Humanities & Social Sciences Communications

ARTICLE

https://doi.org/10.1057/s41599-023-02502-3 OPEN

Check for updates

# Gender and academic year as moderators of the efficacy of mobile app interventions to promote physical activity in adolescents: a randomized controlled trial

No previous study has analyzed the differences in the effectiveness of an intervention with mobile applications, according to gender and academic year, on the level of physical activity, body composition, and physical fitness of adolescents. For this reason, the aim of the present investigation was to establish the differences in the change in level of physical activity, kinanthropometric and derived variables, and fitness with an intervention to promote physical activity base on the use of mobile applications in adolescents according to gender and academic year. A randomized controlled trial was carried out with a 10-week intervention with mobile applications that was promoted by the physical education department of the school. The final sample consisted of 400 adolescents (210 males and 190 females; mean age: 13.96 ± 1.21 years). A total of 240 adolescents were placed in the experimental group, and 160 were placed in the control group. Physical activity, body composition and physical fitness were measured before (pre) and after the intervention (post). During the intervention, four apps were mandatory used by the adolescents (Strava, Pacer, MapMyWalk, Pokémon Go) a minimum of three times a week. The distance to be traveled increased weekly during the intervention. The control group did not use the apps but continued to perform their physical activities as normal. The results showed that the use of mobile apps was higher in females ($p < 0.001$; 71.1% females vs 50.0% males) and adolescents in higher academic year ($p < 0.001$; 74.4% fourth academic year vs 53.8% first academic year). Moreover, the use of the apps prevented the increase of variables related to fat accumulation (body mass index (BMI), fat mass, sum 3 skinfolds, waist, and hips girths). Specifically, the differences between male and female were significant in BMI ($p < 0.001$; mean diff: −0.352), corrected calf girth ($p = 0.008$; mean diff: −0.498), fat mass ($p = 0.025$; mean diff: 0.748), handgrip right ($p = 0.002$; mean diff: −1.359), handgrip left ($p = 0.002$; mean diff: −1.103), and countermovement jump ($p = 0.002$; mean diff: −2.456), while when considering academic year, differences were significant in height ($p < 0.001$–0.044; mean diff: −1.099 to −0.509), sum of 3 skinfolds ($p = 0.046$–0.047; mean diff: −3.255), waist girth ($p = 0.048$; mean diff: 0.584), hip girth ($p < 0.001$–0.008; mean diff: −1.461 to −0.777), corrected calf girth ($p = 0.019$–0.029; mean diff: −0.539 to −0.482), and fat mass ($p = 0.025$–0.046; mean diff: 1.011 to −1.392). It can be concluded that mobile apps can be

A full list of authors and their affiliations appears at the end of the paper.

a great alternative to promote the practice of physical activity, decrease of fat variables, and improve some physical fitness variables, especially in females and adolescents in higher academic year. As a consequence of the above, gender and academic year should be considered in future interventions with mobile apps, as the effects in kinanthropometric and derived variables, and fitness and the follow-up of the intervention by adolescents may be different depending on these factors. The research protocol was registered prior to the start of the study in ClinicalTrials.gov (code: NCT04860128), under the name "New technologies as a tool for health promotion in schoolchildren of compulsory secondary education". https://clinicaltrials.gov/ct2/show/NCT04860128?term=NCT04860128&draw=2&rank=1.

## Introduction

The decrease in the practice of physical activity and the increase in sedentary activities in the adolescent population have become one of major public health problems in recent years (Farooq et al. 2020; Pechtl et al. 2022). After the COVID-19 pandemic, which greatly reduced the physical activity practiced by adolescents (Kim et al. 2022), previous levels of physical activity have not been recovered (Tapia-Serrano et al. 2022), triggering negative consequences on the health of this population (Ilesanmi et al. 2021). Thus, it was shown that up to 50% of adolescents who met the physical activity recommendations of the World Health Organization (WHO) before the pandemic decreased their level of physical activity below the recommendations during the pandemic (Bronikowska et al. 2021), and >10% of adolescents did not recover their pre-pandemic level of physical activity (Tapia-Serrano et al. 2022).

This physical inactivity was found to be related to other unhealthy behaviors during the pandemic, such as reduced intake of fruits and vegetables (López-Bueno et al. 2020), decreased hours of sleep (López-Bueno et al. 2020), increased hours of gaming video games (Haug et al. 2022), or a lower health-related quality of life (Nobari et al. 2021). In addition, two of the aspects that have been most affected by physical inactivity have been kinanthropometric variables, with an increase in variables related to fat mass (Karatzi et al. 2021; Rúa-Alonso et al. 2022), and the physical condition of adolescents, with a decrease in cardiorespiratory capacity and muscular fitness (López-Bueno et al. 2021; Rúa-Alonso et al. 2022), which has had a negative impact on their development from the point of view of achieving healthy lifestyle.

Kinanthropometric variables are fundamental during adolescence, as they are related to the prevalence of suffering certain chronic diseases later in life (Going et al. 2011; Weihrauch-Blüher et al. 2019). Thus, previous research has shown that adolescents with a high fat percentage have a higher risk of suffering from cardiovascular diseases (Going et al. 2011); while obese adolescents have a high probability of remaining obese during adulthood, increasing the risk of suffering cardiovascular and metabolic diseases, as well as different types of cancer (Weihrauch-Blüher et al. 2019). In addition to its influence on the posterior development of adolescents, kinanthropometric variables have been found to be related to performance in certain fitness tests, such as standing broad jump, sit-ups, or squats, with adolescents with higher fat-free mass and lower fat mass showing better performance (Kasović et al. 2022).

This relationship between kinanthropometric variables and fitness makes the latter a determining factor for adolescents. Furthermore, it should be noted that adolescents with better fitness have better cognitive performance, and this acts as a mediator in school vulnerability (Lemes et al. 2021), which is therefore important for the overall health of the adolescent population. On the other hand, regarding the risks of suffering diseases, a low level of fitness is related to a higher risk of inflammatory bowel disease (Melinder et al. 2015), as well as a higher risk of coronary heart disease (Bergh et al. 2015), so that the maintenance of adequate fitness during adolescence also has an impact on later stages of life.

To avoid this decrease in physical activity in the adolescent population (Pechtl et al. 2022), as well as its negative effects on kinanthropometric variables and fitness (Rúa-Alonso et al. 2022), numerous intervention programs have been carried out to increase the level of physical activity in this population (Böhm et al. 2019; van de Kop et al. 2019). Thus, school-based interventions to promote physical activity have acquired special relevance, being effective in those carried out in and outside the classroom (Burns et al. 2017; Hartwig et al. 2021). The duration of these interventions varies in terms of months (2 to 20), but they have been shown to be effective in improving enjoyment during physical activity (Burns et al. 2017), as well as in improving cardiorespiratory capacity and increasing the level of physical activity of the participants (Hartwig et al. 2021). In addition, interventions promoted from the school setting are important (van de Kop et al. 2019), as they generate a greater adherence to the physical activity program, especially when they include an academic reward, for example, in the physical education academic scores (Hardman et al. 2011). In this sense, females may be more interested in these interventions, as they are generally more concerned about academic performance than males (Marcenaro–Gutierrez et al. 2018).

Similarly, interventions to promote physical activity that include electronic devices have shown promising results (Böhm et al. 2019), as they are already fully integrated into the daily lives of adolescents and facilitate program monitoring (Lee et al. 2019). These interventions have included different technological devices such as web-based, text messages, or smartphone apps (Böhm et al. 2019), with mobile applications being the most common interventions in this area (Mateo-Orcajada et al. 2023b). However, physical activity interventions using mobile devices in out-school time have shown effectiveness in promoting physical activity at the beginning of the intervention (Yerrakalva et al. 2019), achieving notable benefits in the variables of physical fitness and body composition (Mateo-Orcajada et al. 2023a), but as the weeks progress, adherence to the intervention decreases (Shin et al. 2019), resulting in very small effects on physical activity and changes in body composition and fitness at the end of the intervention (Mateo-Orcajada et al. 2023b).

Considering the effectiveness of physical activity interventions with mobile applications in out-school time(Shin et al. 2019), especially when they include an academic reward from the subject of physical education (Hardman et al. 2011), one of the most recent lines of research includes the promotion of out-school physical activity in the school environment through mobile step tracker applications (Gil-Espinosa et al. 2020; Mateo-Orcajada et al. 2023a). A similar series of steps have been followed in this type of research, and these steps have been, before starting the intervention, instructed the adolescents on how to use the selected mobile apps (Gil-Espinosa et al. 2020; Mateo-Orcajada et al. 2023a); after that, told the adolescents how far they had to walk each week, with the distance being incremental from the first to the last week, monitoring the steps taken each week by each student (Mateo-Orcajada et al. 2023a). The physical education teachers offered an academic reward to those who completed the physical activity program during the planned time (Gil-Espinosa et al. 2020; Mateo-Orcajada et al. 2023a). All these measures were effective in maintaining adherence for a large proportion of the adolescents who started the intervention, showing positive results in terms of increases in physical activity out-school and changes in kinanthropometric and fitness variables (Mateo-Orcajada et al. 2023a).

However, the available scientific evidence is scarce, and among the aspects that remain to be investigated in this area are the differences in the effectiveness of these programs on the level of physical activity, kinanthropometric variables, and fitness, as a function of gender and the academic year of the adolescents. This is especially relevant because previous research has shown significant differences in the practice of physical activity between males and females, with males practicing to a greater extent (Bann et al. 2019), as well as between older and younger adolescents, with a decrease in the practice of physical activity as adolescence progresses (Dumith et al. 2011). Also mobile phone use differs between gender, with females (Nagata et al. 2022) and older adolescents (Dahlgren et al. 2021) using these devices to a greater extent. In addition, differences have also been found regarding the use of new technologies, with females using them more for social media, while males consume more video games (Leonhardt and Overå 2021). However, in the field of mobile applications, there is no certain conclusion, as previous research has shown that females use step tracker apps to a greater extent than males (Gulec and Smahel, 2022), while in other studies, no differences were found in the use of these types of mobile applications (Elavsky et al. 2017).

