) established that it is important to know the perceived perceptions of the different members of the educational community. Additionally, most of the studies focused on incentives to participate. In this sense, Physical Education teachers are the best educators for improving physical activity from school and they can use technological learning to boost attitudes and participation in physical activity among young people, particularly at primary school age. It is an optimistic opportunity for Physical Education professionals to lead designs of effective physical activity interventions based on games and applications for applying since

early stage (Goodyear, Skinner, McKeever, & Griffiths, 2021). Related parent's implication, only one study used parents' participation. Parental involvement is a decisive factor for the quality of education and their participation is positive at all levels (Sarramona, 2004). Parents should participate in the school, in the activities, maintain positive contact with the teachers of the centre as it will lead to positive results in the students. Getting involved in the child's education will be much more likely for children to develop a good attitude to learning and good self-esteem thanks to achievement and learning-error. Therefore, collaborative work between parents, teachers and students is necessary to create a union that continues in the same direction, in constant and fluid communication (Martínez, 2010).

Finally, all studies were rate as low-quality intervention. This could be because it is complex to control the different variables involved in the school setting such as the time of the sessions, controlling PA when not using an objective tool, or contamination from one class to another or even within the same school. In addition, it seems to exist limited success of school-based physical activity interventions since they are mainly focused on the results and analyses as s if it were a strict clinical trial not on the real setting conditions.

Study IV. Designing the Mystic School mobile app to promote active commuting to school in Spanish adolescents: the PACO study.

In the current study, an app has been developed to promote ACS in adolescents. Adolescents found the app a fun alternative to play, spite of some technical problems, such as the lack of recording steps.

A recent meta-analysis (Romeo et al., 2019) provided evidence that the effectiveness of mobile phone apps to increase PA is the most effective in the short term but unfortunately, this conclusion is inconsistent due to the variety of results in different studies. In addition, the reason can be the intensity of the player activity, due to adolescents often losing interest in playing games for a longer period. Randomized controlled trial designs, larger sample sizes, and validated activity measurements beyond the school day is needed. Limited evidence is available on the long-term efficacy of AVGs for PA promotion (Biddiss & Irwin, 2010).

The perception of Mystic School app has been positive. The students liked playing in a group because they can share experiences. Once again, the need for socialisation, learning to organise, and decision making among all members is confirmed (Pindado, 2005). Thus, identifying what makes an app fun and engaging is important for an optimal game design (Norozi et al., 2020). Perhaps, more work should have been done on

characters that the user may identify with, such as high-end realistic graphic, and well-defined instructions; it has been suggested by a recent systematic review as one of the most important points to successfully achieve the healthy lifestyle promotion (Schwarz et al., 2020). In addition, adolescents wanted more competitive challenges. Consequently, initial gamification mechanisms such as competitions and challenges have been used during the intervention due to competitiveness is found to be associated with greater enjoyment (Frederick-Recascino & Schuster-Smith, 2003). In addition, Shameli et al. (2017) observed that during walking competitions, the average user increases PA by 23%.

On the other hand, the final focus-group was given an award of a healthy breakfast. In addition, each adolescents received a bracelet and backpack (by raffle) to participate in the study according to Sallis et al. (1999) recommended that interventions should provide greater incentives. Moreover, points-based reward systems were implemented to increase commitment to PA but only worked at first. As previous literature confirms (Ahn et al., 2019), this type of system seems to have little long-term impact. However, make something enjoyable depend on, intrinsic motivation based on satisfying three fundamental needs: competence, autonomy, and related-ness (Deci & Ryan, 2000) but current AVGs have failed to adequately meet all of these needs. In our study with AVG, researchers should have provided more motivations tools for the adolescents, to engage them playing and keep the adherence of accumulating steps.

In the light of the results, it is important to use different resources to increase PA in adolescents, and the smartphone apps are crucial in this process. Especially because, around 94% of the adolescents own or have access to a smartphone and 89% of them indicated that they access the internet almost constantly or several times a day (Anderson, 2018). In addition, a number of different applications are now available to increase PA, such as Pokémon Go (Khamzina et al., 2020) or Zombie Run (Direito et al., 2015). And the evidence of a meta-analysis showed that smartphone-based intervention may be a promising strategy to increase steps in children and adolescents (He et al., 2021). Therefore, these tools could have different purposes if the right approach is designed to motivate adolescents to change behaviour such as increasing physical activity.

After the implementation of this AVG, adolescents have shown interest and initiative to use it. This type of proposal can be a useful tool to complement or add to the Physical Education curriculum, although it should be analysed to corroborate that it increases PA. Other lessons learnt from the implementation of the AVG is the difficulty of facing technical problems within the app that cannot be solved by researchers and computer experts are required. So, as researchers, we suggest firstly, to have

enough economical budget to contract a computer business and have a complete and finalised app before using it for research issues.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

The present study examined the adolescent students' and Physical Education teachers' perceptions about a school-based intervention called “alien invasion” to promote ACS integrated into the PE lesson, which used an active video game called "Mystic School”. The sessions of the intervention were perceived by adolescents as entertaining and enjoying session (especially the last session). According to the Physical Education teachers, the intervention strategy was interesting and applicable in Physical Education lessons because of the different approach given to the sessions. However, the active methodology requires prior experience and preparation of the content in advance is needed. The students enjoyed, the different situations proposed s, as such it is defined in the active methodology such as generate experience through emotions and encourage discovery learning (Gálvez, 2013). Today's active methodologies are increasingly having a significant impact (González & Dueñas, 2009). Active methodologies involve students in the learning process through activities and/or discussions in the classroom, where students are the protagonists of learning, through the teacher who guides them (Freeman et al., 2014). Although learning is student-centered, this study must incorporate more feedback to adolescents to meet the objectives. A study showed a positive feedback, intrinsic motivation in PE and the fear of making mistakes has decreased in young people (Torregrosa & Murcia, 2015). A comprehensive program is needed to ensure children have the opportunity to meet PA guidelines. Moreover, these studies (Check, 2013; Hills, Dengel, & Lubans, 2015) suggested that to achieve the benefits of promoting PAs must involve coordination among the following five components: 1) quality PAs; 2) PA during the school day; 3) PA before and after school; 4) staff involvement; and 5) family and community engagement.

