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Mandatory after-school use of step tracker apps improves physical activity, body composition and fitness of adolescents

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Abstract

Previous scientific research on the use of mobile applications to increase physical activity level and improve health among adolescents does not provide conclusive results, one of the main reasons being the lack of adherence to the intervention after the first weeks. For this reason, the main objectives of the research were to determine the changes produced by a compulsory ten-week period of after-school intervention with mobile step-tracking applications on adolescents' health; and the final objective to compare the benefits obtained by each of the mobile applications. To meet the objectives, a longitudinal study with non-probability convenience sampling was proposed. The sample consisted of 400 adolescents from two public compulsory secondary schools in the Region of Murcia, Spain, whose body composition, level of physical activity, adherence to the Mediterranean diet, and physical fitness were measured. The SPSS statistical software was used for statistical analysis. The results showed that adolescents in the experimental group showed a higher level of physical activity and better body composition and physical fitness variables after the intervention compared to the control group, with differences between the different applications used. In conclusion, this research shows the usefulness of mobile applications if they are used in a compulsory way after school hours. The relevance of these results for policymakers lies in the fact that they provide statistical data on the usefulness of mobile applications as an educational resource, being an option to make up for the lack of sufficient physical education teaching hours to meet global physical activity recommendations.

Keywords Adolescent development · Behavior change · Health · Mobile application · High school students

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1 Introduction

Adolescence is a crucial stage for the general population due to the establishment of certain healthy lifestyle habits that are maintained during this and later stages of life (Telama et al., 2005), reducing the possibility of suffering from cardiovascular diseases or certain types of cancer in the future (Barbiellini Amidei et al., 2022; Saint-Maurice et al., 2019). However, during this stage of human development we find the highest rate of abandonment of physical activity practice (Lunn, 2010), which has an impact on the health of adolescents in later years (Llorente-Cantarero et al., 2020), starting with the youth, where there a tendency has been found among sedentary adolescents to be sedentary young people (Kwan et al., 2012), leading to increases in variables related to fat mass, among others (Mcconnell-Nzunga et al., 2022; Vadeboncoeur et al., 2015). Therefore, adolescence is the most decisive stage in the acquisition of healthy habits in the period between childhood and adulthood, and the promotion of physical activity at this stage is essential for the physical well-being and mental health (Hallal et al., 2006).

Despite the importance of physical activity, physical inactivity and sedentary time during adolescence are increasing every year (Conger et al., 2022), reaching more than 80% and 35%, respectively, of this population in the past year. Physical inactivity includes performing less than sixty minutes of physical activity per day, while sedentary time is defined as sitting for three or more hours outside of school (Pechtl et al., 2022). This situation is very worrying, and has become a public health problem in Spain, because the current education law only stipulates two days of curricular physical education classes per week, which added to the decrease in out-of-school physical activity, and the increase in time spent in sedentary activities (Pechtl et al., 2022), results in a completely sedentary adolescent population, and an inability to meet physical activity recommendations with adolescents during school hours. Therefore, the only way to reach the minimum days of physical activity practice for adolescents to be considered active, is to practice physical exercise in their leisure time. However, the level of physical activity in leisure time has decreased to such extent in the last years, that from ages of 9–10 years old until young adulthood, most of the subjects do not reach the minimum recommendations (Corder et al., 2019; Farooq et al., 2020), resulting in a considerable decrease in physical fitness and a body composition far from healthy parameters (Lovecchio et al., 2020; Radulović et al., 2022).

In addition, the COVID-19 pandemic experienced in the last two years has had a major influence on the decline in the physical activity levels (Elnaggar et al., 2022; Yomoda & Kurita, 2021), deteriorating physical fitness (López-Bueno et al., 2021), and adherence to the Mediterranean diet (AMD) (Sánchez-Sánchez et al., 2020), while also increasing the variables related to fat mass (Karatzi et al., 2021), as well as the increased use of new technologies by adolescents (Ventura et al., 2021). Among the new technologies most widely used in this population, mobile phones stand out as being commonly associated with mental disorders and sedentary behavior in adolescents (Fanchang et al., 2021;

Xiang et al., 2021), as well as poorer peer relationships and academic performance (Legkauskas & Steponavičiūtė-Kupčinskė, 2021). However, mobile phones also offers a multitude of possibilities for the establishment of healthy lifestyle habits, among which mobile applications stand out (Groen et al., 2022; Kracht et al., 2021). In recent years, numerous health-related applications have been developed related to physical activity (Mokmin & Jamiat, 2021), highlighting those that push the users to try to increase the number of steps or daily distance covered (Schoeppe et al., 2017), being valid and acceptable tools to measure physical activity (Parmenter et al., 2022). This could be a resource for physical education teachers to promote and monitor physical activity performed by students outside of the school environment.

However, the use of mobile applications that promote physical activity among adolescents has shown very mixed results in increasing the level of physical activity and in improving body composition and AMD (Böhm et al., 2019; Dute et al., 2016; Macdonald et al., 2017). Thus, much of the previous research does not allow drawing solid conclusions on the usefulness of mobile applications for improving adolescents' healthy habits. This could be because previous studies have significant methodological limitations such as small sample sizes, short follow-up periods, lack of quality in the design, or lack of methodological rigor in the selection and use of the instruments used to measure adolescents (Pakarinen et al., 2017; Rose et al., 2017). In addition, one of the main problems encountered is the lack of adherence to mobile applications, with their use decreasing greatly after the initial weeks of practice (He et al., 2021).

More specifically, in the educational field, there is only one research study conducted on physical education with mobile applications (Zhu & Dragon, 2016). This study proved the usefulness of these tools in increasing the level of physical activity of adolescents during physical education classes and the results showed that the use of mobile devices in the physical education classroom was not directly related to increased physical activity (Zhu & Dragon, 2016). The lack of effectiveness in the use of mobile applications aimed at increasing the practice of physical activity during physical education classes could be due to the fact that they do not have an adequate design that facilitates their didactic use, thus lacking educational potential in the classroom (Alonso-Fernández et al., 2022).

However, research has also been conducted in the field of education with mobile applications that encourage physical activity outside school hours (Direito et al., 2015; Gil-espinosa et al., 2020; Seah & Koh, 2021). Although this research the use of mobile application outside of school was shown to be more effective than the use during school hours, the results were not completely clear. Thus, the use of mobile applications during the weekend, for adolescent females, was shown to be effective in increasing the number of total steps, but with an effect that was stable only during the first two weeks, perhaps due to the novelty of the intervention (Seah & Koh, 2021). Other research studies investigated the effectiveness of immersive (Zombies, Run) and non-immersive (Get Running) apps on adolescents after school hours, finding no significant changes in the physical activity and physical fitness variables analyzed after the intervention (Direito et al., 2015). The third study used the Endomondo app with high school students to increase their activity level after school hours, and showed that new technologies could be a useful resource to increase the physical activity time of adolescents (Gil-Espinosa et al., 2020). However, in all of these studies, the practice of physical activity outside school hours was promoted from the subject of Physical Education, but not as an obligation for the student, but rather as an option.

In this situation, previous scientific evidence describes a research gap regarding the real effectiveness of mobile applications promoted from the field of education, as physical education homework, aimed at increasing the number of daily steps, on the level of physical activity, body composition and physical condition of the adolescent population (Direito et al., 2015; Seah & Koh, 2021; Zhu & Dragon, 2016). In this regard, mobile applications such as Strava, Pacer or MapMyWalk have been shown to be ideal for this purpose, as they utilize numerous behavioral change techniques (Bondaronek et al., 2018), but their effectiveness has only been demonstrated in the adult population (Leong & Wong, 2017; Peng et al., 2016; Petersen et al., 2020). Thus, in the adolescent population, attempts to integrate the use of mobile apps in the educational setting have shown no or small benefits on physical activity, fitness, AMD, and body composition in adolescents (Direito et al., 2015; Gil-Espinosa et al., 2020), probably due to the lack of adherence to this type of interventions or to the optional nature of their use (He et al., 2021; Seah & Koh, 2021).

Therefore, it seems clear that interventions promoted in the educational setting, but conducted outside school hours, appear to be more effective, but the results are reduced. This leads to the research question as to whether the mandatory use of the mobile application by students in compulsory secondary education would lead to greater adherence and superior benefits in this population. Thus, as the main differentiating aspect of this research, the lack of adherence to the intervention with mobile applications will be solved with the collaboration of physical education teachers who will promote the mandatory use of mobile applications by students as "homework" for the subject outside school hours. Furthermore, no previous intervention is known to have compared the effect of similar mobile applications (step-tracker apps) on physical activity levels, physical fitness, AMD, or body composition in an adolescent population.

Given that the number of hours of physical education cannot be modified in the curriculum and are not sufficient to make secondary school students be active, and that there are numerous studies that have tried to integrate mobile applications in physical education classes without much success, this research focuses on complementing the work performed in physical education classes using mobile applications during out-of-school hours. This research presents the novel idea of the "mandatory" use of mobile apps as "homework" in the subject of physical education, educating adolescents on a sports culture from an early age. For this reason, the main objectives of the present research were a) to determine the changes produced by a compulsory ten-week period of after-school intervention with mobile step-tracking applications on the level of physical activity, body composition, physical fitness, and AMD of adolescents aged twelve to sixteen years old; and b) to compare the benefits obtained by each of the mobile applications on the level of physical activity, body composition, physical fitness, and AMD of adolescents.

1.1 Hypotheses

Based on previous scientific literature, in which the use of mobile applications had an influence on physical activity, body composition, physical fitness, and AMD of adolescents, although their effects were reduced in the first weeks of intervention due to lack of adherence (He et al., 2021; Seah & Koh, 2021), the following research hypotheses are proposed:

- H1: the mandatory use of the mobile application as "homework" for the physical education subject will lead to a high number of adolescents completing the intervention, and its use will show improvements in the level of physical activity, body composition and physical fitness, and AMD, as compared to the control group.
- H2: There will be no significant differences between intervention groups using different mobile apps in physical activity level, body composition, physical fitness, and AMD.

2 Materials and methods

2.1 Design

A longitudinal study, with non-probability convenience sampling was conducted. Prior to the start of the study, the institutional ethics committee approved the research design in accordance with the World Medical Association (hidden for peer review) and following the guidelines of the Helsinki Declaration. The measurement protocol was registered before the start of the study at ClinicalTrials.gov (hidden for peer review) and followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines. Two public compulsory secondary schools from different areas in the Region of Murcia and with the largest number of students in compulsory education (over 200 students per center) in the selected localities, were selected. First, the management teams of the schools where the research was to be conducted were contacted. After obtaining approval, data collection was coordinated with those responsible for the physical education area. Finally, in a meeting with the parents and adolescents, the objective and procedures were explained, as well as the confidentiality in the treatment of the data obtained. The parents of the students who wished to participate voluntarily signed the informed consent form.