In addition to the differences found in the practice of physical activity and the use of mobile phones between males and females, as well as between older and younger adolescents, it should be added that none of the previous studies with mobile applications that analyzed gender differences was promoted from the field of education, which would mean losing a very valuable resource for facilitating the involvement of the adolescent population. Therefore, the aims of the present study were (a) to determine the existence of differences in the use of step tracker mobile applications to increase physical activity promoted from the physical education subject, according to the gender and academic year of the adolescents; (b) to establish the efficacy of mobile apps interventions to promote physical activity in the level of physical activity, kinanthropometric and derived variables, and the fitness depend on gender; and (c) to establish the efficacy of mobile app interventions to promote physical activity in the level of physical activity, kinanthropometric and derived variables, and the fitness depend on academic year.

Based on the lack of previous studies in this area, and with the present study being novel, it could not be hypothesized whether females will use step tracker apps to a greater extent than males due to their greater use of mobile devices or the influence of the intervention on their academic achievement or, on the contrary, if males will use the apps to a greater extent because they tend to regularly practice more extracurricular physical activity than females. Similarly, it is not known whether adolescents in higher academic grades will use apps to a greater extent due to their greater use of mobile phones or, on the contrary, if adolescents in lower grades will use apps to a greater extent due to the greater practice of regular physical activity. Therefore, the results obtained from this research will be pioneering, and will contribute to a line of research of great relevance in the use of mobile apps in the adolescent population.

## Material and methods

**Design**. A randomized controlled trial (RCT) was carried out with an experimental group and a control group that were measured on two moments (pre- and post-test measurements). These measurements were separated by a period of 10 weeks in which participants in the experimental group used one of the mobile applications selected for the study (Strava, Pacer, MapMyWalk, and Pokémon Go). Adolescents were required to use the apps a minimum of 3 times per week, completing a target distance each day, which increased over the weeks (week 1, 7000 steps per day; week 10, 12,500 steps per day). Participants in the control group did not use the mobile apps, but continued to attend physical education classes, as well as performing their physical activity routine as normal. The variables measured in both groups were physical activity level, kinanthropometric variables, and fitness variables.

The study design was performed following the Consolidated Standards of Reporting Trials (CONSORT) guidelines (Schulz et al. 2011). Prior to the start of the study, the ethics committee of the Catholic University of San Antonio of Murcia approved the study design (code: CE022102), and the recommendations from the Declaration of Helsinki were followed throughout the study. The research protocol was registered prior to the start of the study in ClinicalTrials.gov (code: NCT04860128). The study took place at the participating adolescents from December 2021 to June 2022.

**Participants**. The sampling was non-probabilistic by convenience, with the adolescents belonging to two compulsory secondary schools with the largest number of students in their localities (more than 200 students per school). The compulsory secondary schools with the highest number of students in two different locations in the Region of Murcia were contacted. If they had declined the invitation, the next compulsory secondary school with the most students in the locality would have been contacted, but this was not necessary as both compulsory secondary schools agreed to participate in the research. After receiving approval from the compulsory secondary school, an informative meeting was held with the physical education teachers and, subsequently, another meeting was held with the adolescents and their parents, where they were informed of the procedure and the aims of the research. Participation was voluntary for all the adolescents, who provided informed consent signed by them and their parents prior to the start of the study.

The sample size and power calculation were performed using the statistical software Rstudio 3.15.0 (Rstudio Inc., USA), and using the standard deviations from previous research conducted with mobile applications in adolescents to increase the level of physical activity measured with the physical activity questionnaire for adolescents (SD = 0.66) (Direito et al. 2015). The significance level was set at $\alpha = 0.05$ and a power of 95% ($1-\beta = 0.95$). Thus, for an estimated error (d) of 0.07 and a confidence interval of 95%, a minimum sample of 370 adolescents was required to conduct the study.

A total of 873 adolescents were potentially eligible for the study, but the final participation was 400 adolescents in compulsory secondary education (210 males and 190 females) aged between twelve and sixteen years (mean age: 13.96 ± 1.21 years). The sample selection flowchart is shown in Fig. 1.

The sample inclusion criteria were (a) enrollment in compulsory secondary education; (b) aged between twelve and sixteen years old; (c) participating in the pre- and post-test measurements; and (d) not presenting any disease or disability that prevented the completion of the tests and measurements performed. With respect to the exclusion criteria: (a) not having their own cell phone and not having one that could be used on a regular basis; (b) changing or leaving the compulsory secondary school; (c) not attending at least 80% of the physical education sessions scheduled for the academic year; (d) starting any type of physical activity during the intervention that was not performed before the start of the study, understand this as starting to practice a specific sport or going to the gym, not increasing of walking or running, since this is the aim of the research; and (e) abandoning any type of physical activity that was being carried out prior to the start of the study.

**Randomization and blinding**. The principal investigator carried out the randomization process using a computer-generated random number table in the presence of other uninvolved investigators. All students in the same class in each school center were assigned to the same mobile application group given by the randomization. School classes were randomly assigned to participate as intervention or control classes using a cluster randomized design (Christie et al. 2009). For intervention classes, a second randomization was performed to assign them to the application to be used (Strava, Pacer, MapMyWalk, Pokémon Go). Because of this, there were small differences in the initial

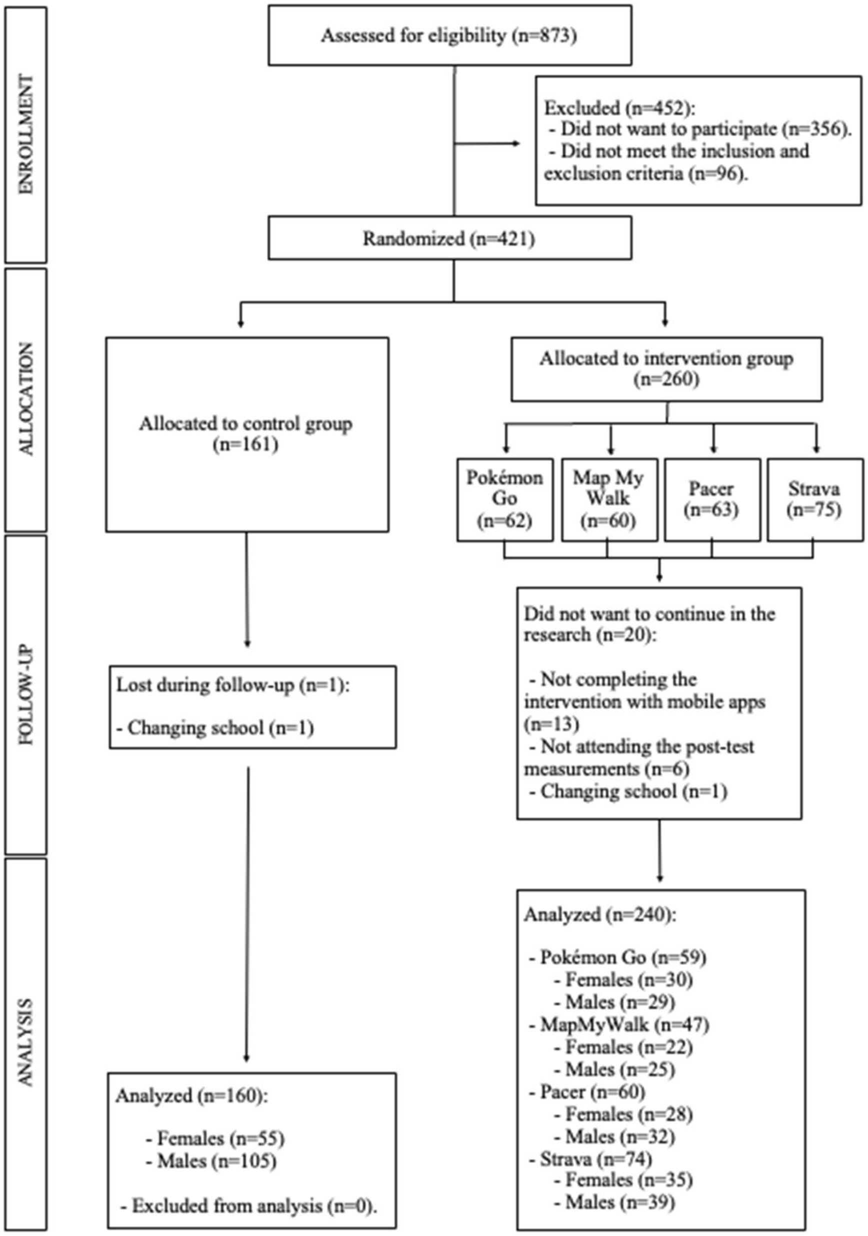


**Fig. 1** Sample selection flowchart.

sample size of each intervention group. There was no need to randomize the use of the applications according to gender, since the number of males and females per class group was equal, and the sample of males and females in each application was similar.

The control classes were asked to continue performing physical education classes as normal, and those classes were offered the intervention after the final data collection. Baseline measures were conducted after randomization. All meters were blinded to the group to which each individual belonged, as well as to the individual's ratings in the previous measurement. Group assignment was concealed from the investigator who analyzed each participant's compliance with the inclusion and exclusion criteria.