Physical Education teachers believe that the sessions can be carried out but require previous experience and more time to prepare the activities than conventional ones. There are a series of barriers in the school environment that hinder the promotion of PA, one of them is the level of experience of the teacher (Jenkinson & Benson, 2010). As one of the teachers in our study commented, although it seemed like a very attractive proposal, it requires more experience to face each situation and prepare the sessions beforehand. It is important to consider also the duration of the sessions, has been considered short in order to complete the contents of the proposal. Previous study has shown that is one of the

barriers in the school environment, since the time is established and there is no flexibility to change or extend the schedule. (Lounsbery, McKenzie, Trost, & Smith, 2011). Using this methodology requires going beyond a focus on the learner (Crisol-Moya, Romero-López, & Caurcel-Cara, 2020). This change requires not only changes in the teacher but also organisational changes, in terms of infrastructure, resources and the cooperative environment among teachers (de la Sablonnière, Taylor, & Sadykova, 2009). As well as motivation of both students and teachers (Maclellan, 2008).

Regarding the use active video game called Mystic School during the Physical Education lessons, adolescents spent pleasant moments. Even so, there were many problems with the system, for example, it did not register correctly, or the steps ran out too quickly or did not load in the AVG. The PE teacher concluded that Mystic School needs to be improved, it could be added to the subject and even used with primary school children due to the design. The use of mobile phones is prohibited in most schools. However, several authors endorse the advantages of mobile devices in schools, due to the attractiveness and wide educational offer they provide to the teacher (Crompton & Burke, 2018). To solve the bad perception of mobile phones, strategies are recommended to regulate the use of mobile phones at school for proper use and enjoyment (Kopecký, Fernández-Martín, Szotkowski, Gómez-García, & Mikulcová, 2021). Previous studies have demonstrated that to establish the effectiveness of behaviour change techniques in PA and diet apps, the interventions must be oriented to implementation in the school curriculum (Brannon & Cushing, 2014). Additionally, it seems that most of the mobile health apps have positive effects on individual health variables (Milne-Ives, Lam, De Cock, Van Velthoven, & Meinert, 2020). Therefore, although the results indicate that it is necessary to continue deepening the proposal, both the perception of students and Physical Education teachers are necessary for the development of student-centered methodologies (Crisol Moya & Caurcel Cara, 2021).

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

The aims of this study were (i) to analyse the associations between HRQoL, PF, and mode of commuting to and from school in children, and separately by gender, and (ii) to analyse the difference in PF by mode of commuting to and from school by gender. The main findings were: 1) CRF was positively correlated (weakly to moderate) with all dimensions of HRQoL in boys, whereas higher muscular strength (standing long jump) was positively correlated with the emotional well-being dimension in girls; 2) children who actively commuted to school presented better scores for the

emotional well-being, family, and school dimensions, as well as total scores (all $p < 0.05$) of HRQoL; and 3) boys who actively commuted to school (walking) presented better CRF than those who passively commuted to school.

Regarding the association between PF and HRQoL, CRF was positively correlated with all dimensions of HRQoL in boys. Previous reports presented that children and adolescents who showed better indicators of psychological health were also those with high levels of CRF (Gerber et al., 2017). Our findings are consistent with the previous literature; for instance, Redondo-Tébar et al. (2019) indicated that children with high PF levels presented better scores in physical well-being, school, and total HRQoL score than those who had low PF levels. Another study carried out by Andersen et al.(2017) suggested that higher CRF was significantly associated with better scores on all of the KIDSCREEN-27 domains. This association could be due to physiological factors such as an increase in the feeling of well-being due to reduced stress and anxiety, (Cowley, Kiely, & Collins, 2017) or because boys have a greater well-being since it improves mood through self-image and self-concept (Strong et al., 2005). In our study, higher muscular strength (standing long jump) was positively correlated with physical well-being, emotional well-being, self-esteem, school, and total score of the HRQoL in boys, and with higher emotional well-being dimension in girls. A previous study noted that higher muscular strength levels were associated with physical well-being in boys and with school in girls (Redondo-Tebar et al., 2019). In addition, higher muscular strength showed an association with higher HRQoL in boys in terms of physical well-being, social support and peers, and social acceptance and in terms of physical well-being in Spanish girls between 8 and 11 years old (Morales et al., 2013). Thus, Tarp et al.(2018) indicated that promoting higher-intensity PA at young ages was the main determinant of variation in cardiometabolic risk factors and could have long-term effects on PF, in particular muscular strength, which improves the well-being of children.