2.1.1 Research model

The research model designed for the study is shown in Table 1. The importance of the model lies in the fact that previous research that attempted to analyze the changes produced in the physical activity level, body composition, physical condition, or AMD of adolescents, through mobile applications, were scarce, used small samples and, on occasions, used invalid and unreliable methods for data collection. The novelty of the present research is the mandatory use of mobile applications, with

Table 1 Constructs and operational definitions included in the research model

Variable type	Construct	Operational definition	Scope conditions
Independent	Mandatory mobile application use	Recording of the kilometers traveled through the mobile application	Applied individually, without location limitations, during after-school hours
Dependent	Physical activity level	Results of the PAQ-A questionnaire (Kowalski et al., 2004)	Applied individually, in a classroom of the educational center, during the physical education class timetable
Dependent	Adherence to Mediterranean diet	Results of the KIDMED questionnaire (Serra-Majem et al., 2004)	Applied individually, in a classroom of the educational center, during the physical education class timetable
Dependent	Body composition	Measurement of body mass, height, sitting height; triceps, thigh, and calf skinfolds; relaxed arm, waist, hip, thigh, and calf girth; and calculation of BMI, muscle mass, sum of the three skinfolds, corrected girths, and waist-to-hip ratio (Esparza-Ros et al., 2019; Poortmans et al., 2005)	Applied individually, in one of the locker rooms of the school's sports pavilion, during physical education class
Dependent	Physical fitness	With the measurement of cardiorespiratory fitness (20 m shuttle run test) (Léger et al., 1988), upper limb strength (hand grip strength and arm flexion) (Castro-Piñero et al., 2010; Matsudo et al., 2014), hamstring and lower back flexibility (sit and reach) (Ayala et al., 2012), lower limb explosive power (countermovement jump) (Barker et al., 2018), abdominal muscular strength and endurance (curl-up) (Garcia-Pastor et al., 2016) and speed (20 m sprint) (García-Manso et al., 1996)	Applied individually or collectively (20-m shuttle run test), in the sports pavilion of the school, during the physical education class

which the level of physical activity performed is expected to increase significantly in the intervention groups. This aspect has not been considered previously, perhaps due to the precociousness of the subject matter addressed, as recent research showed that adherence to this type of intervention was very low after the first few weeks (He et al., 2021; Seah & Koh, 2021). Therefore, the present research aims to go beyond previous studies, by trying to achieve a greater adherence to the intervention, and by including a more representative measurement of body composition (with twelve variables measured and calculated) and physical fitness (with seven physical fitness tests) than previous research, which will allow discovering the benefits produced by mobile applications as an educational complement to physical education classes.

2.2 Participants

For the calculation of the sample size, the methodology from previous studies based on the standard deviation (SD) were used (Bhalerao & Kadam, 2010). The sample size was calculated using Rstudio 3.15.0 statistical software (Rstudio Inc., USA) and using SD from previous research that used mobile applications to improve the level of physical activity (SD = 0.66) (Direito et al., 2015) in adolescents aged twelve to sixteen years old. The estimated error (d) for a 99% confidence interval was 0.09 for physical activity level. The minimum sample necessary for the development of the research was 390 adolescents.

The sample population of all students in compulsory secondary education in the Region of Murcia was 69,888 at the time of measurement, being reduced to 873 students in the two centers that agreed to participate. Figure 1 shows the final sample selection flowchart. The final sample consisted of 400 adolescents (210 boys and 190 girls) between the ages of twelve and sixteen (mean age: 13.96 ± 1.21), who voluntarily participated in the research study after obtaining parental consent. The inclusion criteria for the present study were (a) ages between twelve and sixteen years old; (b) attending compulsory secondary education; (c) not presenting any disabling disease that prevented participation; (d) completing all the questionnaires and physical tests in their entirety; and (e) participating in the measurements taken before (pre-test) and after (post-test) the intervention. The exclusion criteria were (a) missing more than 80% of the physical education sessions scheduled during the course; (b) not having a cell phone; (c) changing schools during the intervention; and (d) starting or abandoning regular physical activity during the intervention, including gym training or enrollment in a sports, as well as an increase in the number of daily steps on days when the app was not used, that could modify the level of physical activity practiced for reasons unrelated to the intervention.

2.3 Instruments

2.3.1 Questionnaire measurements

The level of physical activity of the adolescents was assessed using the "Physical Activity Questionnaire for Adolescents" (PAQ-A) (Kowalski et al., 2004). This

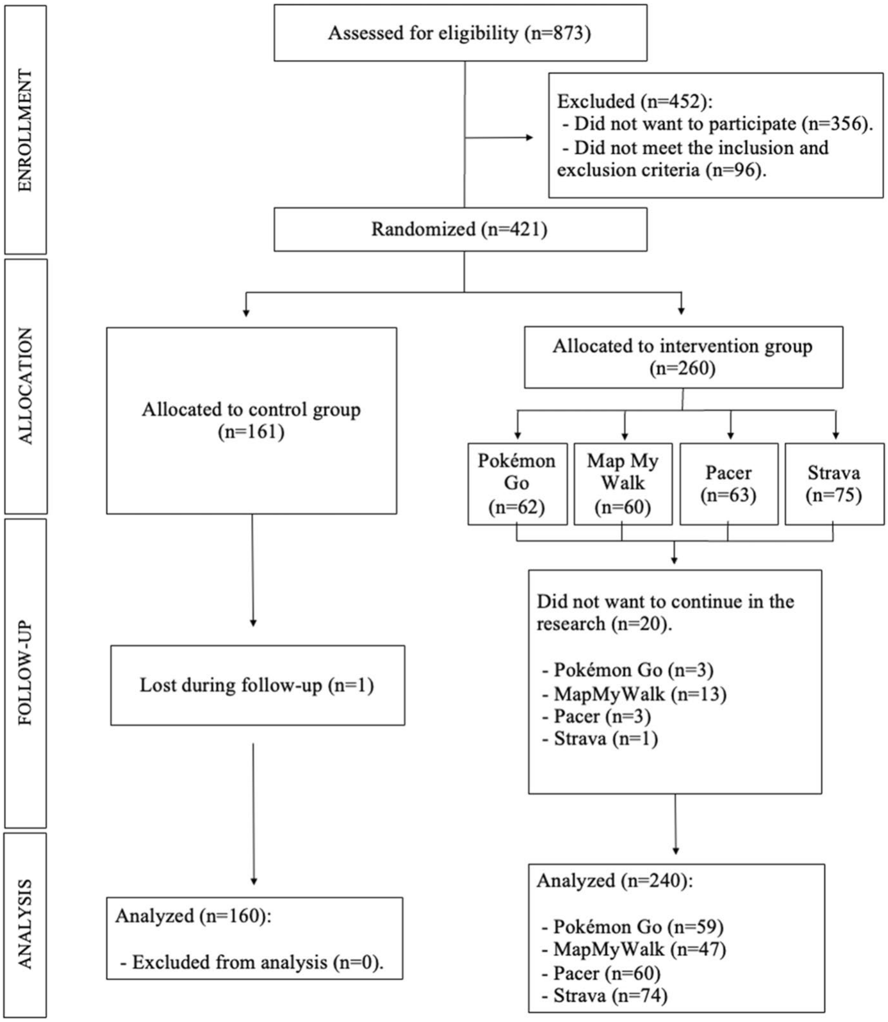

Fig. 1 Selection and division process of the research sample

questionnaire is composed of nine items, the first eight items being answered with a Likert scale of 1 to 5 points (1, low level of physical activity, and 5, high level of physical activity), and the last item by a dichotomous response (yes or no) to find out whether the subject was ill in the last week, which would have prevented him/her from practicing physical activity. The arithmetic mean of the scores from the first eight items allows obtaining a final physical activity score, with adolescents being classified as active or sedentary depending on whether the score was higher or lower than 2.75, respectively (Benítez-Porres et al., 2016). This questionnaire was previously validated and used in previous research, and has an intraclass correlation coefficient of 0.71 for the final score of the questionnaire (Martínez-Gómez et al., 2009).

The adolescents' nutritional habits, specifically AMD, were assessed using the KIDMED questionnaire (Serra-Majem et al., 2004), as it is the most valid and reliable instrument for use in the adolescent population (Štefan et al., 2017). Sixteen items that are answered using a dichotomous scale (yes or no) compose this questionnaire. The score of each item varies depending on whether the connotation is negative (-1) or positive (+1). Of the sixteen items, twelve had a positive value and four had a negative value, for a final score between 0 and 12 points.

2.3.2 Body composition measurement

ISAK accredited anthropometrists (levels 2 to 4) carried out the measurement and analysis of the adolescents' body composition. The measurement consisted of three basic measurements (body mass, height, sitting height), three skinfolds (triceps, thigh, and calf), and five girths (arm relaxed, waist, hip, thigh, and calf). All measurements were performed according to the protocol standardized by the International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al., 2019).

Two measurements of each variable were carried out, with a third measurement in cases where the difference between the first two measurements was greater than 5% in skinfolds or 1% in the rest of the measurements. When two measurements were taken, the final value was their mean, but when a third measurement was taken, the median of the three was used as the final value (Esparza-Ros et al., 2019).

To measure girths, an inextensible tape, Lufkin W606PM (Lufkin, Missouri) with a 0.1 cm accuracy was used a skinfold caliper (Harpenden, Burgess Hill, UK) with an accuracy of 0. 2 mm was used for measuring skinfolds; for body mass, a TANITA BC 418-MA Segmental (TANITA, Tokyo) with an accuracy of 100 g; and for height and sitting height a SECA stadiometer 213 (SECA, Hamburg) with an accuracy of 0.1 cm were used. All the instruments were previously calibrated.

The intra- and inter-evaluator technical error of measurements (TEM) were calculated in a sub-sample. The intra-evaluator TEM was 0.02% for the basic measurements; 1.21% for skinfolds, and 0.04% for the girths; and the inter-evaluator TEM was 0.03% for the basic measurements; 1.98% for skinfolds and 0.06% for the girths.

The final values of the anthropometric measurements were used to calculate the BMI, muscle mass (Poortmans et al., 2005), Σ3 skinfolds (triceps, thigh, and calf), corrected girths of the arm [arm relaxed girth – (π * triceps skinfold)], thigh [middle thigh girth – (π * thigh skinfold)] and calf [calf girth – (π * calf skinfold)], and waist-to-hip ratio (waist girth/hip girth).

2.3.3 Physical fitness test

To measure hamstring and lower back flexibility, the test used was the sit-and-reach, due to its moderate validity in adolescents (Ayala et al., 2012). Participants were seated with knees extended, feet hip-width apart, ankles in 90° flexion, toes pointed upward, and the sole of the foot fully supported on an Acuflex Tester III box (Novel Products, USA). From that position, the subjects had to perform maximum trunk flexion, keeping the knees and arms fully extended, and reach the maximum possible distance by sliding the palms of their hands, one on top of the other, on the box (López-Miñarro et al., 2015).

Two tests were used for upper limb strength. First, the handgrip strength, as it has been shown to be a valid test for the measurement of physical fitness in adolescents (Matsudo et al., 2014). Participants applied the force with the elbow fully extended, as this is the most appropriate position to measure maximal strength (España-Romero et al., 2010). The instrument used for the measurement was a Takei Tkk5401 digital handheld dynamometer (Takei Scientific Instruments, Tokyo, Japan). Secondly, the push-up test was used in which the adolescents had to lay in the prone position, with the tips of their feet in contact with the floor and their arms placed on both sides of the body with the elbows flexed at 90º. From this position, the participants had to lift themselves off the floor until they fully extended their arms, keeping their legs and back straight, and repeat this movement as many times as possible. The test ended when the arms were not fully extended or when exhaustion was reached (Castro-Piñero et al., 2010).

The countermovement jump (CMJ) was used to measure the explosive power of the lower limbs. This test consists of a vertical jump in which the aim is to reach the maximum possible height. For this, the subjects initially stand with their hands on their waists, perform a quick knee flexion to a 90º position, and then fully extend their knees to jump. Following the protocol by Barker et al. (2018), the hands should remain at the waist throughout the execution, the knee flexion should be as fast as possible, and the trunk and legs should remain extended during the flight phase. A force platform with a sampling frequency of 200 Hz (MuscleLab, Stathelle, Norway) was used to perform the test.