## Instruments

*Physical activity measurement*. The "Physical Activity Questionnaire for Adolescents" (PAQ-A) (Kowalski et al. 2004) was used to determine the level of physical activity of the adolescent population. This questionnaire is composed of nine items, the first eight of which are answered with a Likert scale of 1 to 5 points (1 low level of physical activity, 5 high level of physical activity), and the last item is dichotomous to determine whether something prevented the regular practice of physical activity in the last week. This questionnaire has been previously validated in Spanish and has an intra-scale correlation coefficient of 0.71 for the final score (Martínez-Gómez et al. 2009). This instrument allows the establishment of a final physical activity score with the arithmetic mean of the scores of the first eight items.

*Kinanthropometric and derived variables measurement*. Following the protocol established by the International Society for the Advancement of Kinanthropometry (ISAK) (Esparza-Ros et al. 2019), accredited anthropometrists (levels 2–4) measured the kinanthropometric variables of the adolescents: three basic measurements (body mass, height and sitting height), three skinfolds (triceps, thigh, and calf) and five girths (relaxed arm, waist, hips, thigh, and calf). The following derived variables were calculated from these measurements: BMI (body mass/height$^2$), muscle mass (Poortmans et al. 2005), fat mass (Slaughter et al. 1988), Σ3 skinfolds (triceps, thigh, and calf), waist-to-hip ratio (waist girth/hips girth), and corrected girths of the arm [arm relaxed girth – ($\pi$ * triceps skinfold)], thigh [middle thigh girth – ($\pi$ * thigh skinfold)], and calf [calf girth – ($\pi$ * calf skinfold)].

Two measurements were taken for each of the variables mentioned, a third measurement being necessary when the difference between the first two was >5% in the folds and 1% in the rest of the measurements. The final value corresponded to the mean when two measurements were taken, and to the median when three measurements were taken (Esparza-Ros et al. 2019).

The same anthropometrist measured all variables belonging to the same study participant. The technical error of measurement (TEM) was calculated in a subsample, with the intra-evaluator TEM being 0.02% for basic measurements, 1.21% for skinfolds, and 0.04% for girths. The inter-evaluator TEM was 0.03% for basic measurements, 1.98% for skinfolds, and 0.06% for girths.

For the measurements, an inextensible tape, Lufkin W606PM (Lufkin, Missouri), with a 0.1 cm accuracy, was used to measure girths; a skinfold caliper (Harpenden, Burgess Hill, UK), with an accuracy of 0.2 mm for skinfolds; a TANITA BC 418-MA Segmental scale (TANITA, Tokyo), with an accuracy of 100 g for body mass; and a SECA 213 stadiometer (SECA, Hamburg) with an accuracy of 0.1 cm for height and sitting height. All the instruments were calibrated and validated prior to use.

*Physical fitness measurement*. Following the protocol from previous research (Mateo-Orcajada et al. 2023a), the cardiorespiratory capacity of adolescents was measured using the 20-m shuttle run test (Léger et al. 1988). This test consists of running a distance of 20 meters following a sound signal as many times as possible before reaching exhaustion. Finally, the maximum oxygen consumption ($VO_2$ max.) was calculated using Léger's formula (Léger et al. 1988).

Upper limb strength was assessed using the handgrip strength test (Matsudo et al. 2014), by performing the maximum possible force on a Takei Tkk5401 digital handheld dynamometer (Takei Scientific Instruments, Tokyo, Japan) with the adolescents' arm fully extended, as this is the optimal position for applying the maximum force (España-Romero et al. 2010).

Explosive lower limb strength was assessed using the countermovement jump (CMJ). This test assesses the height of a maximum vertical jump with the hands placed on the hips and in which the legs are kept fully extended during the flight phase. The adolescents start in the standing position and flex their knees at 90°, followed by an extension at maximum speed to perform the jump. A force platform with a sampling frequency of 200 Hz (MuscleLab, Stathelle, Norway) was used for its execution (Barker et al. 2018).

Abdominal strength and endurance were assessed using the curl-up test. For this, the adolescents were laid in the supine position, with their knees bent at 90° and their feet fully supported on the floor. With their hands crossed on their chest, the adolescents had to perform the greatest number of trunk flexions, which were valid when the upper back was no longer in contact with the floor (Garcia-Pastor et al. 2016).

Four researchers experienced in measuring physical fitness tests were in charge of overseeing and evaluating the same test during the pre- and post-test measurements, thus avoiding inter-rater error.

**Procedure**. The protocol from previous research conducted with mobile applications in adolescents was followed in the present study (Mateo-Orcajada et al. 2023a). First, the PAQ-A questionnaire was completed; then kinanthropometric measurements were taken; the adolescents were familiarized with the correct execution of the handgrip strength test, CMJ, and curl-up test; a progressive warm-up with joint mobility was performed, followed by the handgrip strength, CMJ, and curl-up tests; and a single repetition of the 20-m shuttle run test was performed.

Two repetitions of each test were performed, with the order in which each adolescent performed the tests being randomized and choosing the best value obtained, except for the 20-m shuttle run test, which was performed by all adolescents only once at the end of the session. This is a maximal incremental test that ends with the participant's exhaustion. Therefore, to prevent the fatigue generated by this test from influencing the results of the rest of the tests, it was performed only once. For the rest of the fitness tests, two minutes of rest were left between each repetition of the same test, as well as five minutes of rest between different tests, following the recommendations of the National Strength and Conditioning Association (NSCA) (Coburn and Malek, 2014), based on the fatigue generated by the different tests, as well as the metabolic demands required to perform each test. This same criterion has been used in previous research with adolescents (Albaladejo-Saura et al. 2022; Mateo-Orcajada et al. 2023a).

**Mobile application intervention**. All participants in the experimental group were assigned to one of the mobile applications groups, all of which had similar characteristics and the aim of increasing the physical activity of the adolescents (Strava®, Pacer®, MapMyWalk®, and Pokémon Go®). A total of 260 adolescents started in the intervention group (Strava: $n = 75$; Pacer: $n = 63$; MapMyWalk: $n = 60$; Pokémon Go: $n = 62$) and 161 in the control group, ending the research a total of 240 in the intervention group (Strava: $n = 74$; Pacer: $n = 60$; MapMyWalk: $n = 47$; Pokémon Go: $n = 59$) and 160 in the control group.

Prior to the start of the intervention, the adolescents in the experimental groups received a talk explaining the use of the applications, how to create a user in the applications, and how to check the distance traveled each day. In addition, these adolescents were informed that they were going to receive an academic reward in physical education subject if they used the mobile applications after-school hours during the 10-week period.

The mobile apps were selected because they included numerous behavior change techniques, which are the most optimal for increasing physical activity (Bondaronek et al. 2018). These applications were characterized by promoting the practice of physical activity through an easy-to-use interface in which users only had to activate the recording of distance or steps when they started walking and end the recording when they finished, except in Pokémon Go in which the distance was automatically recorded. Strava®, Pacer®, and MapMyWalk® are apps that act as pedometers, so they count the steps/distance traveled with the use of these, including motivational messages and reminders to perform physical activity. However, Pokémon Go® is a video game that, since its launch, has acquired great relevance in the promotion of physical activity (Khamzina et al. 2020). The game consists of walking through urban or rural areas while Pokémon appear on the screen of the mobile phone, which can be captured by players. Depending on the area being walked through, the Pokémon that appear are different. In addition, the game includes rewards as you walk, which encourages its use.

The intervention lasted 10 weeks, in which the adolescents were instructed to use the mobile app after-school hours a minimum of three times a week. A total of 5000 steps a day, or 3.19 km, considering that one kilometer corresponds to ~1565 steps in the adolescent population aged 12–16 years (Morency et al. 2007), was the minimum distance needed to stop

**Table 1 Differences in the use of mobile apps between adolescents according to gender and academic year.**

| Variable | Group | App use | | Adj. res. use/not use app | $\chi^2$; p | Contingency coefficient/Cramer's V |
|---|---|---|---|---|---|---|
| | | Yes ($N = 240$) | No ($N = 160$) | | | |
| Gender | Male | 105 (50.0%) | 105 (50.0%) | −4.1/4.1 | 16.558; <0.001 | 0.203 |
| | Female | 135 (71.1%) | 55 (28.9%) | 4.1/−4.1 | | |
| Academic Year | 1° | 77 (53.8%) | 66 (46.2%) | −1.7/1.7 | 19.179 <0.001 | 0.214 |
| | 2° | 35 (44.3%) | 44 (55.7%) | −3.1/3.1 | | |
| | 3° | 70 (70.0%) | 30 (30.0%) | 2.2/−2.2 | | |
| | 4° | 58 (74.4%) | 20 (25.6%) | 2.7/−2.7 | | |

being considered physically inactive (Lubans et al. 2015). Therefore, an intervention was proposed in which adolescents were required to use the mobile app three times per week to walk a distance of 7000 steps, or 4.57 km, each time they used the app in the first week, which was progressively increased each week until reaching a total of 12,520 steps, or 8 km at the end of the intervention (week 10), which is the minimum recommended distance for adolescents to achieve moderate-vigorous physical activity (Adams et al. 2013). The weekly increase in the distance to be covered was indicated by the physical education teachers who collaborated in the research, who were previously informed by the responsible researchers. The intervention was promoted from the physical education school subject of the compulsory secondary schools that decided to participate. Thus, this intervention was included as an activity that was part of the school subject.

The adolescents in the experimental group who did not complete the entire distance to be covered each week were not excluded from their respective groups, since they continued to be part of the research group, and post-test measurements were taken.

The adolescents in the control group did not use any mobile application and continued to attend physical education classes and perform their usual physical activities as normal.