Globally, these differences in our study between boys and girls in relation to the association between PF and HRQoL could be due to various reasons. Firstly, gender and age are the main factors influencing PA in Spanish studies in children who did not meet PA recommendations (62.1% of girls)(Mielgo-Ayuso et al., 2016). In the study by Tomkinson et al.(2018) pointed out that boys performed substantially better than girls in muscular strength, muscular power, muscular endurance, speed-agility, and CRF, but worse on the flexibility test. Dong et al. (2019) suggested a decline in physical PF in children and adolescents during the last decade. This could be because PA levels are lower in children than in adolescents. Second, for young girls between 12 and 16 years old, teasing and body image concerns could contribute to reduced rates of

participation in sports and other physical activities (Slater & Tiggemann, 2011). Third, girls' Physical Education memories were more often negative (Coakley & White, 1992). Furthermore, the fun component in Physical Education lessons is considered very positive for the subsequent practice of physical and sports activity (Gómez-Mármol, 2013). Therefore, enjoyment assumes a very important role in Physical Education lessons and is usually higher in boys than in girls (Fairclough, 2003). In addition, a recent systematic review indicated lower parental and teacher support as barriers limiting girls' PA, hence less participation in sports activities whereas negative experiences could affect self-concept, which is related to less well-being (Corr, McSharry, & Murtagh, 2018). CRF is associated with PA, so intervention programs should focus on improving fitness levels at these ages, thus achieving greater well-being.

In the current study, CRF was associated with HRQoL. Schoolchildren who actively commute to school presented higher scores in the school dimension. It could be that boys who walk to school are more sociable due to they can be accompanied by other classmates and relate throughout the journey, as opposed to being accompanied by an adult (higher psychosocial level and better connection with friends)(Freeman & Quigg, 2009). Additionally, Gerber et al. (2017) showed that children with higher fitness levels experienced higher physical well-being and more positive friendship relationships. Furthermore, high levels of CRF have been associated with enhanced self-esteem in children (Steene-Johannessen, Kolle & Andersen, 2013). Consequently, children who present higher levels of CRF and walk or cycle to school should be more comfortable walking to the rhythm of schoolmates. However, comparing the results is complex because different evaluation tools were used, thus, future studies should address this issue.

Our results provide relevant information about boys who actively commute to school, since they are more likely to improve their CRF than those who passively commute. However, a recent systematic review (Henriques-Neto et al., 2020) suggested that among younger ages, active commuting by cycling is inconsistently related PF. According to Voss & Sandercock(2010) girls and boys who regularly walked to school were fitter and significantly more likely to be categorized as fit compared with passive commuters. To our knowledge, there is little evidence for the association between walking to school and CRF, although somewhat inconsistent(Østergaard, Kolle, Steene-Johannessen, & Andersen, 2013). It must be taken into account that only 30.5% of the sample was actively commuting, and with a journey time of more than 15 minutes. The assessment of PF in young people is relevant from a public health point of view. Existent evidence refers primarily to children above 10 years of age and

adolescents, with nearly no information about PF and health in children from 8 to 9 years old. Henceforth, interventions promoting PF and ACS need to be developed to improve HRQoL.

LIMITATIONS AND STRENGTHS

Limitations and Strengths

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

Interpretations of the current study's findings should take several strengths and some limitations into account. The main strength of this study is the first Spanish research analysing ACS in preschool children, covering a period of 5 years. Furthermore, the inclusion of a large sample of Spanish preschool children allowed this study to examine in detail the changes in ACS using multilevel analyses. The main limitation was that it is not a nationally representative study but a geographically distributed one, even when a variable number of participants regarding every year and region are present. Additionally, sampling procedures and original data from the various studies were not identical. In this sense, the mode of commuting to and/or from school was assessed using different questions in the original studies, and the data collection also varies. However, the systematic process was followed to merge the studies, and the various questions were used to ensure accurate data and appropriate analysis of these data. Another limitation is the impossibility of collecting data about the commuting distance to control for the analyses; the main determinant of ACS is a result of this.

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

The limitations of the review protocol are the language inclusion criteria including only English. Despite RCTs would be the ideal studies design to include in systematic reviews is important taking in account that in the present systematic review protocol all types of studies designs will be included (even studies with no controls) due to it is a novel field of research and in an educational context, where the application of studies with RCTs design are scarce. Regarding the strengths, to our knowledge, there is no review that fills these gaps in the literature by performing a broad search to find interventions based on game and gamification strategies.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

Although the results of this systematic literature review provide novel information on the relationship between PA and games/gamification in the educational context, some limitations of the present study must be acknowledged. Firstly, the language in which the article is published, only articles written in English is included. As for the analysis of the studies, there is no

established design in all interventions. Therefore, it is not possible to compare a 1-day intervention with a 2 academic year intervention due to the heterogeneity of studies. The main strengths of this systematic review are the specific focus on school-based interventions that promote PA at school and the inclusion of different perspectives through games and gamification, and the inclusion of both risk of bias and quality assessment.

Study IV. Designing the Mystic School mobile app to promote ACS in Spanish adolescents: a focus group study.

The strengths of this study included the novel AVG app use and that it has been applied in different educational contexts. In addition, focus groups and qualitative methodology have been included collaborating with experts in this type of analysis. Nevertheless, some limitations must be acknowledged such as the use of a convenience sample in the phase 1 and the fact that AVG was only available for Android software.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

The strengths of this study included a novel and attractive strategy to motivate to participate in the sessions based on active methodology. Mystic School was applicated in different educational contexts. In addition, randomised sampling was carried out and the intervention was implemented as part of the subject curriculum. Although the sessions were focused on a block of curriculum content on PE subject, there was no previous continuity on the part of the teacher. However, some limitations were observed:

AVG presented some inconvenience for its correct operation and, the circumstances were different between both periods due to the COVID. The sessions were of very short duration and the implementation of new strategies requires extensive experience and long-term follow-up. Another important aspect was that in both schools the use of smartphones was not allowed. The research group obtained prior authorization for its use, some students did not bring the device and could not carry out the planned activity. Thus, behavioural science and technology should be more aligned between academia and industry to ensure that technologies are effective in adolescents. In addition, the development of the application was carried out by different people, and this could have influenced the results. Given this situation, the different smartphone models of the students who participated in the study were registered, but it was not possible to implement improvements for all models as it involved much more financial and time expenditure than anticipated.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

A major strength of the study is that it provides results obtained through two self-reported validated questionnaires to evaluate the mode of commuting to and from school and the HRQoL, and we must highlight that this study offers novel results in Spanish children from 8 to 9 years old. In addition, we applied the ALPHA battery assessed in several physical fitness studies and the objective of the association between HRQoL, physical fitness, and active commuting among schoolchildren.