Abdominal muscular strength and endurance were evaluated by means of the curl-up test. Subjects were laid in the supine position with knees bent at 90º and feet flat on the floor. The arms were placed crossed over the chest, and from this position the participants had to perform the maximum number of trunk flexions, with the repetitions in which the upper back area was no longer in contact with the floor deemed as valid (Garcia-Pastor et al., 2016).

Adolescents' speed was measured using the 20-m sprint test. At the beginning of the test, the participants stood at the starting line, and they decided when to start the maximum sprint (García-Manso et al., 1996). To measure the time it took the adolescents to run the 20 m, single-beamed photocells (Polifemo Light, Microgate, Italy) located at hip height were used, with this beam placement being an influential factor in the reliability of the test, due to the fact that at this height, there is only a 4% probability of the arms cutting the photocell before the body, while at chest height there is a 60% probability of this occurring (Altmann et al., 2017; Cronin & Templeton, 2008).

Cardiorespiratory fitness was assessed by means of the 20-m shuttle run test (Léger et al., 1988). This test consists of running 20 m as many times as possible before the beep sounds. The test ends when the participant reaches exhaustion or when he/she is not able to cover the distance before the beep sounds. This incremental test has a high validity and reliability for use with adolescents (Tomkinson et al., 2019). The last speed test at which the subject completed the distance was used to predict maximal oxygen consumption (VO2 max) using the formula from Léger et al. (1988).

To avoid inter-evaluator error in the assessments, five researchers conducted the physical fitness tests. Each investigator was assigned specific tests and performed familiarization and measurement procedures of the same tests on all the adolescents during the pre- and post-test. The selected investigators had previous experience in measuring physical fitness tests.

2.4 Measurement procedure

First, the adolescents completed questionnaires on their level of physical activity and nutritional habits. Subsequently, anthropometric measurements were taken to determine body composition. Prior to warming up, in order to prevent the activation generated during the warm-up from influencing the performance of the test, the sit-and-reach was performed (Díaz-Soler et al., 2015). Once the sit-and-reach test was completed, the correct executions of the handgrip strength, CMJ, curl up, push up and 20-m sprint test were explained to the adolescents so that they became familiarized with them. After completing the familiarization process, a progressive running warm-up with joint mobility was performed, and the handgrip strength, curl up, push up, CMJ, and 20-m sprint tests were carried out. The 20-m shuttle run test was performed after the rest of the physical tests. All the physical fitness tests were performed twice by each adolescent, leaving two minutes between each of the test attempts, and five minutes between tests, considering the best value obtained, except for the sit-and-reach and the 20-m shuttle run test, which were performed only once.

The recommendations established by the National Strength and Conditioning Association (NSCA) were followed to determine the order of the physical fitness tests. To produce the least possible interference in the results, five-minute rest were taken between physical fitness tests to allow the subjects to recover from the fatigue generated and the metabolic demands of the different tests (Coburn & Malek, 2014). The protocol for performing the physical fitness tests has been previously used in research with similar populations (Albaladejo-Saura et al., 2022).

2.5 Mobile application intervention

To carry out the intervention, the initial sample (n = 421) was distributed into five groups (four experimental groups and one control group). Each of the experimental groups used one of the following applications: Pokémon Go®, Pacer®, Strava® and MapMyWalk®. The distribution of the adolescents in the experimental and control groups was randomized, including the entire school class in the corresponding group. Because the number of adolescents participating in the research was different in each school class, the experimental groups had slight initial sample differences (Pokémon Go: n = 62; MapMyWalk: n = 60; Pacer: n = 63; Strava: n = 75).

Before starting the intervention, the adolescents were measured for level of physical activity, body composition, physical fitness, and AMD (pre-test). After the pre-test, the 10-week intervention was conducted in which adolescents in the experimental groups used the assigned mobile apps in their after-school schedule. Adolescents in the experimental group had to use the application a minimum of three times a week, in which they walked a minimum of 5000 steps or 3.19 km, considering that one kilometer corresponded to approximately 1565 steps (Morency et al., 2007), which is the minimum to stop being considered sedentary (Lubans et al., 2015). Those subjects who did not reach this minimum being excluded from the study. Pacer, Strava and MapMyWalk were selected because they include numerous behaviors change techniques (8–10 change techniques per application) (Bondaronek et al., 2018), while Pokémon Go is a game that has been used in previous interventions with children and adults, and has been shown to be effective in increasing the level of physical activity and the number of daily steps (Khamzina et al., 2020; Lee et al., 2021), being suitable options to increase the level of physical activity in this population. The control group did not use any app during their after-school schedule, and attended physical education classes normally, along with the experimental group. At the end of the 10-week intervention, the level of physical activity, body composition, physical fitness, and AMD of the experimental and control groups were measured again (post-test).

The completion rate of the intervention was different between applications. Of the 421 adolescents who started the study, 400 completed the research (4.99% attrition). Regarding the mobile apps used, 59 adolescents on Pokémon Go (4.84% attrition), 47 on MapMyWalk (21.67% attrition), 60 on Pacer (4.76% attrition) and 74 on Strava (1.33% attrition) completed at least 5000 steps three times per week.

2.6 Statistical analysis

After analyzing the normality of the variables using the Kolmogorov-Smirnov test ($p = 0.054$–0.249), as well as kurtosis ($p = -0.136$-3.389), skewness ($p = -3.095$-2.491), and variance ($p = 0.003$–25.535), a Student's t-test was performed to determine the homogeneity of the experimental and control groups at baseline, and two two-way ANOVAs with repeated measures in one-way were carried out to analyze inter- and intra-group differences, following the guidelines from previous research in which educational interventions were carried out with two measurements and two groups (González-Gálvez et al., 2020; Seah & Koh, 2021). The first ANOVA analyzed differences between adolescents who completed the minimum training volume with the app and those who did not, while the second was used to find differences between different mobile app groups at the level of physical activity, body composition, physical fitness, and AMD. The Bonferroni post-hoc test was used to evaluate the statistical significance of the variables. Partial eta squared ($\eta 2$) was used to calculate the effect size and was defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: ≥ 1.2; or very large: $ES \geq 2.0$, with an error of $p < 0.05$ (Hopkins et al., 2009). A value of $p < 0.05$ was set to determine statistical significance. The statistical analysis was performed with the SPSS statistical package (v. 25.0; SPSS Inc., IL).

3 Results

Before analyzing the differences between the pre- and post-intervention, the differences between the experimental and control groups before the start of the intervention were determined to obtain their homogeneity at baseline. Thus, the results showed no significant differences between adolescents who participated in the intervention and those who did not participate at the baseline physical activity score ($p=0.209$), BMI ($p=0.071$), corrected girths (arm: $p=0.512$; thigh: $p=0.946$; calf: $p=0.297$), waist girth ($p=0.282$), muscle mass ($p=0.781$), VO2 max. ($p=0.144$), handgrip (right arm: $p=0.902$; left arm: $p=0.800$), CMJ ($p=0.950$), 20-m sprint ($p=0.818$), curl-up ($p=0.893$), and push-up ($p=0.339$).

Levene's test for homogeneity of variances was performed, showing that all dependent variables were homogeneous: physical activity score (pre: $p=0.739$; post: $p=0.074$); body mass (pre: $p=0.202$; post: $p=0.265$); height (pre: $p=0.858$; post: $p=0.800$); BMI (pre: $p=0.334$; post: $p=0.302$); sitting height (pre: $p=0.159$; post: $p=0.147$); sum of 3 skinfolds (pre: $p=0.115$; post: $p=0.492$); corrected arm girth (pre: $p=0.520$; post: $p=0.686$); corrected thigh girth (pre: $p=0.931$; post: $p=0.422$); corrected calf girth (pre: $p=0.274$; post: $p=0.429$); waist girth (pre: $p=0.082$; post: $p=0.354$); hip girth (pre: $p=0.169$; post: $p=0.453$); waist/hip ratio (pre: $p=0.788$; post: $p=0.177$); muscle mass (pre: $p=0.144$; post: $p=0.075$); AMD (pre: $p=0.193$; post: $p=0.053$); VO2 max. (pre: $p=0.532$; post: $p=0.198$); handgrip right arm (pre: $p=0.835$; post: $p=0.798$); handgrip left arm (pre: $p=0.648$; post: $p=0.434$); sit-and-reach (pre: $p=0.672$; post: $p=0.505$); CMJ (pre: $p=0.939$; post: $p=0.069$); 20-m sprint (pre: $p=0.999$; post: $p=0.052$); curl-up (pre: $p=0.818$; post: $p=0.058$); and push-up (pre: $p=0.417$; post: $p=0.942$).

The differences between adolescents in the control and experimental groups after the intervention are shown in Table 2. After the intervention, the experimental group showed a higher level of physical activity ($p<0.001$), body mass ($p<0.001$), height ($p<0.001$), corrected girths ($p<0.001$–0.003), hip girth ($p<0.001$), muscle mass ($p<0.001$) and better performance in the physical fitness tests ($p<0.001$–0.015), except in the 20-m sprint ($p=0.098$). Similarly, there was a significant decrease in the sum of three skinfolds ($p=0.002$) and waist/hip ratio ($p<0.001$). In the control group, the pre-post measurements showed significant differences in body mass ($p<0.001$), height ($p<0.001$), corrected girths ($p<0.001$–0.013), hip girth ($p<0.001$), waist/hip ratio ($p<0.$ 001) and in all physical fitness tests ($p<0.001$–0.015), except in CMJ ($p=0.438$) and curl up ($p=0.059$), with higher values in all variables, except for the waist/hip ratio, after the intervention.

Table 3 shows the differences between the experimental and control groups in the pre-post change. The differences were significant in the level of physical activity ($p=0.039$), corrected thigh girth ($p=0.034$), muscle mass ($p<0.001$), VO2 max ($p=0.043$), and CMJ ($p=0.034$), with adolescents in the experimental group showing higher values in all variables after the intervention.

The pre- and post-intervention results according to the mobile application used by the adolescents are shown in Fig. 2. All the mobile applications showed

Table 2 Differences pre to post test (intra-groups) for physical activity, physical fitness, adherence to Mediterranean diet, and anthropometric variables