**Data analysis**. The normality of the data was analyzed using the Kolmogorov-Smirnov statistical test, as well as skewness, variance, and kurtosis. As all the variables had a normal distribution, parametric tests were used for their analysis. The mean and standard deviation (mean ± standard deviation) were used as descriptive statistics. The chi-square statistic ($\chi^2$) was used to find the differences in the use of mobile applications according to the gender and academic year of the adolescents. The corrected standardized residuals were used to determine significance, establishing ±1.96 as the reference value. Cramer's $V$ was used for the post-hoc comparison of the $2 \times 2$ tables, and the contingency coefficient was used in the 2×n tables, to obtain the statistical value. The maximum expected value was 0.707; $r < 0.3$ indicated a low association; $r < 0.5$ indicated a moderate association; and $r > 0.5$ indicated a high association (Cramér, 1946). A one-way ANCOVA was performed to find the differences in the pre- and post-test measurements of the study variables as a function of the use of the mobile applications, including the moderators gender and academic year. A moderator is understood as a variable that modifies the form or strength of the relationship between an independent variable and a dependent variable (MacKinnon, 2011). Subsequently, two MANOVAs were performed, allowing the first to find the differences in the study variables between the pre- and post-test measurements as a function of the use of the mobile applications and gender; while the second included the use of the mobile applications and academic year. A subsequent Bonferroni post-hoc analysis established the significant differences between the groups. Partial eta squared ($\eta^2$) was used to calculate the effect size and was defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30; large: ES ≥ 1.2; or very large: ES ≥ 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).

## Results

Table 1 shows the differences in the use of mobile apps according to gender and academic year. The results indicate that females used mobile applications to a large extent, while for males, the number of adolescents who used mobile apps was similar to those who did not use them ($p < 0.001$). With respect to the academic year, it was in the third and fourth year that a greater number of users were found, while in the first and second year, the numbers of users and non-users were similar ($p < 0.001$). The corrected standardized residuals were significant by gender (−4.1/4.1) and by academic year (−1.7/1.7 to −3.1 /3.1).

The differences between the pre-post values of the study variables after the intervention with mobile apps are shown in Table 2. Thus, the experimental group showed a significant change in all the variables after the intervention, except for sitting height ($p = 0.829$) and waist girth ($p = 0.759$). In contrast, the control group showed no changes in physical activity level ($p = 0.753$), sitting height ($p = 0.866$), the sum of three skinfolds ($p = 0.444$), waist girth ($p = 0.146$), fat mass ($p = 0.284$), CMJ ($p = 0.438$), and curl-up ($p = 0.059$). In addition, it should be noted that significant differences were found in both groups in these variables with the inclusion of the moderators gender and academic year. Thus, when considering the moderator gender, significant differences were found in BMI ($p < 0.001$), corrected calf girth ($p = 0.008$), fat mass ($p = 0.025$), handgrip right ($p = 0.002$) and left arm ($p = 0.002$), and CMJ ($p = 0.005$); while when considering the moderator academic year, the differences were significant in height ($p < 0.001$), sum of 3 skinfolds ($p = 0.046$), waist girth ($p = 0.048$), hip girth ($p < 0.001$), corrected calf girth ($p = 0.019$), and fat mass ($p = 0.025$).

Figure 2 shows the Bonferroni post-hoc analysis of the study variables that showed significant differences when considering the use of mobile apps and gender. There was a significant increase in BMI in males, regardless of the use of mobile apps ($p = 0.009$–$0.014$), but not in females, as those who used mobile apps did not show a significant increase in this variable ($p = 0.238$). As for the corrected calf girth, differences were found only in the males in both the intervention ($p = 0.011$) and control ($p = 0.008$) groups. With respect to fat mass, there was a significant decrease in the group of males who used mobile apps ($p = 0.025$). Regarding the handgrip strength test, there was a significant increase in the score obtained in the two arms in the males of the intervention ($p < 0.001$–$0.011$) and control ($p = 0.002$) groups, but this increase was only observed in females of the intervention group ($p = 0.005$–$0.011$). And with respect to the CMJ score, a significant improvement was only observed in the males of the experimental group ($p = 0.002$).

**Table 2 Pre- and post-test values of the study variables according to the use of mobile apps.**

| Descriptors (M ± SD) | | | | | | | App use × gender | | | App use × academic year | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variable** | **App use** | **Pre-test** | **Post-test** | **Mean diff.** | ***p*** | **Effect size** | ***F*** | ***p*** | **Effect size** | ***F*** | ***p*** | **Effect size** |
| Physical activity level | Yes ($n = 240$) | 2.63 ± 0.67 | 2.80 ± 0.60 | −0.170 | <0.001 | 0.052 | 8.691 | 0.053 | 0.021 | 9.812 | 0.072 | 0.024 |
| | No ($n = 160$) | 2.72 ± 0.68 | 2.70 ± 0.74 | 0.014 | 0.753 | 0.001 | | | | | | |
| Body mass (kg) | Yes ($n = 240$) | 55.47 ± 12.81 | 56.39 ± 12.64 | −0.918 | <0.001 | 0.126 | 0.123 | 0.726 | 0.001 | 0.419 | 0.181 | 0.001 |
| | No ($n = 160$) | 52.47 ± 10.65 | 53.39 ± 10.57 | −0.925 | <0.001 | 0.089 | | | | | | |
| Height (cm) | Yes ($n = 240$) | 162.91 ± 9.12 | 163.65 ± 9.03 | −0.738 | <0.001 | 0.109 | 1.809 | 0.473 | 0.005 | 0.962 | <0.001 | 0.002 |
| | No ($n = 160$) | 160.87 ± 8.75 | 161.52 ± 8.70 | −0.645 | <0.001 | 0.059 | | | | | | |
| BMI ($kg/m^2$) | Yes ($n = 240$) | 20.85 ± 3.83 | 20.98 ± 3.70 | −0.124 | 0.009 | 0.017 | 2.131 | 0.001 | 0.005 | 0.675 | 0.412 | 0.002 |
| | No ($n = 160$) | 20.19 ± 3.33 | 20.43 ± 3.22 | −0.236 | <0.001 | 0.041 | | | | | | |
| Sitting height | Yes ($n = 240$) | 84.89 ± 9.21 | 85.13 ± 9.28 | −0.234 | 0.829 | 0.001 | 0.169 | 0.681 | 0.001 | 0.006 | 0.939 | 0.001 |
| | No ($n = 160$) | 82.17 ± 14.99 | 81.95 ± 17.07 | 0.222 | 0.866 | 0.001 | | | | | | |
| Sum of three skinfolds | Yes ($n = 240$) | 52.08 ± 26.96 | 50.22 ± 24.35 | 1.855 | 0.002 | 0.025 | 2.271 | 0.133 | 0.006 | 2.052 | 0.046 | 0.005 |
| | No ($n = 160$) | 44.87 ± 23.71 | 44.32 ± 22.85 | 0.554 | 0.444 | 0.002 | | | | | | |
| Waist girth | Yes ($n = 240$) | 68.50 ± 8.73 | 68.55 ± 8.38 | −0.044 | 0.759 | 0.001 | 0.909 | 0.341 | 0.002 | 0.493 | 0.048 | 0.001 |
| | No ($n = 160$) | 67.49 ± 7.03 | 67.75 ± 7.13 | −0.259 | 0.146 | 0.005 | | | | | | |
| Hip girth | Yes ($n = 240$) | 89.41 ± 9.15 | 90.35 ± 8.68 | −0.937 | <0.001 | 0.094 | 2.743 | 0.098 | 0.007 | 1.078 | <0.001 | 0.003 |
| | No ($n = 160$) | 86.22 ± 7.69 | 87.50 ± 7.59 | −1.280 | <0.001 | 0.113 | | | | | | |
| Waist-to-hip ratio | Yes ($n = 240$) | 0.77 ± 0.05 | 0.76 ± 0.05 | 0.007 | <0.001 | 0.078 | 0.358 | 0.550 | 0.001 | 0.141 | 0.708 | 0.001 |
| | No ($n = 160$) | 0.78 ± 0.05 | 0.77 ± 0.05 | 0.009 | <0.001 | 0.068 | | | | | | |
| Corrected arm girth (cm) | Yes ($n = 240$) | 20.90 ± 2.79 | 21.31 ± 2.70 | −0.411 | <0.001 | 0.099 | 0.055 | 0.815 | 0.001 | 0.116 | 0.734 | 0.001 |
| | No ($n = 160$) | 20.73 ± 2.69 | 21.12 ± 2.62 | −0.382 | <0.001 | 0.059 | | | | | | |
| Corrected thigh girth (cm) | Yes ($n = 240$) | 39.19 ± 4.68 | 40.14 ± 4.56 | −0.944 | <0.001 | 0.096 | 3.403 | 0.066 | 0.009 | 4.401 | 0.057 | 0.011 |
| | No ($n = 160$) | 39.23 ± 5.10 | 39.68 ± 4.15 | −0.451 | 0.013 | 0.016 | | | | | | |
| Corrected calf girth (cm) | Yes ($n = 240$) | 28.95 ± 3.46 | 29.32 ± 2.85 | −0.368 | 0.003 | 0.023 | 0.278 | 0.008 | 0.001 | 0.130 | 0.019 | 0.001 |
| | No ($n = 160$) | 28.68 ± 2.69 | 29.18 ± 2.61 | −0.497 | 0.001 | 0.027 | | | | | | |
| Fat mass (%) | Yes ($n = 240$) | 22.77 ± 10.42 | 22.17 ± 9.80 | 0.606 | 0.006 | 0.019 | 1.153 | 0.025 | 0.003 | 0.729 | 0.025 | 0.002 |
| | No ($n = 160$) | 20.08 ± 9.95 | 19.79 ± 9.75 | 0.293 | 0.284 | 0.003 | | | | | | |
| Muscle mass (kg) | Yes ($n = 240$) | 18.03 ± 4.99 | 18.73 ± 5.03 | −0.698 | <0.001 | 0.145 | 2.765 | 0.097 | 0.007 | 2.629 | 0.106 | 0.007 |
| | No ($n = 160$) | 18.24 ± 4.64 | 18.71 ± 4.40 | −0.472 | <0.001 | 0.048 | | | | | | |
| $VO_2$ max. (ml/kg/min) | Yes ($n = 240$) | 38.04 ± 4.87 | 39.09 ± 5.70 | −1.050 | <0.001 | 0.073 | 3.654 | 0.057 | 0.011 | 0.549 | 0.459 | 0.002 |
| | No ($n = 160$) | 38.57 ± 5.02 | 39.26 ± 5.12 | −0.686 | 0.006 | 0.021 | | | | | | |
| Handgrip right arm (kg) | Yes ($n = 240$) | 24.49 ± 7.63 | 25.97 ± 8.27 | −1.481 | <0.001 | 0.060 | 3.071 | 0.002 | 0.008 | 0.953 | 0.329 | 0.002 |
| | No ($n = 160$) | 24.39 ± 7.24 | 25.27 ± 8.49 | −0.875 | 0.015 | 0.015 | | | | | | |
| Handgrip left arm (kg) | Yes ($n = 240$) | 23.00 ± 7.11 | 23.83 ± 7.41 | −0.830 | <0.001 | 0.031 | 0.453 | 0.002 | 0.001 | 2.932 | 0.088 | 0.007 |
| | No ($n = 160$) | 23.18 ± 6.74 | 23.87 ± 7.93 | −0.688 | 0.014 | 0.015 | | | | | | |
| CMJ (cm) | Yes ($n = 240$) | 21.99 ± 7.35 | 23.26 ± 7.98 | −1.262 | 0.015 | 0.015 | 1.670 | 0.005 | 0.004 | 0.973 | 0.324 | 0.002 |
| | No ($n = 160$) | 22.04 ± 7.55 | 22.53 ± 9.42 | −0.487 | 0.438 | 0.002 | | | | | | |
| Curl-up (number) | Yes ($n = 240$) | 20.43 ± 11.49 | 24.39 ± 10.67 | −3.953 | <0.001 | 0.075 | 3.473 | 0.063 | 0.009 | 2.299 | 0.130 | 0.006 |
| | No ($n = 160$) | 20.33 ± 11.31 | 21.94 ± 11.93 | −1.614 | 0.059 | 0.009 | | | | | | |