FUTURE RESEARCH DIRECTIONS

Future Research Directions

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

Future research may want to analyse the trends using a representative sample of Spanish preschool children and use objective tools, such as a global positioning system (GPS), to obtain a child's distance and route. An accelerometer could also be incorporated to study the intensity that preschool children travel to school to understand more firmly how ACS in these ages helps to achieve the daily PA recommendations. It would be important to use a valid and reliable questionnaire that evaluates the mode of commuting in order to compare between various schools. Future research should continue analysing ACS trends to understand the factors that influence this behaviour among preschool children (i.e., environmental characteristics, time, safety, or traffic). The school context represents an opportunity to promote health-related behaviours, such as ACS, from an early age (Sevil, García-González, Abós, Generelo, & Aibar, 2019). The promotion of active commuting must be based on an interdisciplinary work between teachers, parents, and communities to have a guaranteed success. As a result, it is already known that effective PA programmes could generate considerable cost savings for public health services (Abu-Omar et al., 2017).

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

Although the novelty systematic review protocol format does not include a section on future research directions, the authors desire to share their impressions about it.

Despite the recent studies based on games and gamification, there is no full review following a rigorous process to identify the overall school-based interventions focused on these strategies. In addition, research is needed to assess the impact of games and/or gamification strategies on the PA levels of young people. Due to there is great terminological and methodological confusion in the use of games and gamifications strategies to increase PA levels, in future systematic reviews in need to include all the terms mentioned in the current protocol study, as well as, needs to taken into account for the implementations of future interventions.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

The findings of this systematic literature review have implications for both researchers and practitioners working

around games and gamification applied in educational context. After analysing and evaluating the interventions, future research should improve the risk of bias and quality of intervention programmes such as calculating sample size to be able to compare and replicate studies. In addition, it is necessary to include the control group and using objective and rigorous evaluation tools to ensure effectiveness. To increase PA may focus on strategies like motivational side to meet positive effect long-term. Moreover, the findings of this review show that most of the studies reported interventions and evaluations during a short period of time, which diminished the accuracy of the results. Thus, future research on games and gamification-based interventions could be beneficial to implement interventions in longer periods. The involvement of family members and even the whole school community should be taken into consideration. Design an intervention programme with constant monitoring to know its effect in the short and long term. There is a need for researchers and teachers to collaborate on design for best results. In addition, the heterogeneity of the study design, sample size, and different components of the intervention must be applied, such as the measurement of the main variables through different tools, do not allow to carry out a meta-analysis.

Study IV. Designing the Mystic School mobile app to promote ACS in Spanish adolescents: a focus group study.

The Mystic School application was interesting for adolescents, however, it will need to be implemented in a more realistic context within the Physical Education curriculum. In this way, it will be possible to know the opinion of the teachers as well as the adolescents. With this, it will be possible to consider the application as a tool for the Physical Education teacher to promote physical activity.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

It would be very interesting if the previous design of the sessions was carried out together between the research team and the teacher and, if possible, if the teacher was the one in charge of delivering the sessions due to his wide experience and knowledge of his students. Although the application was positively evaluated in terms of its design and objective, the application entails a very high economic cost. Future studies should focus on the design and implementation of this type of intervention over a longer period with the collaboration of researchers, teachers and schools.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

These findings suggest that future research should aim to understand the relationship between ACS and quality of life related to children's health according to different factors. In addition, future studies should analyse the associations between ACS by walking and cardiorespiratory fitness. Moreover, future interventions should promote PA in Physical Education enjoyment sessions, emphasizing girls. A good alternative to increasing PA outside the school is through ACS to achieve greater adherence and PA. The school and parents could organize walking trips or create safe routes in the school environment. More studies are needed that implement objective measurements that may be considered when comparing different studies.

CONCLUSIONS

CONCLUSIONS

Study I. Active Commuting to School among Spanish Preschool Children: A Temporal Trend Study between 2013 and 2017.

The rates of ACS in Spanish preschool children are around 50% between 2013 and 2017, and these rates have remained stable. This study sheds light on the relevance of promoting ACS from early stages. Actions focused on a strong collaboration between the researchers and schools to achieve high levels of ACS are required.

Study II. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: A Systematic Review Protocol.

A detailed description of the systematic review protocol on school-based interventions to promote PA in pre-schoolers, children, and adolescent students using games and/or gamification has been presented in this manuscript. The review methodology—including recommended electronic database searching, identification of records, screening, and data extraction strategies, as well as recommended tools for quality and effective analyses of intervention studies—has been described in detail. Additionally, an update and clarification on the different terms related to games and gamification in the school context has been included.

Study III. School-Based Interventions for Promoting Physical Activity Using Games and Gamification: a systematic review.