Variable	Group	Pre-intervention	Post-intervention	Diff. Pre-post	*p*	95% CI Diff.	ES
Physical activity score	EG	2.63 ± 0.67	2.80 ± 0.60	-0.170 ± 0.47	< 0.001	-0.241; -0.098	0.052
	CG	2.72 ± 0.68	2.70 ± 0.74	0.014 ± 0.67	0.753	-0.073; 0.101	0.001
Body mass	EG	55.47 ± 12.81	56.39 ± 12.64	-0.917 ± 1.84	< 0.001	-1.158; -0.677	0.126
	CG	52.47 ± 10.65	53.39 ± 10.57	-0.925 ± 1.94	< 0.001	-1.220; -0.630	0.089
Height	EG	162.91 ± 9.12	163.65 ± 9.03	-0.738 ± 1.52	< 0.001	-0.948; -0.528	0.109
	CG	160.87 ± 8.75	161.52 ± 8.70	-0.645 ± 1.79	< 0.001	-0.902; -0.388	0.059
BMI	EG	20.85 ± 3.83	20.98 ± 3.70	-0.124 ± 0.70	0.009	-0.217; -0.031	0.017
	CG	20.19 ± 3.33	20.43 ± 3.22	-0.236 ± 0.76	< 0.001	-0.349; -0.122	0.041
Sitting height	EG	84.90 ± 9.21	85.13 ± 9.28	-0.234 ± 11.32	0.829	-2.360; 1.892	0.001
	CG	82.17 ± 14.99	81.95 ± 17.07	0.222 ± 22.36	0.829	-2.356; 2.799	0.001
Sum 3 skinfolds	EG	52.08 ± 26.96	50.22 ± 24.35	1.854 ± 9.41	0.002	0.703; 3.006	0.025
	CG	44.87 ± 23.71	44.31 ± 22.85	0.554 ± 8.28	0.445	-0.869; 1.977	0.002
Corrected arm girth	EG	20.90 ± 2.79	21.31 ± 2.70	-0.411 ± 1.06	< 0.001	-0.535; -0.287	0.099
	CG	20.73 ± 2.69	21.12 ± 2.62	-0.382 ± 0.79	< 0.001	-0.229; 0.535	0.059
Corrected thigh girth	EG	39.19 ± 4.68	40.14 ± 4.56	-0.944 ± 1.76	< 0.001	-1.233; -0.654	0.096
	CG	39.23 ± 5.10	39.68 ± 4.15	-0.451 ± 2.84	0.013	-0.808; -0.094	0.016
Corrected calf girth	EG	28.95 ± 3.46	29.32 ± 2.85	-0.368 ± 2.32	0.003	-0.609; -0.127	0.023
	CG	28.68 ± 2.69	29.18 ± 2.61	-0.497 ± 0.84	0.001	-0.794; -0.199	0.027
Waist girth	EG	68.50 ± 8.73	68.55 ± 8.38	-0.044 ± 2.11	0.759	-0.327; 0.239	0.001
	CG	67.49 ± 7.03	67.75 ± 7.13	-0.259 ± 2.34	0.146	-0.608; 0.090	0.005
Hip girth	EG	89.41 ± 9.15	90.35 ± 8.68	-0.937 ± 2.28	< 0.001	-1.227; -0.646	0.094
	CG	86.22 ± 7.69	87.50 ± 7.59	-1.280 ± 2.24	< 0.001	-1.639; -0.922	0.113
Waist/hip ratio	EG	0.77 ± 0.05	0.76 ± 0.05	0.007 ± 0.02	< 0.001	0.005; 0.010	0.078
	CG	0.78 ± 0.05	0.77 ± 0.05	0.009 ± 0.02	< 0.001	0.005; 0.012	0.068
Muscle mass	EG	18.03 ± 4.99	18.62 ± 4.24	-0.590 ± 1.82	< 0.001	-0.835; -0.344	0.055
	CG	18.24 ± 4.64	18.03 ± 3.83	0.203 ± 2.04	0.189	-0.100; 0.507	0.004
AMD	EG	6.85 ± 2.44	6.83 ± 2.56	0.021 ± 2.35	0.899	-0.306; 0.348	0.001
	CG	5.82 ± 2.54	5.75 ± 2.84	0.062 ± 2.84	0.759	-0.334; 0.458	0.001

Table 2 (continued)

Variable	Group	Pre-intervention	Post-intervention	Diff. Pre-post	p	95% CI Diff.	ES
VO2 max	EG	38.04 ± 4.87	39.09 ± 5.70	-1.050 ± 0.20	< 0.001	-1.445; -0.655	0.073
	CG	38.57 ± 5.02	39.26 ± 5.12	-0.686 ± 0.25	0.006	-1.178; -0.194	0.021
Handgrip right arm	EG	24.49 ± 7.63	25.97 ± 8.27	-1.481 ± 4.67	< 0.001	-2.060; -0.902	0.060
	CG	24.39 ± 7.24	25.27 ± 8.49	-0.875 ± 4.36	0.015	-1.577; -0.173	0.015
Handgrip left arm	EG	23.00 ± 7.11	23.83 ± 7.41	-0.830 ± 3.77	< 0.001	-1.284; -0.376	0.031
	CG	23.18 ± 6.74	23.87 ± 7.93	-0.688 ± 3.23	0.014	-1.238; -0.137	0.015
Sit-and-reach (cm)	EG	14.56 ± 8.00	16.06 ± 8.44	-1.497 ± 3.63	< 0.001	-1.993; -1.002	0.083
	CG	12.70 ± 7.48	13.76 ± 8.10	-1.063 ± 4.16	0.001	-1.664; -0.462	0.030
CMJ (cm)	EG	21.99 ± 7.35	23.26 ± 7.98	-1.262 ± 6.97	0.015	-2.280; -0.245	0.015
	CG	22.04 ± 7.55	22.53 ± 9.42	-0.487 ± 9.28	0.438	-1.720; 0.746	0.002
20-m sprint (s)	EG	3.88 ± 0.81	3.77 ± 0.82	0.102 ± 0.76	0.098	-0.019; 0.224	0.007
	CG	3.86 ± 0.80	3.54 ± 1.20	0.315 ± 1.18	< 0.001	0.168; 0.462	0.043
Curl-up	EG	20.43 ± 11.49	24.39 ± 10.67	-3.95 ± 10.33	< 0.001	-5.330; -2.577	0.075
	CG	20.33 ± 11.31	21.94 ± 11.93	-1.614 ± 11.31	0.059	-3.293; 0.065	0.009
Push-up	EG	6.67 ± 9.34	8.37 ± 10.41	-1.700 ± 5.94	< 0.001	-2.519; -0.880	0.042
	CG	7.80 ± 9.31	9.07 ± 9.84	-1.270 ± 6.95	0.014	-2.284; -0.256	0.016

EG: experimental group; CG: control group; BMI: body mass index; AMD: adherence to Mediterranean diet; VO2: maximum oxygen consumption; CMJ: countermovement jump

significant increases in body mass ($p < 0.001$–0.009), height ($p < 0.001$), corrected arm girth ($p < 0.001$–0.003), corrected thigh girth ($p < 0.001$–0.029), hip girth ($p < 0.001$–0.029), waist/hip ratio ($p < 0.001$–0.010), and VO2 max ($p < 0.001$–0.011) after the intervention. In addition, no experimental group showed significant changes in sitting height, waist girth, AMD, CMJ, and 20-m sprint.

The level of physical activity increased significantly in all mobile applications groups ($p = 0.002$–0.041), except for the Pacer group. Regarding muscle mass ($p = 0.001$–0.038), hand grip strength ($p < 0.001$–0.039), and sit-and-reach test ($p < 0.001$–0.014), all the apps showed significant increases, except for Pokémon Go; The BMI did not show significant differences in any intervention group, except for Strava, where it increased ($p = 0.001$); a significant decrease in the sum of 3 skinfolds, as well as an increase in corrected calf girth, was found in the Pokémon Go

Table 3 Differences between groups in the pre-post-test change for physical activity, physical fitness, adherence to Mediterranean diet, and anthropometric variables

Variable	Group	Diff. Pre-post	Diff. Post-pre EG – Diff. Post-pre CG	F	*p*	95% CI Diff.	ES
Physical activity score	EG	-0.170 ± 0.47	-0.183	4.286	0.039	-0.296; -0.071	0.013
	CG	0.014 ± 0.67					
Body mass	EG	-0.917 ± 1.84	0.007	0.012	0.912	-0.373; 0.388	0.001
	CG	-0.925 ± 1.94					
Height	EG	-0.738 ± 1.52	-0.093	0.080	0.778	-0.426; 0.238	0.001
	CG	-0.645 ± 1.79					
BMI	EG	-0.124 ± 0.70	0.111	2.244	0.135	-0.035; 0.258	0.006
	CG	-0.236 ± 0.76					
Sitting height	EG	-0.234 ± 11.32	-0.456	1.440	0.231	-3.797; 2.886	0.004
	CG	0.222 ± 22.36					
Sum 3 skinfolds	EG	1.854 ± 9.41	1.301	0.882	0.348	-0.530; 3.131	0.003
	CG	0.554 ± 8.28					
Corrected arm girth	EG	-0.411 ± 1.06	-0.029	0.019	0.891	-0.226; 0.168	0.001
	CG	-0.382 ± 0.79					
Corrected thigh girth	EG	-0.944 ± 1.76	-0.493	4.528	0.034	-0.952; -0.033	0.013
	CG	-0.451 ± 2.84					
Corrected calf girth	EG	-0.368 ± 2.32	0.129	1.155	0.283	-0.254; 0.512	0.003
	CG	-0.497 ± 0.84					
Waist girth	EG	-0.044 ± 2.11	0.215	0.854	0.356	-0.235; 0.664	0.003
	CG	-0.259 ± 2.34					
Hip girth	EG	-0.937 ± 2.28	0.344	1.516	0.219	-0.118; 0.805	0.004
	CG	-1.280 ± 2.24					
Waist/hip ratio	EG	0.007 ± 0.02	-0.001	0.088	0.767	-0.005; 0.003	0.001
	CG	0.009 ± 0.02					
Muscle mass	EG	-0.590 ± 1.82	-0.793	12.736	< 0.001	-1.184; -0.402	0.036
	CG	0.203 ± 2.04					
AMD	EG	0.021 ± 2.35	-0.041	0.507	0.477	-0.554; 0.472	0.001
	CG	0.062 ± 2.84					
VO2 max	EG	-1.050 ± 0.20	0.364	4.110	0.043	-1.338; 0.128	0.012
	CG	-0.686 ± 0.25					
Handgrip right arm	EG	-1.481 ± 4.67	-0.605	1.286	0.258	-1.515; 0.305	0.004
	CG	-0.875 ± 4.36					
Handgrip left arm	EG	-0.830 ± 3.77	-0.142	0.001	0.994	-0.856; 0.572	0.001
	CG	-0.688 ± 3.23					
Sit-and-reach (cm)	EG	-1.497 ± 3.63	-0.435	0.830	0.363	-1.214; 0.344	0.002
	CG	-1.063 ± 4.16					
CMJ (cm)	EG	-1.262 ± 6.97	-0.776	4.534	0.034	-2.374; 0.823	0.013
	CG	-0.487 ± 9.28					
20-m sprint (s)	EG	0.102 ± 0.76	-0.213	1.708	0.192	-0.404; -0.022	0.005
	CG	0.315 ± 1.18					

Table 3 (continued)

Variable	Group	Diff. Pre-post	Diff. Post-pre EG – Diff. Post-pre CG	F	*p*	95% CI Diff.	ES
Curl-up	EG	-3.95 ± 10.33	-2.339	3.365	0.067	-4.510; -0.168	0.010
	CG	-1.614 ± 11.31					
Push-up	EG	-1.700 ± 5.94	-0.430	0.171	0.679	-1.733; 0.874	0.001
	CG	-1.270 ± 6.95					

EG: experimental group; CG: control group; BMI: body mass index; AMD: adherence to Mediterranean diet; VO2: maximum oxygen consumption; CMJ: countermovement jump

Fig. 2 Differences pre to post test (intra-groups) in physical activity, physical fitness, adherence to Mediterranean diet, and anthropometric variables according to the mobile application used