*BMI* body mass index, *VO2* max, maximum oxygen consumption, *CMJ* countermovement jump.

The Bonferroni post-hoc analysis of the study variables that showed significant differences as a function of mobile app use and academic year is shown in Fig. 3. It is noteworthy that height increased significantly in all academic years of the experimental ($p < 0.001$–$0.023$) and control ($p < 0.001$–$0.044$) groups, except in the fourth year of both groups ($p = 0.133$–$0.247$). In addition, the differences in the sum of 3 skinfolds and fat mass were only significant in the fourth-year students, with this variable increasing in the control group ($p = 0.046$; $p = 0.046$) and decreasing in the experimental group ($p = 0.047$; $p = 0.025$) after the intervention. Similarly, the fourth-year group that used the mobile applications showed a significant decrease in waist girth ($p = 0.048$) and was the only one that did not show a significant increase in hip girth ($p = 0.475$). Furthermore, corrected calf girth increased significantly in all intervention groups ($p = 0.019$–$0.029$), except in the fourth-year group ($p = 0.738$), while the control groups did not show significant changes ($p = 0.056$–$0.807$).

## Discussion

The first aim of the present investigation was to determine the existence of differences in the use of mobile applications promoted from the physical education school subject according to the gender and academic year of the adolescents. The results showed that females used the applications to a greater extent than males, as did third- and fourth-year students, as compared to first- and second-year ones. Previous scientific literature does not provide consistent conclusions in this regard, as the research shows that females use m-Health apps to track physical activity more frequently (Gulec and Smahel, 2022), while other studies show no differences in the use of apps for physical activity between males and females (Elavsky et al. 2017). One possible explanation for these results could be that the practice of physical activity differs between males and females, with males spending more time and practicing a greater number of sports during after-school hours (Mateo-Orcajada et al. 2021), so that females have more time available to practice physical activity through the use of mobile apps. In addition, a novelty of this study is that it analyzes gender differences in the results obtained with a step tracker intervention promoted from the educational field, forming part of the final grade of the physical education subject, so the greater importance given by females, to academic achievement during compulsory secondary education, could be another explanation for these results (Marcenaro–Gutierrez et al. 2018). These results could indicate that the promotion of interventions with mobile applications from the educational setting could be an effective way to reduce the lack of physical activity in adolescent females, which is a great novelty of the present research.

Another novel result of the present investigation refers to the differences in the use of mobile applications according to the academic year, with adolescents of higher education courses, and therefore older, using mobile applications the most. It should be noted that no previous research has analyzed differences in the use of mobile applications for the practice of physical activity according to the age or academic year of adolescents. Therefore, a possible explanation for the results obtained would be that, although adolescents obtain their own mobile phone between the ages of twelve and thirteen (Richter et al. 2022; Sun et al. 2023), their use is not as continuous and frequent as that of older adolescents who have more dependence on these devices (Nikhita et al. 2015). This could lead to more difficulties in younger adolescents in the use of mobile applications, as these devices have not yet become fully integrated into their daily lives. Therefore, while mobile apps would be a great tool for physical activity practice outside of the school environment for adolescents in the higher academic year, who also prefer to practice it with their peers (Garcia et al. 2016), family-based interventions could perhaps be an option to increase the use of mobile applications for physical activity in younger adolescents (Wunsch et al. 2020), as demonstrated in previous research conducted in elementary education (Chai et al. 2022).

In addition, differences in app use based on the age of adolescents could be due to the fact that the purposes for which these devices are used change throughout adolescence. Thus, it has been observed that older adolescents use mobile devices to search for information and stay connected through social networks to a greater extent than younger ones, the latter those who tend to use them more for playing videogames (Lauricella et al. 2014; Lenhart et al. 2019). This aspect leads to consider the possibility that there are differences in the use of applications depending on the academic year, with younger adolescents being those who would use Pokémon Go to a greater extent than other applications as it is gamified, as previous research has shown the benefits of gamification in physical activity of younger people (Corepal et al. 2018). On the contrary, as the age of the adolescents increased, they would use other apps that included sports information or information on healthy lifestyle habits, such as Strava, Pacer, or MapMyWalk, since the ease of use of gamification declines with age (Koivisto and Hamari, 2014). Since the groups of use of each application would be too small if they were divided according to academic year in the present investigation, this opens up a possible line of research in which future investigations should analyze whether the interests and motivations for mobile apps are different depending on the academic year, since it would provide very relevant information to be considered in research that promotes mobile applications at school environment. Another possible explanation could be that adolescents in higher academic years are more interested in academic degrees than younger adolescents since the psychological maturity of older adolescents is directly related to academic achievement (Morales-Vives et al. 2020), so the inclusion of an academic reward in the present research could be important for the use of the mobile apps. However, future studies should analyze the motives for the use of mobile apps in adolescents of different academic years since the scientific literature available is scarce in this regard.

The second aim of the present study was to establish the efficacy of mobile app interventions to promote physical activity in terms of the level of physical activity, kinanthropometric and derived variables, and fitness depending on gender. BMI increased significantly in males, independently of the use of mobile applications, although in females, it only increased in the group that did not use mobile applications. These results differ from those found in previous research, in which there were no significant differences in the BMI of adolescents after the use of physical activity mobile apps (Shin et al. 2019; De Freitas et al. 2021). One of the main drawbacks of BMI is that it does not express the amount of muscle mass and fat mass present in the subject, with this being a limiting aspect of its use (Micozzi and Albanes, 1988). Thus, it could be that the changes in this variable in the males of the intervention group were due to an improvement in body composition, as shown by the increase in the variables muscle mass and corrected calf girth, as well as the decrease in fat mass in the present study. This is perhaps due to the fact that the increase in physical activity performed with the step tracker mobile apps could decrease fat mass, and improve muscle mass of the lower limbs, as observed in previous intervention programs (Mateo-Orcajada et al. 2023a). However, the changes found in the muscle mass of males could also be due to hormonal changes, as there is a significant increase in the concentration of testosterone during adolescence (Clark and Rogol, 1996; Wells, 2007), while in females, although this increase also occurs, it is not as noticeable and previous evidence does not