The studies included in this review showed that games-based interventions, in particular exergaming (i.e., AVG), were the most type of strategies used to promote PA in the young population instead of gamification in the school context. The AVGs used mainly technological tools such as Wii, Xbox 360, or Play station focused on playing sports, dancing, or doing fitness circuit training, which was feasible and attractive strategies to increase PA in at short term. Its implementation is easy in scholar settings with minimal funding and with the great advantage that they can be personalized to each student. Incentives for participation, longer intervention duration, and the teacher and research group implication was an essential characteristic of successful interventions. However, including the family and parents' implication is needed as well as proportionating an attractive content. Supervision and the quality of the intervention must also be improved.

Study IV. Designing the Mystic School mobile app to promote ACS in Spanish adolescents: a focus group study.

The Mystic School was positively accepted by adolescents, although the software needs some technical improvements. It can be confirmed that Mystic School app might be a good game to promote PA increasing the number of steps, conducting some technical

modifications regarding the design and the software after experiencing and listening the participants. Future works should implement a more active methodology together with the AVG, to increase the motivation and adherence of the participants within the PE curriculum.

Study V. Active methodologies in Physical Education lessons: a school-based intervention.

This study provided key information for the implementation of the Physical Education intervention according to the curriculum. Physical Education proposal combined active methodologies and new strategies such as AVG for the promotion of healthy PA habits such as ACS. The proposed intervention, as well as the integration of the Mystic School app to promote ACS, were perceived by adolescent students as entertaining and enjoying, however, some technical improvements are needed for future implementations. The Physical Education teachers found the educational approach interesting and in that the use of the Mystic School app improved motivation among the adolescents, albeit in the short term and the need of teacher experienced to correctly apply the educational proposal. However, future research on behaviour changes techniques and the level of contact with participants to maximise user engagement and extend the intervention period is needed.

Study VI. Is children's health-related quality of life associated with physical fitness and mode of commuting? PREVIENE Project.

The current study identified that CRF level was positively correlated with all dimensions of HRQoL in boys, whereas higher muscular strength (standing long jump) was positively correlated with the emotional well-being dimension in girls. In addition, children who actively commuted to school presented better scores for the emotional well-being, family, school dimensions, as well as the total scores of HRQoL. Finally, boys who actively commute to school (walking) presented better CRF compared to their passive counterparts. Consequently, more school-based interventions to increase the PA through ACS could contribute to improving CRF and HRQoL. In addition, future work should seek to more rigorous research designs, including objective measures, random experimental group assignment, and longitudinal sampling.

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SHORT CURRICULUM VITAE

Short Curriculum Vitae

1. Personal Data

Name: ROMINA GISELE, SAUCEDO ARAUJO
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Birth Date: 27/09/1992
ORCID/Research ID: 0000-0002-4494-2353
Research Gate: Romina G. Saucedo-Araujo

2. Current Affiliations

PhD candidate - PROFITH "PROmoting FITness and Health through Physical Activity" Research Group, Sport and Health University Research Institute (iMUDS), Department of Physical Education and Sports, Faculty of Sport Sciences, University of Granada, 18011 Granada, Spain.
Funded by the Spanish Ministry of Economy and Competitiveness.
Supervisor: Dr. Pablo Tercedor Sánchez.
Co-supervisor: Dr. Yaira María Barranco Ruiz.
Tutor: Palma Chillón Garzón.
2017 - 2022

3. Research experience

Project Manager **01/01/2018 – 30/09/2022**
Project Title & Design: "PROMESA" Program for the improvement of health through physical education.
Principal Investigator: Pablo Tercedor Sánchez.
Department of Physical Education and Sport, University of Granada, Spain.
Funding: Junta de Andalucía - European Funding €6000.

Collaborator **01/01/2022 – 31/12/2022**
Project Title & Design: Mobility and Exposure to Atmospheric Pollution at the UGR.
Principal Investigator: Pablo Campos-Garzón.
Department of Physical Education and Sport, University of Granada, Spain.
Funding: Spanish Ministry & European Funding. *MECA-COFUND* €2000.

Researcher **30/12/2016– 30/06/2022**
Project Title & Design: "Pedalea y Anda al COle: PACO" (Cycling and Walk to School) study.
Principal Investigator: Palma Chillón Garzón.
Department of Physical Education and Sport, University of Granada, Spain.
Funding: Spanish Ministry & European Funding €84700.

Researcher **01/03/2015 – 01/03/2017**
Project Title & Design: PREVIENE "Promotion of Healthy Lifestyles in the School Environment.
Principal Investigator: Pablo Tercedor Sánchez.
Department of Physical Education and Sport, University of Granada, Spain.
Funding: Spanish Ministry & European Funding €90750.

Collaborator **01/03/2012 – 28/02/2014**

Project Title & Design: Multicentre prefit study: fitness evaluations in pre-schoolers.
Principal Investigator: Francisco Ortega Poncel.
Department of Physical Education and Sport, University of Granada, Spain.
Funding**:** RAMON Y CAJAL €15000.

4. Education and training

Doctoral Programme in Education Sciences 12/12/2017 – 15/07/2022
Thesis title: School-based interventions to promote active commuting to school and quality of life in Spanish children and adolescents.
Supervisor: Dr. Pablo Tercedor Sánchez.
Co-supervisor: Dr. Yaira María Barranco Ruiz.
Department of Physical Education and Sports, University of Granada, Spain.

Master's degree in Research on Physical activity and Health
01/10/2016 – 05/07/2017
University of Granada, Spain

Bachelor's Degree in Teacher Training Grade in Child Education
15/09/2011 - 27/07/2015
University of Almería, Spain

5. Research internships

- 01/05/2021 - 31/07/2021: University of Palacký- Olomouc, Czech Republic with **Josef Mitas**.
- 10/01/2020 - 10/03/2020: University of Valencia, Spain with **Javier Molina-García**.
- 25/08/2018 - 25/11/2018: University of Castilla-La Mancha, Spain with **Susana Aznar**.