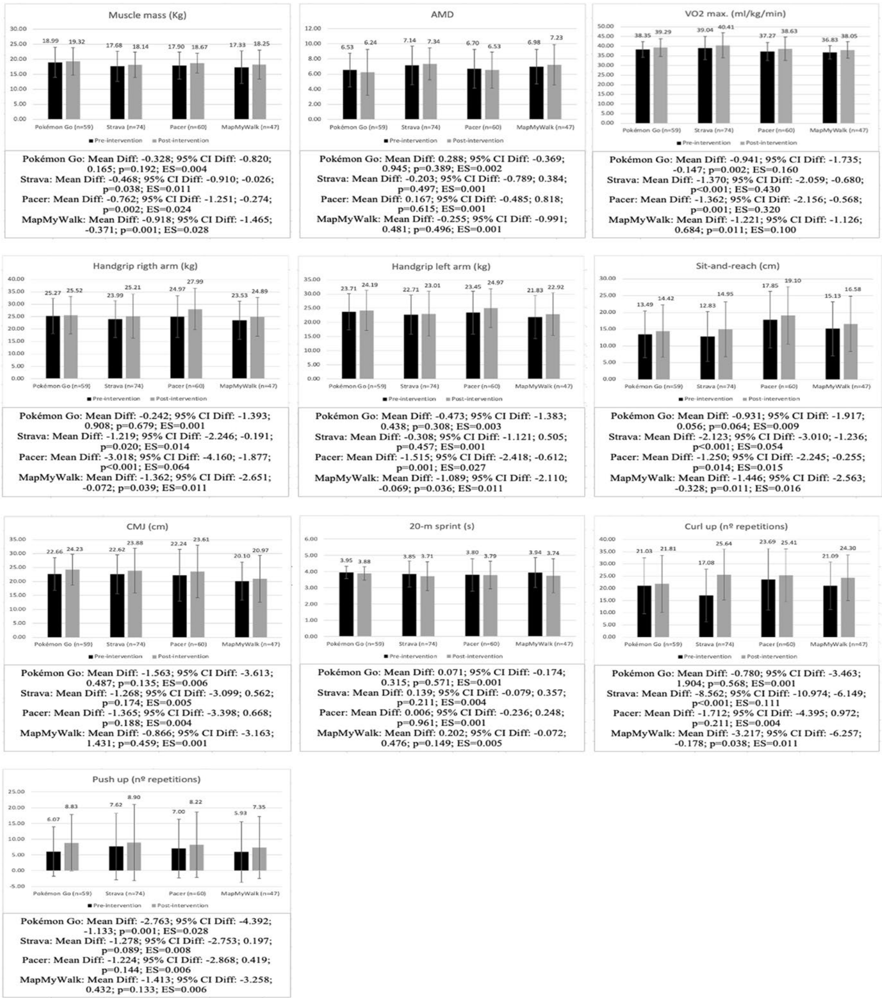

Fig. 2 (continued)

($p = 0.047$; $p = 0.045$) and Pacer ($p = 0.004$; $p = 0.011$) groups. The curl up test score showed significant increases in the Strava ($p < 0.001$) and MapMyWalk ($p = 0.038$) groups, while in push-ups, only the Pokémon Go group showed a significant increase ($p < 0.001$).

Table 4 shows the differences in the pre-post change between each one of the four experimental groups according to the mobile application used. The Strava group showed a significant increase in body mass with respect to the Pacer group ($p = 0.043$), and in curl up with respect to the Pacer ($p = 0.013$) and Pokémon Go ($p < 0.001$) groups. The Pacer group significantly increased handgrip strength, as compared to the Pokémon Go group ($p = 0.009$).

Table 4 Differences between apps in the pre-post-test change for physical activity, physical fitness, adherence to Mediterranean diet, and anthropometric variables

Variable	Comparison Group	Diff. Pre-post	Diff. Post-pre EG – Diff. Post-pre CG	F	*p*	95% CI Diff.	ES
Body mass	Strava	-1.284	-0.926	2.148	0.043	-1.836; -0.017	0.025
	Pacer	-0.631					
Handgrip right arm	Pokémon Go	-0.242	2.363	3.812	0.009	0.377; 4.350	0.044
	Pacer	-3.018					
Curl-up	STRAVA	-8.562	-8.069	5.897	<0.001	-13.537; -2.600	0.066
	Pokémon Go	-0.780					
	STRAVA	-8.562	-6.257	5.897	0.013	-11.695; -0.818	0.066
	Pacer	-1.712					

CG: control group; BMI: body mass index; VO2: maximum oxygen consumption. Only those pairwise comparisons that were significant have been included in the table

4 Discussion

The present research was conducted to answer the research question of whether the mandatory use of the mobile application by students in compulsory secondary education would achieve a sufficient adherence to out of school time physical activity, for students in compulsory secondary education to obtain health benefits on their level of physical fitness and body composition, as previous research in this area had shown initial positive results, although these lost after a few weeks of intervention. The results obtained show that the mandatory use of the application led to its continuous use, with the study ending with a sample of 400 subjects, from the original 421, with only 21 subjects lost, and with this sample number being much higher than the samples from previous research, composed of 36–53 subjects by the time the studies ended (Direito et al., 2015; Seah & Koh, 2021; Zhu & Dragon, 2016), with the exception of one study in which 138 adolescents finished the study (Gil-Espinosa et al., 2020). These results allow us to accept the first part of the first hypothesis, regarding the high number of adolescents who would complete the intervention, when it was defined as homework in physical education classes.

It should be noted that the comparative analysis of the control and experimental groups at baseline showed no significant differences in physical activity score, BMI, corrected girths, waist girth, muscle mass, VO2 max, handgrip, CMJ, 20-m sprint, curl-up, and push-up, but after the intervention, the changes were significantly higher in the intervention group compared to the control in physical activity score, corrected thigh girth, muscle mass, VO2 max, and CMJ, indicating that the regular and prolonged use of the mobile apps selected in the present study was useful for improving the level of physical activity, body composition, and physical fitness of adolescents.

The first objective of the present study was to determine the changes produced by a compulsory ten-week period of intervention with step tracker mobile applications on the level of physical activity, body composition, physical fitness, and AMD of adolescents aged twelve to sixteen years old. The experimental group showed a significant improvement in the level of physical activity, while the control group did not. In addition, a significantly greater difference was found in the change produced in the pre-post measurement of this variable in the experimental group with respect to the change produced in the control group. Previous research conducted in this area had not shown conclusive results, as some investigations showed significant increases in the level of physical activity (Khamzina et al., 2020; Lee et al., 2021; Schoeppe et al., 2016), while others found no improvements (Böhm et al., 2019). This could be because previous research using mobile apps had methodological limitations (invalid measuring instruments, heterogeneous outcome measures) and small sample sizes (n = 42–300) (Böhm et al., 2019; Lee et al., 2021), making it difficult to extrapolate the results. The results obtained in the present study could indicate that mobile applications are useful for promoting physical activity in the adolescent population, which would refute previous results that showed no effects of the apps used after school hours (Direito et al., 2015), but future research is still needed to corroborate them.

Regarding AMD, no significant differences were found in the experimental and the control groups. Previous research conducted with specific mobile applications for diet control showed significant results, favoring the consumption of fruits and vegetables (Elbert et al., 2016; Schoeppe et al., 2016), and decreasing the fat mass, weight, and body mass index in the intervention group (Lee et al., 2010). The absence of significant results in the present investigation could be due none of the selected applications including nutritional recommendations. So, if the aim is to establish a healthy lifestyle that includes physical activity and healthy eating, it seems necessary to use mobile applications that address both aspects, but this should be contrasted in future research to know the real effects of these applications.

The sum of 3 skinfolds showed a significant decrease in the experimental group after the intervention, but not in the control group. Previous research so far had determined changes in body composition through improvement in BMI (Shin et al., 2019), but the changes produced in the sum of skinfolds are unknown. These results could be because the regular practice of physical activity produces improvements in the body composition of adolescents (Bogataj et al., 2021; Smith et al., 2019), and after a period of ten weeks using mobile applications to promote the practice of physical activity, walking a minimum of 5000 steps daily three times per week, the improvements were significant in the sum of skinfolds.

Muscle mass increased significantly in the experimental group, while in the control group no significant changes were observed. Previous research conducted in overweight children showed similar results, with increases in muscle mass after the use of the app (De Freitas et al., 2021). However, both the experimental and control groups presented greater corrected thigh girth, but the change between pre and post measurements was significantly higher in the experimental group. The improvement in both groups could be because the students continued to attend school physical education classes and sports activities in which they were already participating, this being a factor to consider because previous research has shown different changes in the body composition of adolescents according to the physical education program carried out during the school year (Cohen et al., 2022). These results are relevant because the use of the mobile applications would produce a significantly greater improvement in the muscle mass of the lower limbs, although future research is needed to corroborate the changes produced in the muscle mass of the adolescents.

VO2 max showed a significant increase in the experimental and control groups, but the improvement was significantly higher in the experimental group at the end of the intervention. These results refute previous research in which no differences were observed in the cardiorespiratory capacity of adolescents after app use (Direito et al., 2015). The increase in VO2 max in both groups in the present investigation could be because VO2 max improves during adolescence, regardless of the physical activity practiced (Kolunsarka et al., 2022). However, the improvement was significantly higher in the experimental group due to the fact that the group members used the mobile application for a long period of time, following the line of previous research in which intervention programs of long duration showed a remarkable effect on VO2 max (Kriemler et al., 2011). This could explain why adolescents who did not use the application showed a lower effect on this variable.

CMJ height was significantly higher only in the experimental group after the intervention. It should be noted that most previous interventions in adolescents analyzed the changes produced in cardiorespiratory fitness (Badawy & Kuhns, 2017; Goodyear et al., 2021), a few studies assessed changes in capacities such as muscular endurance (Schoeppe et al., 2016), but no previous research with mobile applications is known to have analyzed the modifications produced in jump height. The differences obtained in the present study could be due to the increase in muscle mass and corrected thigh girth observed in the intervention group, since they are factors that favor the production of lower limb strength (De Almeida-Neto et al., 2021; Figueiredo et al., 2020; Vuk et al., 2015).

Regarding the curl up test, the intervention group with mobile applications showed a significant increase in the score obtained. These results are similar to those obtained in previous research in which a six-week aerobic walking program showed significant improvements in abdominal endurance (Shnayderman & Katz-Leurer, 2013). This could be because the deep and superficial trunk musculature is active while walking (Lamoth et al., 2006), so increasing walking time with the use of mobile applications could favor the improvement of abdominal endurance.

According to the results obtained in the present investigation, the second part of the first hypothesis proposed, which indicated that the experimental group would show improvements in body composition, physical condition, and level of physical activity in comparison with the control group, can be confirmed.

The second objective of the present research was to compare the benefits obtained from the use of each of the mobile applications, on the level of physical activity, body composition, physical fitness, and AMD of adolescents. The level of activity showed a significant increase with the use of all the mobile applications, except for Pacer. Previous research that has compared the effects produced by the use of different mobile applications is scarce, and significant differences in the level of physical activity in any of the intervention groups were not found (Direito et al., 2015). In the present study, the absence of significant differences with the use of the Pacer app is similar to previous research in which this particular app did not show significant results in terms of improved physical activity level, which could be explained by difficulties in handling the app or problems with the mobile device (De Barros Gonze et al., 2020).

The changes produced in body composition were significant with the use of all mobile applications, with a significant decrease in the sum of three skinfolds with the use of Pokémon Go and Pacer, as well as an increase in muscle mass with all applications except Pokémon Go. Previous studies showed improvements in body composition with the use of mobile apps (Likhitweerawong et al., 2021; Shin et al., 2019), but no previous research is known to have compared the effectiveness of different mobile apps in the same population. The results obtained could indicate that each mobile application is more effective in producing certain changes in body composition, because they use different behaviors change techniques (Bondaronek et al., 2018). If these findings were confirmed in future research, it would be necessary to analyze the mobile applications currently being used by adolescents to learn the most relevant aspects of each of them and use them in the areas where they are most effective.

Regarding physical fitness, there was a significant increase in VO2 max, handgrip strength, sit-and-reach, and curl up test with the use of all the mobile applications, except with Pokémon Go, where the changes were significant only in VO2 max. These results follow the line of previous research regarding the improvement in VO2 max, since significant improvements were found in this variable after the use of gamified and non-gamified mobile applications (Goodyear et al., 2021; Mora-Gonzalez et al., 2020). However, the absence of significant differences in the rest of the fitness variables with the use of Pokémon Go could be because it can be played in two different ways, intermittent and continuous (Beach et al., 2021). The form of play has been shown to be influential in increasing the level of physical activity, with the continuous form producing similar improvements in activity levels to traditional walking, while the intermittent form resulted in a reduced effect (Beach et al., 2021). This could be a possible explanation for the absence of significant differences in Pokémon Go on the physical fitness variables, since just as the form of gameplay influences the level of physical activity, it could do so on the fitness variables, but future research is needed to confirm this conclusion.