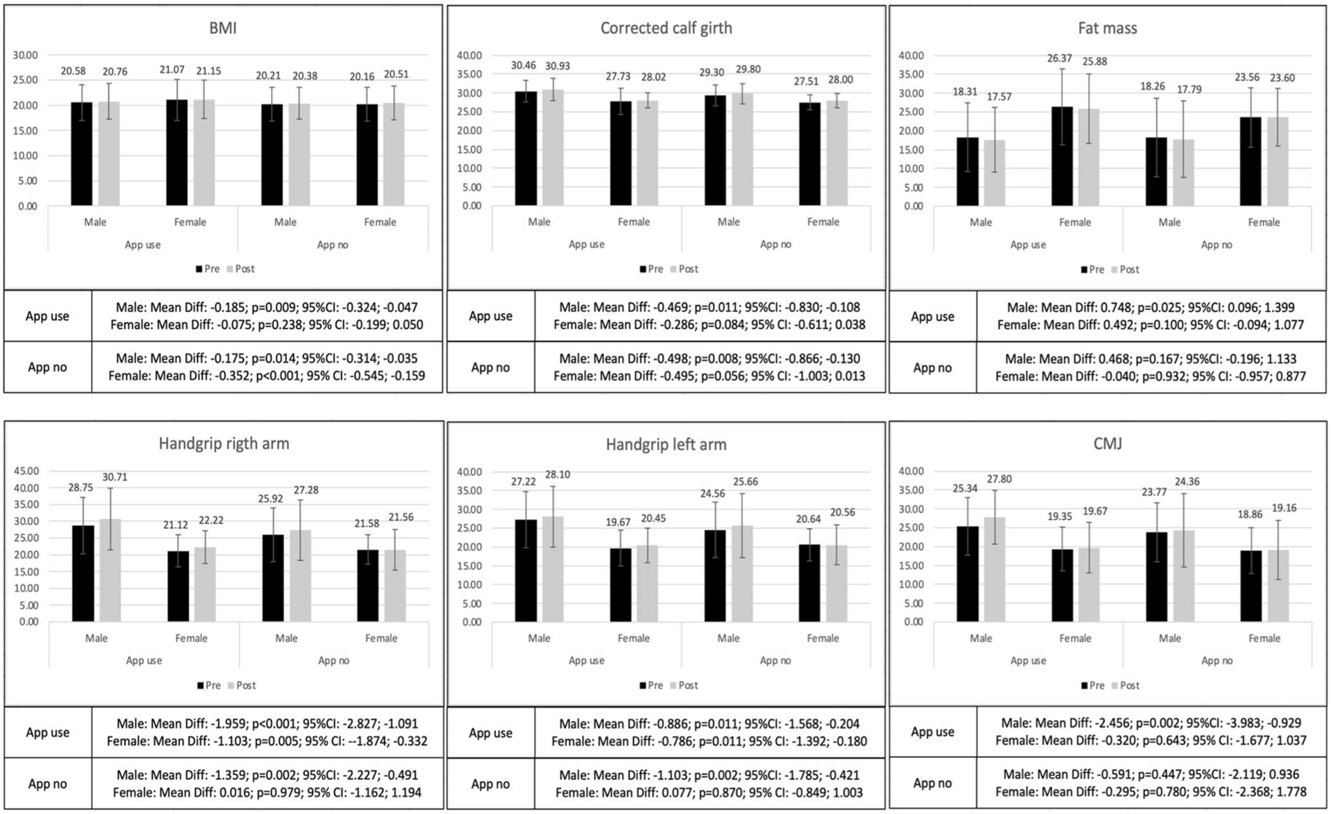


**Fig. 2 Differences in body composition and fitness of adolescent males and females according to their use of mobile apps.** The first three upper graphs show changes in BMI, corrected calf girth and fat mass in male and female adolescents according to app use. Lower part of the graph shows the differences in the fitness variables handgrip and CMJ.

show a significant increase in muscle mass due to biological maturation in females (Albaladejo-Saura et al. 2021; Rusek et al. 2021). Therefore, the decrease in BMI in females could be explained by a decrease in fat mass in the adolescents who used the app, as the control group that did not use the app increased it. This result would indicate that the use of mobile apps could favor the practice of physical activity in female adolescents, leading to a decrease in BMI and fat mass, which would be a great health indicator given the relationship of these variables with certain diseases (De Oliveira et al. 2016; Weihrauch-Blüher et al. 2019). However, future research is needed to provide more scientific evidence on the results found, to try to establish the volume and intensity of training needed through mobile applications to produce a significant decrease in fat mass in adolescent females.

Regarding physical condition, the results showed an increase in the handgrip strength score in males in both groups, but only in the intervention group of females, whereas the CMJ jump height only increased in the intervention group of males. Only one previous study is known to have analyzed differences in handgrip strength or CMJ in adolescents after the use of mobile apps to increase physical activity (Mateo-Orcajada et al. 2023a), and the results were similar to those of the present study, with differences observed in handgrip in the intervention and control groups, but in CMJ only in the intervention group. The novelty of this investigation lies in the fact that the improvements were more evident in males than in females. A possible explanation for these results would be that males develop greater muscle mass than females during puberty (Rusek et al. 2021), as observed in the differences found in the corrected girths of the present investigation, which would influence the production of force. However, two determinants of strength production in the stage between pre-adolescence and adolescence should also be considered. The first would be the neuromuscular adaptations (Gillen et al. 2019) that are strongly related to the increased physical activity experienced by males at this stage, resulting in increased strength and endurance in this population (Rudroff et al. 2013). The second would be that adolescent males have higher testosterone levels than females (Handelsman et al. 2018), with this hormone highly associated with the production of muscle strength, especially in the upper limbs (Almeida-Neto et al. 2020). In addition, other factors such as maturation could play a determinant role, as the age in which the different stages of the maturational process take place differ between males and females (Beunen and Malina, 1988; Beunen et al. 2006), so future research addressing these issues is needed.

The third aim of the present investigation was to establish the efficacy of mobile app interventions to promote physical activity in terms of the level of physical activity, kinanthropometric and derived variables, and fitness depending on the academic year. Thus, a significant increase in height was found in all intervention and control groups, except in the fourth-year students. These results are similar to those of previous research, in which older adolescents had minimal differences in their height (Chae et al. 2013), and a possible explanation would be that the age at peak height velocity (APHV), understood as the time of puberty when the fastest growth occurs (Pitlović et al. 2013), occurs between 12 and 14 years of age (Beunen and Malina, 1988; Beunen et al. 2006), so that adolescents in the fourth academic year, between 15 and 16 years old, would be outside this range. Thus, the growth of older adolescents, although still occurring, is reduced to an average of one centimeter per year (Chae et al. 2013), so it is not as remarkable as that of younger adolescents.

Regarding fat mass and the sum of three skinfolds, changes were only observed in the fourth-year group, with increased values in these variables in the control group and decreased values

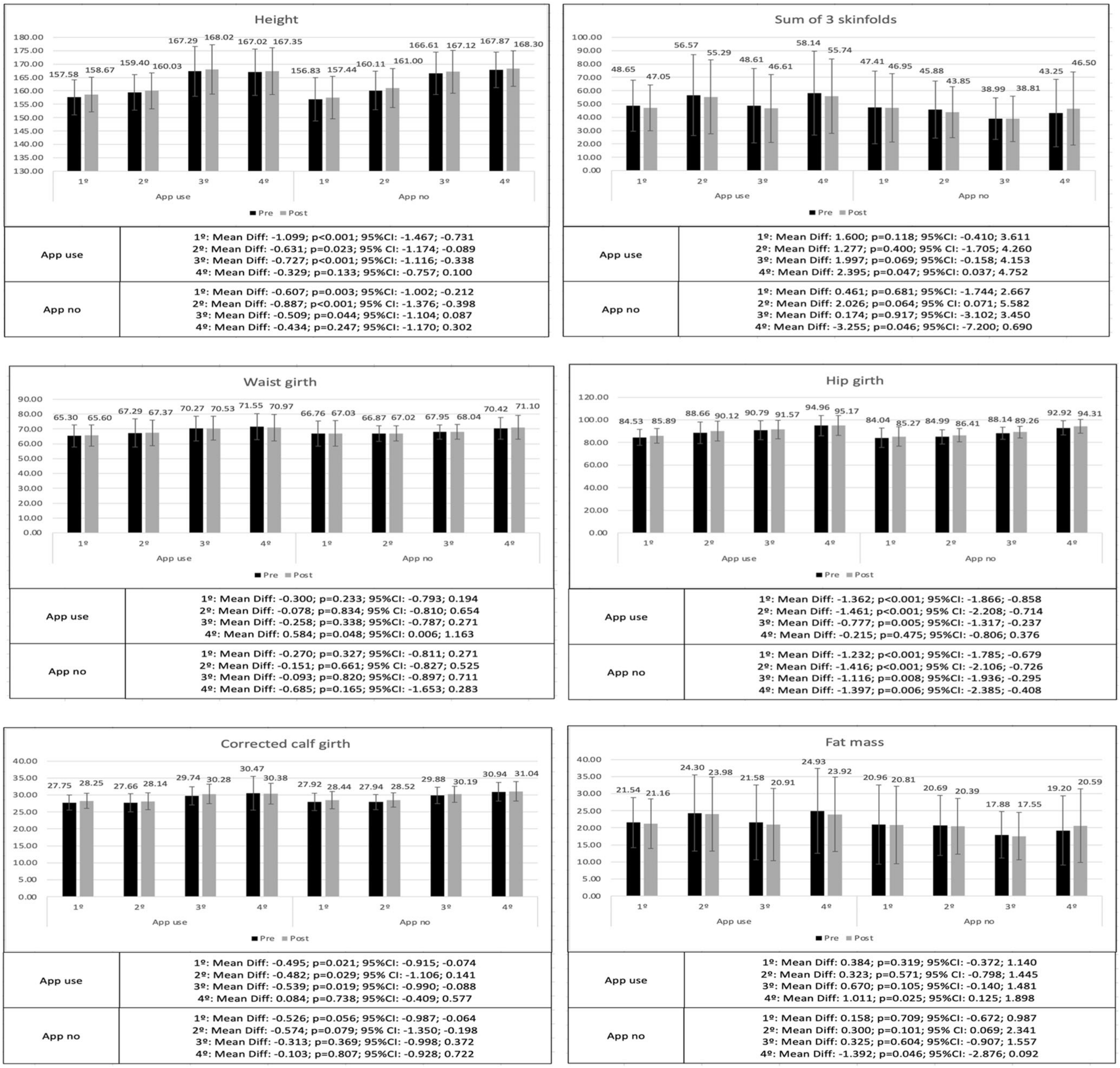


**Fig. 3 Differences in the study variables in adolescents from different academic years according to their use of mobile apps.** The figure shows the differences in anthropometric variables between adolescents of different academic year. Height showed significant differences, as well as the sum of three folds, hip and waist girth, corrected calf girth and fat mass. Fourth academic year adolescents showed the most significant differences.