6. Research staff in predoctoral training

- 25/01/2021 - 25/06/2021: **Research contract funded by PROMESA project**. University of Granada.
- 14/02/2020 - 15/05/2020: **Research contract funded by PACO project.** University of Granada.
- 15/01/2019 - 15/07/2019: **Research contract funded by PACO project**. University of Granada.
- 01/05/2018 - 01/06/2018: **Training programme funded by STARS project**. University of Granada.

7. Awards and grants

- 22/04/2021 - NAOS Strategy Award to **PACO project.**
- 22/11/2017 - NAOS Strategy Award to **PREVIENE project.**
- 01/09/2017 - 30/06/2018: **Initiation to research grant**. University of Granada (**€1000**).

8. Teaching and supervising activities

- **Substitute Teaching Tutor** - teaching and research staff of University of Granada. Double Grado (Bachelor's Degree) in Primary School Education and in Sport and Exercise Sciences.
- **Substitute Teaching Tutor** - teaching and research staff of University of Almería. Grado (Bachelor's Degree) in Sport and Exercise Sciences.
- **Lectures** on the Master's degree: "Research on Physical activity and Health", University of Granada.
- **Co-supervisor** (non-formally) of 1 Master Thesis during my PhD studies.
- **Orientation seminars in university students.** Grado (Bachelor's Degree) in Early Childhood Education.

9. PhD Courses attended (focus on teaching)

27/06/2022 – 01/07/2022	FIDO Training FIDO-TFGs, TFMs and Doctoral Theses.
23/04/2022 - 12/05/2022	Neuroeducation and creativity: new challenges for teachers. Meaningful learning.
14/02/2022 - 25/02/2022	New technologies to improve academic training. Gamification, Edutainment and Chatbots in the classroom.
09/05/2021 - 21/05/2021	Mindfulness and emotional balance II. Connecting with others.
04/05/2021 - 01/06/2021	Neuroeducation and creativity: optimisation and virtual teaching.
13/10/2020	The ABC of gamification.
25/03/2020	E-learning and emerging pedagogies for a confined university.
05/05/2020	Play and fiction as generators of emotion and learning.

10. Publications

I have published in **journals** of different areas, with a very **multidisciplinary profile**. This is supported by the fact that all my publications as first author are in the first quartile (Q1, at its moments of publication) according to the Web of Sciences (WOS), and link of Google Scholar Citations to access to the full list of publications: https://shortest.link/3TRF

- Herrador-Colmenero M, Estévez-Piñeiro P, **Saucedo-Araujo R.G**., Aranda-Balboa M, Girela-Rejón M. The permission for walking to school: An analysis from a gender perspective. Journ. M. Health. 2022;19(2). Disponible en: doi:10.5027/jmh-Vol19-Issue2(2022)art165.
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11. Book Chapter

- **Saucedo-Araujo, R. G.,** Campos-Garzón, P & Barranco-Ruiz, Y. En: Hinojo Lucena FJ, Sadio Ramos FJ, López Núñez JA, Romero Rodríguez JF (Eds.). Experiencias e investigaciones en contextos educativos 2020, pp 246-267. ISSBN: 978-84-1377-171-7. Madrid, España: Dykinson S.L

12. International Conferences

Top 5 International Conferences

	ISBNPA XChange 2021, Virtual.
08/06/2021 - 10/06/2021	Oral presentation: "Associations between health-related quality of life with physical fitness and mode of commuting in Spanish school-aged children".
	ISBNPA XChange 2021, Virtual.
08/06/2021 - 10/06/2021	Oral presentation: "School-Based Interventions for Promoting Physical Activity Using Games and Gamification: Preliminary results of a Systematic Review".
	International on Education and Innovation Congress, Coimbra, Portugal.
11/12/2020 - 13/12/2020	Oral presentation: "Games and gamification at school for the promotion of physical activity: conceptual approaches and keys to their implementation in physical education".
	International Society for Behavioral nutrition and Physical activity Congress**,** Prague, Czech Republic.
04/06/2019 - 07/06/2019	Poster presentation: "Is active commuting to school associated to health-related quality of life in Spanish children? PREVIENE Project".
	International Society for Behavioral nutrition and Physical activity Congress**,** Prague, Czech Republic.
04/06/2019 - 07/06/2019	Poster presentation: "Changes of active commuting to and from school in Spanish preeschoolers during the last 5 years: the PACO project".

13. Others participations in national and international conferences

23/03/2022 - 25/03/2022 **VI Congreso Internacional en Investigación y didáctica de la Educación Física - ADDIJES**, Granada, Spain. López-Centeno, F.D., **Saucedo-Araujo, R.G.** & Herrador-Colmenero, M. Asociación entre el modo de desplazamiento al centro educativo y las características del entorno construido familiar y escolar en adolescentes españoles.

17/12/2020 - 18/12/2020 **XVIII Seminario Nacional y VIII Internacional de Investigación en Ciencias de la Actividad Física, Didáctica de la Educación Física y Estilos de vida activo y saludables.** Virtual. Rodríguez-Rodríguez F., Huertas-Delgado F.J., Aranda-Balboa M.J., **Saucedo-Araujo, R.G.,** Herrador-Colmenero, M. "Factores sociodemográficos, actividad física y desplazamiento activo de padres, como predictores de la movilidad independiente al colegio en niños y adolescentes".