The results obtained when comparing the different mobile applications used lead to a partial rejection of the second initial hypothesis proposed, since it was indicated that no differences would be found in the variables analyzed between the different groups of mobile applications, but the results show that the level of physical activity, changes in body composition and improvements in physical condition were significantly different between the groups.

4.1 Practical implications

Regarding the practical implications derived from this study, the use of mobile applications promoted from the subject of physical education could be useful, in contrast to the results found in previous research, where no relationship was found between the use of these tools and the improvement of physical activity (Direito et al., 2015; Zhu & Dragon, 2016). However, two aspects should be highlighted for this to be useful: firstly, the use of the applications should take place outside school hours, as the design and interface of current mobile applications greatly limit their use during class hours (Alonso-Fernández et al., 2022); and, secondly, their use should be mandatory for adolescents, through the integration of their use into the physical education subject as homework, with the help of physical education teachers. In this way, the difficulties found in previous research in relation to the lack of adherence and reduced use of mobile applications could be overcome, to therefore increase the level of physical activity of the adolescent population and achieve improvements in body composition and physical condition. Therefore, although future research is needed in this area, the use of mobile applications promoted as physical education "homework" may be a key aspect in improving the health status of the adolescent population, which especially necessary after the COVID-19 pandemic, with the step tracker apps being a very valuable educational resource, although its use should be centered on out-of-school hours.

4.2 Educational implications

These results are relevant for physical education teachers, who could promote the use of these tools in physical education classes, without the app used being excessively decisive, if it includes resources to facilitate behavioral change, as the differences between them are minimal. However, it should be noted that the results found may also be relevant for the Ministry and the Department of Education, which could promote the inclusion of these applications on a regular basis, being considered as "homework" as in other subjects, given that the extracurricular work is crucial for integrating the contents worked on in the classroom, although in the field of physical education, this is forgotten.

5 Conclusion

To conclude, the results of the present study indicate that mobile applications used after school are useful tools for producing changes in the level of physical activity, body composition, and physical fitness of adolescents aged 12 to 16 years old. The mobile applications used in the present investigation do not seem effective in improving AMD in adolescents. It should be noted that depending on the mobile application used, different benefits on physical activity level, body composition, and physical fitness may occur, with the gamified mobile application used in the present research being useful for producing changes in physical activity and body composition, but not in physical fitness, with future research to discover the effectiveness of each application being necessary.

5.1 Limitations

The present study is not free of limitations. The sample was selected by convenience from the educational centers that could be accessed. Although the sample size at the beginning of the research was high, the sample in the intervention groups for certain applications was small, making statistical analysis difficult. The PAQ-A questionnaire, despite being valid and reliable for use in this population, is a self-report that considers physical activity performed in the last seven days, so this should be considered if an intervention of several weeks' duration is carried out. In addition, two relevant aspects that were not considered in the present research and with which one could more strongly attribute the changes produced in the adolescents to the mobile apps, were the adolescents' motivation and enjoyment of participating in the intervention, as this could be used to assess adherence and continuity in the use of the apps once it is no longer mandatory. Moreover, although starting to practice a new sport activity during the intervention was an exclusion criterion, special consideration should be given in future research to the adolescents who regularly exercise in the gym, since the changes in body composition and physical fitness obtained could be due to advances in this area. Furthermore, in the area of nutrition, more exhaustive monitoring should be carried out before starting the research, on the total daily energy expenditure or the caloric status of the adolescents, as this could hinder or facilitate the changes observed during the intervention.

5.2 Future studies

The results of the present research can be a first step for the development of future research from the Education and Information Technology communities. This is because the results obtained have shown improvements in the level of physical activity, body composition and physical fitness of adolescents using applications that were not specifically designed for adolescents. Therefore, this raises the possibility that a specific application could be designed with adolescents in mind, as in previous research with Healthy Jeart (Duarte-Hueros et al., 2020) and TRAINIME (Mokmin & Jamiat, 2021), and following the quality recommendations included in previous research on mobile apps (Gil-Espinosa et al., 2022). This app could be aimed at the field of physical education, including extracurricular “homework” along with educational content of interest to this population, which could facilitate obtaining more evident and significant results in terms of improving the level of physical activity, body composition and physical condition, and to improve the knowledge needed to maintain a healthy lifestyle.

In addition to the design of a mobile app aimed at increasing the practice of physical activity in the adolescent population, with useful educational resources that can be used in the physical education classroom for the knowledge of healthy lifestyle habits, another possible future line of research would be to analyze whether the changes produced at the levels of physical activity, physical condition and body composition differed among adolescents who covered a greater distance with the use of the application, thus being able to establish an optimal range and more precise recommendations for the appropriate use of these tools.

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A-C, L. participated in conceptualization, data curation, formal analysis, methodology, project administration, supervision, visualization, and writing review and editing.

A-S, M. D. participated in methodology, project administration, supervision, and writing original draft.

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Code availability The measurement protocol was registered before the start of the study at ClinicalTrials.gov (code: NCT04860128).

Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval Prior to the start of the study, the institutional ethics committee approved the research design in accordance with the World Medical Association (code: CE022102). The research was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent Informed consent was obtained from all individual participants included in the study.A-C, L. participated in conceptualization, data curation, formal analysis, methodology, project administration, supervision, visualization, and writing review and editing. Authors' contribution statements A-S, M. D. participated in methodology, project administration, supervision, and writing original draft. V-C, R. participated in conceptualization, data curation, formal analysis, methodology, project administration, supervision, validation, and writing review and editing.

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References

Albaladejo-Saura, M., Vaquero-Cristóbal, R., García-Roca, J. A., & Esparza-Ros, F. (2022). Influence of biological maturation status on selected anthropometric and physical fitness variables in adolescent male volleyball players. *PeerJ, 10*, e13216. https://doi.org/10.7717/peerj.13216

Alonso-Fernández, D., Gutiérrez-Sánchez, Á., Portela-Pino, I., & Taboada-Iglesias, Y. (2022). Evaluation of applications for Mobile Devices on the practice of Physical Exercise in Adolescents. *Applied Sciences (Switzerland)*, *12*(6). https://doi.org/10.3390/app12062784

Altmann, S., Spielmann, M., Engel, F. A., Neumann, R., Ringhof, S., Oriwol, D., & Haertel, S. (2017). Validity of single-beam timing lights at different heights. *Journal of Strength and Conditioning Research, 31*(7), 1994–1999. https://doi.org/10.1519/JSC.0000000000001889

Ayala, F., De Baranda, S., De Ste Croix, P., & Santonja, F. (2012). Reliability and validity of sit-and-reach tests: systematic review. *Revista Andaluza de Medicina Del Deporte, 5*(2), 57–66. https://doi.org/10.1016/s1888-7546(12)70010-2

Badawy, S. M., & Kuhns, L. M. (2017). Texting and mobile phone app interventions for improving adherence to preventive behavior in adolescents: a systematic review. *JMIR MHealth and UHealth*, *5*(4). https://doi.org/10.2196/mhealth.6837

Barbiellini Amidei, C., Trevisan, C., Dotto, M., Ferroni, E., Noale, M., Maggi, S., Corti, M. C., Baggio, G., Fedeli, U., & Sergi, G. (2022). Association of physical activity trajectories with major cardiovascular diseases in elderly people. *Heart (British Cardiac Society), 108*(5), 360–366. https://doi.org/10.1136/heartjnl-2021-320013

Barker, L. A., Harry, J. R., & Mercer, J. A. (2018). Relationships between countermovement jump groud reaction forces and jump height, reactive strength index, and jump time. *Journal of Strength and Conditioning Research, 32*(1), 248–254.

Beach, C., Montoye, A., & Steeves, J. (2021). Differences in physical activity during walking and two Pokémon Go playing Styles. *Games for Health Journal, 10*(2), 130–138.

Benítez-Porres, J., Alvero-Cruz, J. R., Sardinha, L. B., López-Fernández, I., & Carnero, E. A. (2016). Cut-off values for classifying children and adolescents using the physical activity questionnaire: PAQ-C and PAQ-A. *Nutrición Hospitalaria, 33*(5), 1036–1044.

Bhalerao, S., & Kadam, P. (2010). Sample size calculation. *International Journal of Ayurveda Research, 1*(1), 55. https://doi.org/10.4103/0974-7788.59946

Bogataj, Š, Trajković, N., Cadenas-Sanchez, C., & Sember, V. (2021). Effects of school-based exercise and nutrition intervention on body composition and physical fitness in overweight adolescent girls. *Nutrients, 13*(1), 1–12. https://doi.org/10.3390/nu13010238

Böhm, B., Karwiese, S. D., Böhm, H., & Oberhoffer, R. (2019). Effects of mobile health including wearable activity trackers to increase physical activity outcomes among healthy children and adolescents: systematic review. *JMIR MHealth and UHealth*, *7*(4). https://doi.org/10.2196/mhealth.8298

Bondaronek, P., Alkhaldi, G., Slee, A., Hamilton, F. L., & Murray, E. (2018). Quality of publicly available physical activity apps: review and content analysis. *JMIR MHealth and UHealth*, *6*(3). https://doi.org/10.2196/mhealth.9069

Castro-Piñero, J., Ortega, F., Artero, E., Girela-Rejón, M., Mora, J., Sjöström, M., & Ruiz, J. (2010). Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. *Journal of Strength and Conditioning Research, 24*(7), 1810–1817.

Coburn, J., & Malek, M. (2014). *Manual NSCA: Fundamentos del Entrenamiento Personal* (2ª). Paidotribo.

Cohen, D., Carreno, J., Camacho, P., Otero, J., Martínez, D., López-López, J., Sandercock, G., & López-Jaramillo, P. (2022). Fitness changes in adolescent girls following in-school combined aerobic and resistance exercise: interaction with birthweight. *Pediatric Exercise Science, 34*(2), 76–83.

Conger, S. A., Toth, L. P., Cretsinger, C., Raustorp, A., Mitáš, J., Inoue, S., & Bassett, D. R. (2022). Time trends in physical activity using wearable devices: a systematic review and meta-analysis of studies from 1995 to 2017. *Medicine and Science in Sports and Exercise, 54*(2), 288–298. https://doi.org/10.1249/MSS.0000000000002794

Corder, K., Winpenny, E., Love, R., Brown, H. E., White, M., & Van Sluijs, E. (2019). Change in physical activity from adolescence to early adulthood: a systematic review and meta-analysis of longitudinal cohort studies. *British Journal of Sports Medicine, 53*(8), 496–503. https://doi.org/10.1136/bjsports-2016-097330

Cronin, J., & Templeton, R. (2008). Timing light height affects sprint times. *Journal of Strength and Conditioning Research, 22*(1), 318–320.