in the experimental group. Similarly, the fourth-year intervention group decreased their mean waist girth, and it was the only group that did not significantly increase hip girth. A possible explanation for these results could be that during adolescence, the level of physical activity and the time spent in sedentary activities fluctuates according to age. Thus, previous research has shown that steps per day and moderate to vigorous physical activity increase until 8–9 years of age and, from that moment on, continuously decrease, reaching its minimum between 14 and 17 years of age (Schmidt et al. 2020; Steene-johannessen et al. 2020). In turn, time spent in sedentary activities increases from 250 min per day at 4–5 years of age, to 450–500 min per day between 14 and 17 years of age (Schmidt et al. 2020; Steene-johannessen et al. 2020), resulting in greater accumulations of fat tissue due to lack of physical activity (Mateo-Orcajada et al. 2022). This could be due to the fact that older adolescents give more importance to other aspects, such as studying or other sedentary activities (Jodkowska et al. 2015), in addition to the fact that older adolescents still practice sports tend to do so in organized activities, while younger ones do so in informal activities that increase their chances of physical practice (Mota and Esculcas, 2002). For these reasons, the mandatory use of mobile applications for the practice of physical activity promoted in a compulsory way from the physical education school subject could acquire great relevance for adolescents, mainly for adolescents in higher academic years who have less free time and sacrifice the practice of physical activity for other activities. These results are encouraging, but future research is needed to truly show whether these interventions are effective in reducing the accumulation of fat mass and preventing the onset of future diseases in the adolescent population.

The results also showed that corrected calf girth significantly increased in all intervention groups, except for the fourth-year group. These results are similar to those of previous physical activity programs in which adolescents in the experimental group showed a greater development of lower limb muscle mass (Contreras-Jordán et al. 2017). However, the absence of differences in the fourth-year group could be due to the fact that adaptations during adolescence are due to the practice of physical activity (Mateo-Orcajada et al. 2022) and hormonal changes, mainly due to the increase in testosterone (Clark and Rogol, 1996; Wells, 2007). These hormonal changes occur most predominantly near the APHV (Cole et al. 2015), with fourth-year adolescents having completely surpassed this age.

The absence of previous scientific literature on the use of mobile applications promoted from the subject of physical education in relation to the academic year and the gender of adolescents did not allow us to establish specific hypotheses for the present research. The results obtained in this study show that females and adolescents in higher academic year used the applications to a greater extent than males and younger adolescents, respectively. In addition, it was observed that in these groups of adolescents there was a decrease in BMI, fat mass, sum of 3 skinfold, and waist girth, as well as an increase in physical activity practiced after the period of use of the applications. Improvements in fitness were more pronounced in males than in females who used mobile apps. Therefore, gender and academic year seem to be moderators to be considered in research conducted with mobile applications in schoolchildren and adolescents.

The results obtained in the present investigation have contributed new knowledge to this line of research, showing that the use of mobile step tracker apps promoted from the school subject of physical education has a beneficial effect on the practice of physical activity of females, and also in adolescents in the last years of compulsory secondary education. These results are important because allow to increase the physical activity practice of female adolescents, whose physical activity level is lower than that of male adolescents (Mateo-Orcajada et al. 2021), and in adolescents in higher academic year, whose physical activity decreases as adolescence progresses (Dumith et al. 2011). However, future research should analyze whether the academic reward proposed from the physical education subject motivates female and adolescents in higher academic year to use mobile apps (Marcenaro–Gutierrez et al. 2018; Morales-Vives et al. 2020), or whether there are other motives that influence the use of these devices. Another important finding of the present research is that females and adolescents in higher academic year decrease BMI, fat mass, sum of 3 skinfold, and waist girth using mobile apps, which could be due to the fact that these groups use the app to a greater extent than males and younger adolescents. Future studies should analyze if there are differences in participation in this type of intervention in males and females, and in adolescents in different academic years, depending on the different ones used. This is because males and younger adolescents use mobile phones mainly to play videogames, whereas females and older adolescents use it to stay connected or search for information (Lauricella et al. 2014; Lenhart et al. 2019), so it is likely that they use gamified and non-gamified apps may influence participation in the study. Finally, physical fitness changes were more pronounced in males than in females, which could be explained by the fact that maturation plays a determinant role during puberty, as the age at which the different stages of the maturational process take place differ between males and females (Beunen and Malina, 1988; Beunen et al. 2006). Future research in this regard should include maturation as a key variable, as it could be a moderator of the changes produced in fitness or body composition in adolescents with the use of mobile apps. In addition, other training variables, such as volume or intensity, should be considered to assess whether they influence the changes achieved in the study variables.

The present study is not free of limitations. The effect of maturation on changes in kinanthropometric and fitness variables in the adolescent population should be considered in future research. In addition, the measurement of the level of physical activity was performed using a questionnaire, which, although previously validated, reports a subjective measurement of the physical activity performed, so it would be appropriate to use objective measures such as accelerometers. It would also be interesting for future research to consider variables specific to the mobile apps training plan, such as volume or intensity, as the frequency of practice could be insufficient to explain the changes observed. In addition, it would be interesting to know, according to gender and academic year, the reasons and motives for carrying out the intervention, both intrinsic and extrinsic motives, as well as the barriers or motives for not using the apps to a greater extent. As the classes that belonged to the control group were aware of the existence of the intervention with mobile applications, this could have affected the data by some bias. Another limitation to consider is the lack of control over participants' dietary habits since kinanthropometric and body composition variables may be affected by this (Costa et al. 2018; Cunha et al. 2018), and future research should, therefore follow up on this. This limits our ability to draw conclusions with regard to the significant and nonsignificant results.

## Conclusions

Based on the results obtained, it can be concluded that the main novelty of the present study is the existence of differences in the use of mobile physical activity apps according to gender and academic year, as well as in the effects produced on the kinanthropometric variables and the fitness of this population. Thus, in males in the intervention group, a decrease in fat mass and an increase in CMJ height were observed, whereas BMI did not significantly increase in females in the intervention group. As for the academic year, adolescents in the fourth year did not increase their height or correct calf girth, while the rest of the intervention groups did. However, the fourth-grade experimental group showed a decrease in the sum of three skinfolds, fat mass, and waist girth. Thus, although females and older adolescents used mobile apps to a greater extent, changes were observed in the kinanthropometric and physical fitness variables in all the groups. This shows the need for future research to analyze other mobile app intervention program variables, such as training intensity or training volume, as they could be the origin of the changes found.

## Data availability

The data sets generated and/or analyzed during the present study include the personal information of the participants, so they are not in any repository, but an anonymized version is available to the corresponding author upon reasonable request.

Received: 3 August 2023; Accepted: 7 December 2023;
Published online: 22 December 2023

## References

Adams MA, Johnson WD, Tudor-Locke C (2013) Steps/day translation of the moderate-to-vigorous physical activity guideline for children and adolescents. Int J Behav Nutr Phys Act 10:1–11. https://doi.org/10.1186/1479-5868-10-49

Albaladejo-Saura M, Vaquero-Cristóbal R, García-Roca JA, Esparza-Ros F (2022) Influence of maturity status on kinanthropometric and physical fitness variables in adolescent female volleyball players. Appl Sci 12:1–19. https://doi.org/10.3390/app12094400

Albaladejo-Saura M, Vaquero-Cristóbal R, González-Gálvez N, Esparza-Ros F (2021) Relationship between biological maturation, physical fitness, and kinanthropometric variables of young athletes: a systematic review and meta-analysis. Int J Environ Res Public Health 18:1–20. https://doi.org/10.3390/ijerph18010328

Almeida-Neto PF, de Matos DG, Pinto VCM et al. (2020) Can the neuromuscular performance of young athletes be influenced by hormone levels and different stages of puberty? Int J Environ Res Public Health 17:1–16. https://doi.org/10.3390/ijerph17165637

Bann D, Scholes S, Fluharty M, Shure N (2019) Adolescents' physical activity: cross-national comparisons of levels, distributions and disparities across 52 countries. Int J Behav Nutr Phys Act 16: https://doi.org/10.1186/s12966-019-0897-z

Barker LA, Harry JR, Mercer JA (2018) Relationships between countermovement jump groud reaction forces and jump height, reactive strength index, and jump time. J Strength Cond Res 32:248–254

Bergh C, Udumyan R, Fall K et al. (2015) Stress resilience and physical fitness in adolescence and risk of coronary heart disease in middle age. Heart 101:623–629. https://doi.org/10.1136/heartjnl-2014-306703

Beunen G, Malina R (1988) Growth and physical performance relative to the timing of the adolescent spurt. Exerc Sport Sci Rev 16:503–540

Beunen G, Rogol AD, Malina RM (2006) Indicators of biological maturation and secular changes in biological maturation. Food Nutr Bull 27:244–256. https://doi.org/10.1177/15648265060274s508

Böhm B, Karwiese SD, 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 Uhealth 7: https://doi.org/10.2196/mhealth.8298

Bondaronek P, Alkhaldi G, Slee A, et al (2018) Quality of publicly available physical activity apps: review and content analysis. JMIR Mhealth Uhealth 6: https://doi.org/10.2196/mhealth.9069