19/03/2020 - 20/03/2020 **VI Congreso Internacional en Investigación y didáctica de la Educación Física - ADDIJES,** Granada, Spain. Gálvez-Fernández P, Huertas-Delgado F.J., **Saucedo-Araujo R.G**., Herrador-Colmenero. Asociación entre movilidad independiente con grupos de edad y género en niños en la provincia de Granada.

04/06/2019 - 07/06/2019 **International Society for Behavioral nutrition and Physical activity Congress**, Prague, Czech Republic. Chillón P, Gálvez-Fernández P, Huertas-Delgado FJ, Villa-González E, Barranco-Ruiz Y, Aranda-Balboa MJ, **Saucedo-Araujo RG**, Segura-Díaz JM, Pérez-López IP, Martín-Matillas M, Santiago-Zaragoza JM, Molina-García J, Queralt, Lara-Sánchez A, Aznar S, Rodríguez-Rodríguez F, Mandic S, Herrador-Colmenero M. A cluster-randomized controlled trial to promote active commuting to and from school and physical activity: The PACO Study.

04/06/2019 - 07/06/2019 **International Society for Behavioral nutrition and Physical activity Congress**, Prague, Czech Republic. Herrador-Colmenero M, Aranda-Balboa MJ, **Saucedo-Araujo RG**, Salto C, Chillón P. Feasibility of a cycle training course in physical education lessons for Spanish adolescents: the PACO Project.

04/06/2019 - 07/06/2019 **International Society for Behavioral nutrition and Physical activity Congress,** Prague, Czech Republic. Segura-Díaz JM, Barranco-Ruiz Y, **Saucedo-Araujo RG**, Aranda-Balboa MJ, Cadenas-Sánchez C, Migueles JH, Herrador-Colmenero M, Chillón P, Villa-González E. Feasibility and reliability of the Spanish version of the Youth Activity Profile questionnaire (YAP-Spain) in children and adolescents.

04/06/2019 - 07/06/2019 **International Society for Behavioral nutrition and Physical activity Congress**, Prague, Czech Republic. Segura-Díaz JM, Rojas-Jiménez A, Esteban-Cornejo I, Villa-González E, Barranco-Ruiz Y, Herrador-Colmenero M, Murillo-Pardo B, **Saucedo-Araujo RG**, Aranda-Balboa MJ, Chillón P. Reliability of a questionnaire to assess the mode and frequency of commuting to and from school: the PACO project.

04/06/2019 - 07/06/2019	**International Society for Behavioral nutrition and Physical activity Congress**, Prague, Czech Republic. Segura-Díaz JM, Rojas-Jiménez A, Esteban-Cornejo I, Villa-González E, Barranco-Ruiz Y, Herrador-Colmenero M, Murillo-Pardo B, **Saucedo-Araujo RG**, Aranda-Balboa MJ, Chillón P. Reliability of a questionnaire to assess the mode and frequency of commuting to and from school: the PACO project.
21/10/2019	**International Workshop: a focus on statistical methods to analyse accelerometer-measured physical activity.** Granada, Spain. Campos-Garzón P, Gálvez-Fernández P, **Saucedo-Araujo RG**, Aranda-Balboa MJ, Villa-González E, Herrador-Colmenero M, Lara-Sánchez A, Chillón P, Barranco-Ruiz Y. The adolescents that active commute to school had higher total physical activity levels and energy expenditure.
15/10/2018 - 17/10/2018	**7th International Society for Physical Activity and Health Congress** London, United Kingdom. Aranda-Balboa MJ, Fernández M, Esteban-Cornejo I, Villa-González E, Murillo-Pardo B, Segura-Díaz JM, **Saucedo-Araujo RG**, Barranco-Ruiz Y, Herrador-Colmenero M, Huertas-Delgado FJ, Chillón P. Reliability of a parents' questionnaire to assess the behaviour of commuting to and from school: The PACO project.

14. Reviewer articles

I have reviewed several manuscripts: European Physical Education Review; Journal of Transport & Health; Espirales. Cuaderno del profesorado; Publicaciones; Retos; Journal of sport and health research and Journal of Movement and Health.

15. Patent

21/05/2019	**"Mystic School", register number: 1905210950475- SAFE CREATIVE.** Palma Chillón, **Romina Gisele Saucedo Araujo**, Manuel Herrador-Colmenero, Juan Manuel Fernández Luna.

16. Courses attended (Transferable skills)

27/04/2020	Introduction to data analysis with SPSS II.
09/04/2020	Introduction to the potential of NVIVO to support qualitative research: content analysis, social network analysis and bibliographic management.
15/05/2020	Qualitative research with the NVivo software.
05/05/2020	Questionnaire design and validation.
05/06/2020	How to conduct a systematic review of the social science literature?
24/01/2019	Qualitative research design using Nvivo software.

09/05/2018	How to design and defend a poster communication.
18/04/2018	Theoretical and practical basics of multilevel analysis in SPSS.
13/04/2018	Ethics and validity in qualitative research.
21/03/2018	Introduction to Geographic Information Systems: territorial analysis with Arcgis.
09/06/2017	Data analysis in qualitative research.

17. Outreach activities

Several interview by local **media** to make public our project and results.