De Almeida-Neto, P. F., Da Silva Cunha, R. C., De Matos, D. G., Baxter-Jones, A. D. G., Aidar, F. J., de Assis, G. G., Dantas, P. M. S., & de Araújo, B. G. (2021). Lean mass and biological maturation as predictors of muscle power and strength performance in young athletes. *PLoS ONE*, *16*(7 July), 1–12. https://doi.org/10.1371/journal.pone.0254552

De Barros Gonze, B., Padovani, D. C., Do Socorro Simoes, R., Lauria, M., Proença, V., Sperandio, N. L., Di Paschoale Ostolin, E. F., de Oliveira Gomes, T. L. V., Castro, G. A., Romiti, P. C., Gagliardi, M., Arantes, A., & Dourado, V. Z. (2020). Use of a smartphone app to increase physical activity levels in insufficiently active adults: feasibility sequential multiple assignment randomized trial (SMART). *JMIR Research Protocols, 9*(10), 1–16. https://doi.org/10.2196/14322

De Freitas, F., De Silva, C. D., Mendes, C., Antonio, R., & Zambon, M. (2021). The effect of the use of a physical-activity mobile application on body composition and sleep quality of overweight children. *Revista Da Associacao Medica Brasileira, 67*(3), 373–377. https://doi.org/10.1590/1806-9282.20200763

Díaz-Soler, M. A., Vaquero-Cristóbal, R., Espejo-Antúnez, L., & López-Miñarro, P. (2015). Efecto de un protocolo de calentamiento en la distancia alcanzada en el test sit-and-reach en alumnos adolescents. *Nutricion Hospitalaria, 31*(6), 2618–2623. https://doi.org/10.3305/nh.2015.31.6.8858

Direito, A., Jiang, Y., Whittaker, R., & Maddison, R. (2015). Apps for IMproving FITness and increasing physical activity among young people: the AIMFIT pragmatic randomized controlled trial. *Journal of Medical Internet Research, 17*(8), 1–13. https://doi.org/10.2196/jmir.4568

Duarte-Hueros, A., Yot-Domínguez, C., & Merino-Godoy, A. (2020). Healthy Jeart. Developing an app to promote health among young people. *Education and Information Technologies, 25*(1), 1837–1854.

Dute, D. J., Bemelmans, W. J. E., & Breda, J. (2016). Using mobile apps to promote a healthy lifestyle among adolescents and students: a review of the theoretical basis and lessons learned. *JMIR MHealth and UHealth*, *4*(2). https://doi.org/10.2196/mhealth.3559

Elbert, S. P., Dijkstra, A., & Oenema, A. (2016). A mobile phone app intervention targeting fruit and vegetable consumption:the efficacy of textual and auditory tailored health information tested in a randomized controlled trial. *Journal of Medical Internet Research*, *18*(6). https://doi.org/10.2196/jmir.5056

Elnaggar, R. K., Alqahtani, B. A., Mahmoud, W. S., & Elfakharany, M. S. (2022). Prospective analysis of physical activity levels and associated fitness factors amid COVID-19 pandemic and social-distancing rules. A special focus on adolescents. *Science and Sports, 37*(2), 131–138. https://doi.org/10.1016/j.scispo.2021.07.002

España-Romero, V., Ortega, F. B., Vicente-Rodriguez, G., Artero, E., Pablo-Rey, J., & Ruiz, J. R. (2010). Elbow position affects handgrip strength in adolescents: validity and reliability of Jamar, Dynex, and TKK dynamometers. *Journal of Strength and Conditioning Research, 24*(1), 272–277.

Esparza-Ros, F., Vaquero-Cristóbal, R., & Marfell-Jones, M. (2019). *International Standards for Anthropometric Assessment*. International Society for Advancement in Kinanthropometry.

Fanchang, K., Guofeng, L., Qiufeng, G., & Jianjun, D. (2021). From early to late adolescence: Effect of problematic mobile phone use on depression of adolescents. *School Psychology International, 1*(1), 1–12.

Farooq, A., Martin, A., Janssen, X., Wilson, M. G., Gibson, A. M., Hughes, A., & Reilly, J. J. (2020). Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: a systematic review and meta-analysis. *Obesity Reviews, 21*(1), 1–15. https://doi.org/10.1111/obr.12953

Figueiredo, D., Figueiredo, D., Dourado, A., Stanganelli, L., & Gonçalves, H. (2020). Evaluation of body composition and its relationship with physical fitness in professional soccer players at the beginning of pre-season Evaluación de la composición corporal y su relación com la aptitud física em futebolistas professionales al inicio de l. *Retos, 40*, 117–125.

García-Manso, J., Navarro, M., & Ruiz-Caballero, J. (1996). *Pruebas para la valoración de la capacidad motriz en el deporte. Evaluación de la condición física*. Gymnos.

Garcia-Pastor, T., Salinero, J. J., Sanz-Frias, D., Pertusa, G., & Coso, D. (2016). Body fat percentage is more associated with low physical fitness than with sedentarism and diet in male and female adolescents. *Physiology and Behavior, 165*, 166–172. https://doi.org/10.1016/j.physbeh.2016.07.016

Gil-Espinosa, F. J., Merino-Marbán, R., & Mayorga-Vega, D. (2020). Aplicación móvil Endomondo para promocionar la actividad física en estudiantes de educación secundaria (Endomondo smartphone app to promote physical activity in high school students). *Cultura Ciencia y Deporte, 15*(46), 465–473. https://doi.org/10.12800/ccd.v15i46.1597

Gil-Espinosa, F. J., Nielsen-Rodríguez, A., Romance, R., & Burgueño, R. (2022). Smartphone applications for physical activity promotion from physical education. *Education and Information Technologies*, 1–21. https://doi.org/10.1007/s10639-022-11108-2

González-Gálvez, N., Marcos-Pardo, P. J., Trejo-Alfaro, H., & Vaquero-Cristóbal, R. (2020). Effect of 9-month Pilates program on sagittal spinal curvatures and hamstring extensibility in adolescents: randomised controlled trial. *Scientific Reports, 10*(1), 1–8. https://doi.org/10.1038/s41598-020-66641-2

Goodyear, V. A., Skinner, B., McKeever, J., & Griffiths, M. (2021). The influence of online physical activity interventions on children and young people's engagement with physical activity: a systematic review. *Physical Education and Sport Pedagogy*, *26*(2), 1–15. https://doi.org/10.1080/17408989.2021.1953459

Groen, G., Jorns-Presentati, A., Dessauvagie, A., Seedat, S., Van den Heuvel, L., Suliman, S., Grobler, G., Jansen, R., Mwape, L., Mukwato, P., Chapima, F., Korhonen, J., Stein, D., Jonker, D., Mudenda, J., Turunen, T., Valtins, K., Beinarovica, A., Grada, L., & Lahti, M. (2022). Development of a mobile application for detection of adolescent mental health problems and feasibility assessment with primary health care workers. *Issues in Mental Health Nursing, 43*(11), 1046–1055.

Hallal, P., Victora, C., Azevedo, M., & Wells, J. (2006). Adolescent physical activity and health. A systematic review. *Sports Medicine, 36*(12), 1019–1030. https://doi.org/10.1377/hlthaff.2017.0801

He, Z., Wu, H., Yu, F., Fu, J., Sun, S., Huang, T., Wang, R., Chen, D., Zhao, G., & Quan, M. (2021). Effects of smartphone-based interventions on physical activity in children and adolescents: systematic review and meta-analysis. *JMIR MHealth and UHealth*, *9*(2). https://doi.org/10.2196/22601

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Karatzi, K., Poulia, K., Papakonstantinou, E., & Zampelas, A. (2021). The impact of nutritional and lifestyle changes on body weight, body composition and cardiometabolic risk factors in children and adolescents during the pandemic of COVID-19: a systematic review. *Children, 8*(1), 1–13.

Khamzina, M., Parab, K. V., An, R., Bullard, T., & Grigsby-Toussaint, D. S. (2020). Impact of Pokémon go on physical activity: a systematic review and Meta-analysis. *American Journal of Preventive Medicine, 58*(2), 270–282. https://doi.org/10.1016/j.amepre.2019.09.005

Kolunsarka, I., Grasten, A., Huhtiniemi, M., & Jaakkola, T. (2022). Development of children's actual and perceived motor competence, cardiorespiratory fitness, physical activity, and BMI. *Medicine & Science in Sports & Exercise, 53*(12), 2653–2660.

Kowalski, K. C., Crocker, P. R. E., Columbia, B., & Donen, R. M. (2004). *The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual*. University of Saskatchewan.

Kracht, C. L., Hutchesson, M., Ahmed, M., Müller, A. M., Ashton, L. M., Brown, H. M., DeSmet, A., Maher, C. A., Mauch, C. E., Vandelanotte, C., Short, C. E., & Staiano, A. E. (2021). E-&mHealth

interventions targeting nutrition, physical activity, sedentary behavior, and/or obesity among children: a scoping review of systematic reviews and meta-analyses. *Obesity Reviews*, *22*(12). https://doi.org/10.1111/obr.13331
Kriemler, S., Meyer, U., Martin, E., Van Sluijs, E. M. F., Andersen, L. B., & Martin, B. W. (2011). Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. *British Journal of Sports Medicine, 45*(11), 923–930. https://doi.org/10.1136/bjsports-2011-090186
Kwan, M. Y., Cairney, J., Faulkner, G. E., & Pullenayegum, E. E. (2012). Physical activity and other health-risk behaviors during the transition into early adulthood: a longitudinal cohort study. *American Journal of Preventive Medicine, 42*(1), 14–20. https://doi.org/10.1016/j.amepre.2011.08.026
Lamoth, C. J. C., Meijer, O. G., Daffertshofer, A., Wuisman, P. I. J. M., & Beek, P. J. (2006). Effects of chronic low back pain on trunk coordination and back muscle activity during walking: changes in motor control. *European Spine Journal, 15*(1), 23–40. https://doi.org/10.1007/s00586-004-0825-y
Lee, W., Chae, Y., Kim, S., Ho, S., & Choi, I. (2010). Evaluation of a mobile phone-based diet game for weight control. *Journal of Telemedicine and Telecare, 16*(5), 270–275.
Lee, J. E., Zeng, N., Oh, Y., Lee, D., & Gao, Z. (2021). Effects of pokémon GO on physical activity and psychological and social outcomes: a systematic review. *Journal of Clinical Medicine*, *10*(9). https://doi.org/10.3390/jcm10091860
Léger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *Journal of Sports Sciences, 6*(2), 93–101. https://doi.org/10.1080/02640418808729800
Legkauskas, V., & Steponavičiūtė-Kupčinskė, I. (2021). Links between in-class use of social media and school adjustment of high-school pupils. *Education and Information Technologies, 26*(3), 2853–2861. https://doi.org/10.1007/s10639-020-10389-9
Leong, J. Y., & Wong, J. E. (2017). Accuracy of three android-based pedometer applications in laboratory and free-living settings. *Journal of Sports Sciences, 35*(1), 14–21. https://doi.org/10.1080/02640414.2016.1154592
Likhitweerawong, N., Boonchooduang, N., Kittisakmontri, K., Chonchaiya, W., & Louthrenoo, O. (2021). Effectiveness of mobile application on changing weight, healthy eating habits, and quality of life in children and adolescents with obesity: a randomized controlled trial. *BMC Pediatrics, 21*(1), 1–9. https://doi.org/10.1186/s12887-021-02980-x
Llorente-Cantarero, F. J., Aguilar-Gómez, F. J., Anguita-Ruiz, A., Rupérez, A. I., Vázquez-Cobela, R., Flores-Rojas, K., Aguilera, C. M., Gonzalez-Gil, E. M., Gil-Campos, M., Bueno-Lozano, G., & Leis, R. (2020). Changes in physical activity patterns from childhood to adolescence: genobox longitudinal study. *International Journal of Environmental Research and Public Health, 17*(19), 1–13. https://doi.org/10.3390/ijerph17197227
López-Bueno, R., Calatayud, J., Andersen, L. L., Casaña, J., Ezzatvar, Y., Casajús, J. A., López-Sánchez, G. F., & Smith, L. (2021). Correction to: cardiorespiratory fitness in adolescents before and after the COVID-19 confinement: a prospective cohort study. *European Journal of Pediatrics, 180*(7), 2295. https://doi.org/10.1007/s00431-021-04107-x
López-Miñarro, P., Vaquero-Cristóbal, R., Muyor, J. M., & Espejo-Antúnez, L. (2015). Criterion-related validity of sit-and-reach test as a measure of hamstring extensibility in older women. *Nutricion Hospitalaria, 32*(1), 312–317. https://doi.org/10.3305/nh.2015.32.1.8999
Lovecchio, N., Giuriato, M., Pellino, V. C., Valarani, F., Codella, R., & Vandoni, M. (2020). Italian physical fitness decline: a true fact or a mindset? A 10-year observational perspective study. *International Journal of Environmental Research and Public Health, 17*(21), 1–12. https://doi.org/10.3390/ijerph17218008
Lubans, D. R., Plotnikoff, R. C., Miller, A., Scott, J. J., Thompson, D., & Tudor-Locke, C. (2015). Using pedometers for measuring and increasing physical activity in children and adolescents: the next step. *American Journal of Lifestyle Medicine, 9*(6), 418–427. https://doi.org/10.1177/1559827614537774
Lunn, P. D. (2010). The sports and exercise life-course: a survival analysis of recall data from Ireland. *Social Science and Medicine, 70*(5), 711–719. https://doi.org/10.1016/j.socscimed.2009.11.006
Macdonald, E. Z., Vehrs, P. R., Fellingham, G. W., Eggett, D., George, J. D., & Hager, R. (2017). Validity and reliability of assessing body composition using a Mobile Application. *Medicine and Science in Sports and Exercise, 49*(12), 2593–2599. https://doi.org/10.1249/MSS.0000000000001378
Martínez-Gómez, D., Martínez-de-Haro, V., Pozo, T., Welk, G. J., Villagra, A., Calle, M. E., Marcos, A., & Veiga, O. L. (2009). Fiabilidad y validez del cuestionario de actividad física PAQ-A en adolescentes españoles. *Revista Española de Salud Pública, 83*(3), 427–439.