21/04/2021	Change of direction. PACO Project in Almería. Interalmería TV https://www.youtube.com/watch?app=desktop&v=igXFL5oiePA&feature=youtu.be
21/06/2019	Estepona city council, Málaga: https://profith.ugr.es/pages/tablon/*/noticias/el-proyecto-paco-en-estepona-malaga-buscando-soluciones-entre-todos#.YsTOr3ZBwsU
20/09/2018	Estepona city council, Málaga: https://educacionfisicaplus.wordpress.com/2018/11/01/la-infancia-se-mueve/ https://uceens.ugr.es/noticias/el-proyecto-paco-en-la-semana-europea-de-la-movilidad/

APPENDICES

APPENDICES

Appendix 1.

Vicerrectorado de Investigación y Transferencia

COMITE DE ETICA EN INVESTIGACION
DE LA UNIVERSIDAD DE GRANADA

La Comisión de Ética en Investigación de la Universidad de Granada, analizado el informe preliminar del Presidente del Comité en Investigación Humana, emite informe favorable a la metodología en la investigación titulada 'PACO (PEDALEA Y ANDA AL COLEGIO). ANáLISIS, DISEñO E INTERVENCIóN SOBRE EL DESPLAZAMIENTO ACTIVO EN ESCOLARES ESPAñOLES.' que dirige D./Dña. PALMA CHILLÓN GARZÓN, con NIF 74.637.361-S, quedando registrada con el nº: 162/CEIH/2016.

Granada, a 22 de Noviembre de 2016.

EL PRESIDENTE
Fdo: Enrique Herrera Viedma

EL SECRETARIO
Fdo: Fernando Comet Sánchez del Águila

Appendix 2.

INTERVENCIÓN MYSTIC SCHOOL

Estimado Centro

Somos profesores y doctorandos del Departamento de Educación Física y Deportiva de la Universidad de Granada. Estamos trabajando en el proyecto PACO (Pedalea y Anda al COle) dirigido por la profesora Palma Chillón Garzón; es un proyecto I+D+i financiado por el Ministerio de Economía y Competitividad (DEP2016-75598-R) que trata de fomentar que los escolares se desplacen al colegio de forma activa (es decir, andando o en bicicleta).

La práctica de **actividad física** tiene numerosos **beneficios para la salud física y mental**. Es importante, por tanto, identificar los hábitos de los adolescentes para poder promover estrategias que incrementen los niveles de actividad física, se desplacen activamente al instituto y disminuyan el tiempo dedicado a actividades sedentarias, con los posteriores beneficios para su salud. Por ello, esta intervención se centra en andar para lograr de forma progresiva un estilo de vida más saludable. Como requisito para poder participar será necesario: Poder usar el teléfono móvil **(sistema operativo ANDROID)** en clase con los alumnos durante, al menos 1-2 sesiones en el mes de la intervención de andar y que los alumnos de tercero de ESO no hubieran participado en otras intervenciones en el centro sobre desplazamiento activo durante la etapa de ESO.

El estudio va dirigido a un grupo de **alumnos/as de 3º de la E.S.O.** Los alumnos/as deberán, tras recibir el consentimiento de sus padres, participar en una evaluación inicial, seguidamente participar en la intervención de un juego para móvil para **ANDROID** denominada "Mystic School" en el que irán acumulando puntos a través de sus propios pasos diarios. Además, le permitirá descubrir nuevos retos hasta superar los niveles del juego. Finalmente, participarán en la evaluación final. Todo será realizado y supervisado por profesores del centro y de la Facultad de Ciencias del Deporte que acudirán al centro educativo. Detallamos las tareas que se llevarán a cabo:

1. **Consentimiento de participación:** se entregará un consentimiento informando a cada adolescente para que se lo hagan llegar a las familias y se devuelva firmado. **NO podrá participar** en el estudio ningún adolescente que no haya entregado el consentimiento firmado por su padre/madre/tutor. **Evaluación inicial:** los alumnos/as cumplimentarán un **cuestionario** sobre hábitos saludables, sencillo de cumplimentar y con una duración aproximada de una clase lectiva (aproximadamente 50 minutos). Además, se les entregará un **cuestionario de familias** para que completen sus padres de similar temática. En otra sesión de una clase lectiva, a los alumnos se les colocará un **cinturón con un acelerómetro y un GPS (para medir actividad física)**, que deberán de llevarlo 7 días completos las 24 horas del día, al que le acompañará un diario; y en esta misma sesión se realizarán medidas básicas de **composición corporal** (peso, talla y perímetros corporales) que se realizarán en una sala cerrada de manera individualizada. El uso del GPS puede ser algo opcional por el alumno o familia, si bien es recomendado.
2. **Intervención**: se llevarán a cabo **4 sesiones**. La primera sesión (30-45min) versará sobre la explicación de cómo usar la app Mystic School. La segunda sesión (10-15min) será para solventar dudas. En la tercera sesión (10-15min), se conocerá el ritmo de cada uno en el juego. Y en la última sesión (20min), sabremos quienes la han estado jugando durante todo el mes y sí ha supuesto cambios en sus hábitos diarios.
3. **Evaluación final:** Exactamente igual que en la evaluación inicial.

Esperamos poder contar con su colaboración para involucrar a los alumnos/as en este estudio y hacer llegar a los padres el consentimiento informado. Adjuntamos a continuación datos de contacto, para solventarle cualquier duda que pueda surgir. Muchas gracias de antemano por su colaboración,

Palma Chillón Garzón
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HOJA DE PARTICIPACIÓN DEL CENTRO

El centro educativo_____ con fecha de __/__/____se encuentra interesado en participar en la intervención.

Firma:_____

DEPARTAMENTO DE EDUCACIÓN FÍSICA Y DEPORTIVA. Ctra. Alfacar sin s/n. 18011- GRANADA Telef. 958244370 FAX 958244369

Appendix 3.

Figure 1. Mystic school application.