Matsudo, V. K. R., Matsudo, S. M., de Rezende, L. F. M., & Raso, V. (2014). Handgrip strength as a predictor of physical fitness in children and adolescents. *Revista Brasileira de Cineantropometria e Desempenho Humano, 17*(1), 1–10. https://doi.org/10.5007/1980-0037.2015v17n1p1

Mcconnell-Nzunga, J., Gabel, L., Macdonald, H., Rhodes, R., Hofer, S., Patti-Jean, N., & Heather, M. (2022). A 4-yr mixed longitudinal study of health behaviors and fat mass accrual during adolescence and early adulthood. *Medicine & Science in Sports & Exercise, 54*(12), 2178–2187. https://doi.org/10.1249/mss.0000000000003003

Mokmin, A., & Jamiat, N. (2021). The effectiveness of a virtual fitness trainer app in motivating and engaging students for fitness activity by applying motor learning theory. *Education and Information Technologies, 26*(1), 1847–1864.

Mora-Gonzalez, J., Pérez-López, I. J., & Delgado-Fernández, M. (2020). The "$in TIME" gamification project: using a mobile app to improve cardiorespiratory fitness levels of college students. *Games for Health Journal, 9*(1), 37–44. https://doi.org/10.1089/g4h.2019.0001

Morency, C., Demers, M., & Lapierre, L. (2007). How many steps do you have in reserve? *Transportation Research Record: Journal of the Transportation Research Board, 1*(1), 1–6. https://doi.org/10.3141/2002-01

Pakarinen, A., Parisod, H., Smed, J., & Salanterä, S. (2017). Health game interventions to enhance physical activity self-efficacy of children: a quantitative systematic review. *Journal of Advanced Nursing, 73*(4), 794–811. https://doi.org/10.1111/jan.13160

Parmenter, B., Burley, C., Stewart, C., Whife, J., Champion, K., Osman, B., Newton, N., Green, O., Wescott, A. B., Gardner, L. A., Visontay, R., Birrell, L., Bryant, Z., Chapman, C., Lubans, D. R., Sunderland, M., Slade, T., & Thornton, L. (2022). Measurement properties of smartphone approaches to assess physical activity in healthy young people: systematic review. *JMIR MHealth and UHealth, 10*(10), e39085. https://doi.org/10.2196/39085

Pechtl, S., Kim, L., & Jacobsen, K. (2022). Physical inactivity and sedentariness: languorous behavior among adolescents in 80 countries. *Journal of Adolescent Health, 70*(6), 950–960.

Peng, W., Yuan, S., & Holtz, B. E. (2016). Exploring the challenges and opportunities of health mobile apps for individuals with type 2 diabetes living in rural communities. *Telemedicine and E-Health, 22*(9), 733–738. https://doi.org/10.1089/tmj.2015.0180

Petersen, J. M., Kemps, E., Lewis, L. K., & Prichard, I. (2020). Associations between commercial app use and physical activity: cross-sectional study. *Journal of Medical Internet Research*, *22*(6). https://doi.org/10.2196/17152

Poortmans, J. R., Boisseau, N., Moraine, J. J., Moreno-Reyes, R., & Goldman, S. (2005). Estimation of total-body skeletal muscle mass in children and adolescents. *Medicine and Science in Sports and Exercise, 37*(2), 316–322. https://doi.org/10.1249/01.MSS.0000152804.93039.CE

Radulović, A., Jurak, G., Leskošek, B., Starc, G., & Blagus, R. (2022). Secular trends in physical fitness of slovenian boys and girls aged 7 to 15 years from 1989 to 2019: a population-based study. *Scientific Reports, 12*(1), 1–18. https://doi.org/10.1038/s41598-022-14813-7

Rose, T., Barker, M., Maria Jacob, C., Morrison, L., Lawrence, W., Strömmer, S., Vogel, C., Woods-Townsend, K., Farrell, D., Inskip, H., & Baird, J. (2017). A systematic review of digital interventions for improving the diet and physical activity behaviors of adolescents. *The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine, 61*(6), 669–677. https://doi.org/10.1016/j.jadohealth.2017.05.024

Saint-Maurice, P. F., Coughlan, D., Kelly, S. P., Keadle, S. K., Cook, M. B., Carlson, S. A., Fulton, J. E., & Matthews, C. E. (2019). Association of leisure-time physical activity across the adult life course with all-cause and cause-specific mortality. *JAMA Network Open, 2*(3), 1–12. https://doi.org/10.1001/jamanetworkopen.2019.0355

Sánchez-Sánchez, E., Ramírez-Vargas, G., Avellaneda-López, Y., Orellana-Pecino, J. I., García-Marín, E., & Díaz-Jimenez, J. (2020). Eating habits and physical activity of the spanish population during the covid-19 pandemic period. *Nutrients, 12*(9), 1–12. https://doi.org/10.3390/nu12092826

Schoeppe, S., Alley, S., Van Lippevelde, W., Bray, N. A., Williams, S. L., Duncan, M. J., & Vandelanotte, C. (2016). Efficacy of interventions that use apps to improve diet, physical activity and sedentary behaviour: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1). https://doi.org/10.1186/s12966-016-0454-y

Schoeppe, S., Alley, S., Rebar, A. L., Hayman, M., Bray, N. A., Van Lippevelde, W., Gnam, J. P., Bachert, P., Direito, A., & Vandelanotte, C. (2017). Apps to improve diet, physical activity and sedentary behaviour in children and adolescents: a review of quality, features and behaviour change techniques. *International Journal of Behavioral Nutrition and Physical Activity*, *14*. https://doi.org/10.1186/s12966-017-0538-3

Seah, M. L. C., & Koh, K. T. (2021). The efficacy of using mobile applications in changing adolescent girls' physical activity behaviour during weekends. *European Physical Education Review, 27*(1), 113–131. https://doi.org/10.1177/1356336X20930741

Serra-Majem, L., Ribas, L., Ngo, J., Ortega, R. M., García, A., Pérez-Rodrigo, C., & Aranceta, J. (2004). Food, youth and the Mediterranean diet in Spain. Development of KIDMED, Mediterranean diet quality index in children and adolescents. *Public Health Nutrition, 7*(7), 931–935. https://doi.org/10.1079/phn2004556

Shin, Y., Kim, S. K., & Lee, M. (2019). Mobile phone interventions to improve adolescents' physical health: a systematic review and meta-analysis. *Public Health Nursing, 36*(6), 787–799. https://doi.org/10.1111/phn.12655

Shnayderman, I., & Katz-Leurer, M. (2013). An aerobic walking programme versus muscle strengthening programme for chronic low back pain: a randomized controlled trial. *Clinical Rehabilitation, 27*(3), 207–214. https://doi.org/10.1177/0269215512453353

Smith, J. J., Eather, N., Weaver, R. G., Riley, N., Beets, M. W., & Lubans, D. R. (2019). Behavioral correlates of muscular fitness in children and adolescents: a systematic review. *Sports Medicine*. https://doi.org/10.1007/s40279-019-01089-7

Štefan, L., Prosoli, R., Juranko, D., Čule, M., Milinović, I., Novak, D., & Sporiš, G. (2017). The reliability of the Mediterranean diet quality index (KIDMED) questionnaire. *Nutrients*, *9*(4). https://doi.org/10.3390/nu9040419

Telama, R., Yang, X., Viikari, J., Välimäki, I., Wanne, O., & Raitakari, O. (2005). Physical activity from childhood to adulthood: a 21-year tracking study. *American Journal of Preventive Medicine, 28*(3), 267–273. https://doi.org/10.1016/j.amepre.2004.12.003

Tomkinson, G. R., Lang, J. J., Blanchard, J., Léger, L. A., & Tremblay, M. S. (2019). The 20-m shuttle run: assessment and interpretation of data in relation to youth aerobic fitness and health. *Pediatric Exercise Science, 31*(2), 152–163. https://doi.org/10.1123/pes.2018-0179

Vadeboncoeur, C., Townsend, N., & Foster, C. (2015). A meta-analysis of weight gain in first year university students: is freshman 15 a myth? *BMC Obesity*, *2*(1). https://doi.org/10.1186/s40608-015-0051-7

Ventura, P. S., Ortigoza, A. F., Castillo, Y., Bosch, Z., Casals, S., Girbau, C., Siurana, J. M., Arce, A., Torres, M., & Herrero, F. J. (2021). Children's health habits and covid-19 lockdown in catalonia: implications for obesity and non-communicable diseases. *Nutrients, 13*(5), 1–12. https://doi.org/10.3390/nu13051657

Vuk, S., Gregov, C., & Marković, G. (2015). Relationship between knee extensor muscle strength and movement performance: the effect of load and body size. *Kinesiology, 47*(1), 27–32.

Xiang, M. Q., Wang, Z. R., Xu, Z., Sun, P., & Zhang, L. (2021). Sedentary behavior, physical exercise, and cellphone use time among early adolescents: the moderating but not mediating role of self-control. *Current Psychology*. https://doi.org/10.1007/s12144-021-01585-y

Yomoda, K., & Kurita, S. (2021). Influence of social distancing during the COVID-19 pandemic on physical activity in children: a scoping review of the literature. *Journal of Exercise Science and Fitness, 19*(3), 195–203. https://doi.org/10.1016/j.jesf.2021.04.002

Zhu, X., & Dragon, L. A. (2016). Physical activity and situational interest in mobile technology integrated physical education: a preliminary study. *Acta Gymnica, 46*(2), 59–67. https://doi.org/10.5507/ag.2016.010

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