Bronikowska M, Krzysztoszek J, Łopatka M et al. (2021) Comparison of physical activity levels in youths before and during a pandemic lockdown. Int J Environ Res Public Health 18:5139. https://doi.org/10.3390/ijerph18105139

Burns RD, Fu Y, Podlog LW (2017) School-based physical activity interventions and physical activity enjoyment: a meta-analysis. Prev Med (Balt) 103:84–90. https://doi.org/10.1016/j.ypmed.2017.08.011

Chae HW, Suh I, Kwon AR et al. (2013) Longitudinal standards for height and height velocity in Korean children and adolescents: the Kangwha cohort study [Korean Med Sci (2013) 28(10):1512-7]. J Korean Med Sci 28:1512–1517. https://doi.org/10.3346/jkms.2013.28.12.1842

Chai LK, Farletti R, Fathi L, Littlewood R (2022) A rapid review of the impact of family-based digital interventions for obesity prevention and treatment on obesity-related outcomes in primary school-aged children. Nutrients 14:1–19

Christie J, O'Halloran P, Stevenson M (2009) Planning a cluster randomized controlled trial. Nurs Res 58:128–134. https://doi.org/10.1097/NNR.0b013e3181900cb5

Clark PA, Rogol AD (1996) Growth hormones and sex steroid interactions at puberty. Endocrinol Metab Clin North Am 25:665–681. https://doi.org/10.1016/S0889-8529(05)70346-7

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

Cole TJ, Ahmed ML, Preece MA et al. (2015) The relationship between insulin-like growth factor 1, sex steroids and timing of the pubertal growth spurt. Clin Endocrinol (Oxf) 82:862–869. https://doi.org/10.1111/cen.12682

Contreras-Jordán OR, Gil-Madrona P, Tortosa-Martínez M, Pastor-Vicedo JC (2017) Effects of a physical activity programme on body perception and composition in overweight adolescents. Australas Med J 10:211–219. https://doi.org/10.21767/AMJ.2016.2857

Corepal R, Best P, O'Neill R et al. (2018) Exploring the use of a gamified intervention for encouraging physical activity in adolescents: a qualitative longitudinal study in Northern Ireland. BMJ Open 8:e019663. https://doi.org/10.1136/bmjopen-2017-019663

Costa CS, Del-Ponte B, Assunção MCF, Santos IS (2018) Consumption of ultra-processed foods and body fat during childhood and adolescence: a systematic review. Public Health Nutr 21:148–159. https://doi.org/10.1017/S1368980017001331

Cramér H (1946). Mathematical methods of statistics. Princeton University Press, http://www.jstor.org/stable/j.ctt1bpm9r4

Cunha C, de M, Costa PRF, de Oliveira LPM et al. (2018) Dietary patterns and cardiometabolic risk factors among adolescents: systematic review and meta-analysis. Br J Nutr 119:859–879. https://doi.org/10.1017/S0007114518000533

Dahlgren A, Sjöblom L, Eke H et al. (2021) Screen time and physical activity in children and adolescents aged 10–15 years. PLoS One 16:1–14. https://doi.org/10.1371/journal.pone.0254255

De Freitas F, De Cassia Da Silva C, Mendes R et al. (2021) The effect of the use of a physical-activity mobile application on body composition and sleep quality of overweight children. Rev Assoc Med Bras 67:373–377. https://doi.org/10.1590/1806-9282.20200763

De Oliveira PM, Da Silva FA, Oliveira RMS et al. (2016) Association between fat mass index and fat-free mass index values and cardiovascular risk in adolescents. Rev Paul de Pediatr 34:30–37. https://doi.org/10.1016/j.rppede.2015.06.020

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. J Med Internet Res 17:1–13. https://doi.org/10.2196/jmir.4568

Dumith SC, Gigante DP, Domingues MR, Kohl HW (2011) Physical activity change during adolescence: a systematic review and a pooled analysis. Int J Epidemiol 40:685–698. https://doi.org/10.1093/ije/dyq272

Elavsky S, Smahel D, Machackova H (2017) Who are mobile app users from healthy lifestyle websites? Analysis of patterns of app use and user characteristics. Transl Behav Med 7:891–901. https://doi.org/10.1007/s13142-017-0525-x

España-Romero V, Ortega FB, Vicente-Rodriguez G et al. (2010) Elbow position affects handgrip strength in adolescents: validity and reliability of Jamar, Dynex, and TKK dynamometers. J Strength Cond Res 24:272–277

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

Farooq A, Martin A, Janssen X et al. (2020) Longitudinal changes in moderate-to-vigorous-intensity physical activity in children and adolescents: a systematic review and meta-analysis. Obes Rev 21:1–15. https://doi.org/10.1111/obr.12953

Garcia JM, Sirard JR, Deutsch NL, Weltman A (2016) The influence of friends and psychosocial factors on physical activity and screen time behavior in adolescents: a mixed-methods analysis. J Behav Med 39:610–623. https://doi.org/10.1007/s10865-016-9738-6

Garcia-Pastor T, Salinero JJ, Sanz-Frias D et al. (2016) Body fat percentage is more associated with low physical fitness than with sedentarism and diet in male and female adolescents. Physiol Behav 165:166–172. https://doi.org/10.1016/j.physbeh.2016.07.016

Gil-Espinosa FJ, 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). Cult, Cienc y Deporte 15:465–473. https://doi.org/10.12800/ccd.v15i46.1597

Gillen ZM, Shoemaker ME, McKay BD et al. (2019) Muscle strength, size, and neuromuscular function before and during adolescence. Eur J Appl Physiol 119:1619–1632. https://doi.org/10.1007/s00421-019-04151-4

Going SB, Lohman TG, Cussler EC et al. (2011) Percent body fat and chronic disease risk factors in U.S. children and youth. Am J Prev Med 41:S77–S86. https://doi.org/10.1016/j.amepre.2011.07.006

Gulec H, Smahel D (2022) Individual and parental factors of adolescents' mHealth app use: nationally representative cross-sectional study. JMIR Mhealth Uhealth 10:1–13. https://doi.org/10.2196/40340

Handelsman DJ, Hirschberg AL, Bermon S (2018) Circulating testosterone as the hormonal basis of sex differences in athletic performance. Endocr Rev 39:803–829. https://doi.org/10.1210/er.2018-00020

Hardman C, Horne P, Lowe F (2011) Effects of rewards, peer-modelling and pedometer targets on children's physical activity: a school-based intervention study. Psychol Health 26:3–21. https://doi.org/10.23751/pn.v22i1.8117

Hartwig TB, Sanders T, Vasconcellos D et al. (2021) School-based interventions modestly increase physical activity and cardiorespiratory fitness but are least effective for youth who need them most: an individual participant pooled analysis of 20 controlled trials. Br J Sports Med 55:721–729. https://doi.org/10.1136/bjsports-2020-102740

Haug E, Mæland S, Lehmann S, et al (2022) Increased gaming during COVID-19 predicts physical inactivity among youth in norway—a two-wave longitudinal cohort study. Front Public Health 10: https://doi.org/10.3389/fpubh.2022.812932

Hopkins WG, Marshall SW, Batterham AM, Hanin J (2009) Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc 41:3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Ilesanmi O, Afolabi A, Kwaghe A (2021) A scope review on the global impact of COVID-19 lockdown on adolescents' health. Afr Health Sci 21:1518–1526. https://doi.org/10.4314/ahs.v21i4.4

Jodkowska M, Mazur J, Oblacińska A (2015) Perceived barriers to physical activity among polish adolescents. Epidemiol Rev 69:73–78

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 8:1–13

Kasović M, Oreški A, Vespalec T et al. (2022) Associations between fat mass and fat free mass with physical fitness in adolescent girls: a 3-year longitudinal study. Biol (Basel) 11:1–8. https://doi.org/10.3390/biology11050783

Khamzina M, Parab KV, An R et al. (2020) Impact of Pokémon go on physical activity: a systematic review and meta-analysis. Am J Prev Med 58:270–282. https://doi.org/10.1016/j.amepre.2019.09.005

Kim NH, Lee JM, Yoo E (2022) How the COVID-19 pandemic has changed adolescent health: physical activity, sleep, obesity, and mental health. Int J Environ Res Public Health 19:1–12. https://doi.org/10.3390/ijerph19159224
Koivisto J, Hamari J (2014) Demographic differences in perceived benefits from gamification. Comput Hum Behav 35:179–188. https://doi.org/10.1016/j.chb.2014.03.007
Kowalski KC, Crocker PRE, Columbia B, Donen RM (2004) The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. University of Saskatchewan, Canada
Lauricella AR, Cingel DP, Blackwell C et al. (2014) The mobile generation: youth and adolescent ownership and use of new media. Commun Res Rep. 31:357–364. https://doi.org/10.1080/08824096.2014.963221
Lee AM, Chavez S, Bian J et al. (2019) Efficacy and effectiveness of mobile health technologies for facilitating physical activity in adolescents: scoping review. JMIR Mhealth Uhealth 7:1–14. https://doi.org/10.2196/11847
Léger LA, Mercier D, Gadoury C, Lambert J (1988) The multistage 20 metre shuttle run test for aerobic fitness. J Sports Sci 6:93–101. https://doi.org/10.1080/02640418808729800
Lemes V, Gaya AR, Sadarangani KP et al. (2021) Physical fitness plays a crucial mediator role in relationships among personal, social, and lifestyle factors with adolescents' cognitive performance in a structural equation model. the cogni-action project. Front Pediatr 9:1–12. https://doi.org/10.3389/fped.2021.656916
Lenhart A, Purcell K, Smith A, Zickuhr K (2019) Social media & mobile internet use among teens and young adults. Pew Internet American Life Project
Leonhardt M, Overå S (2021) Are there differences in video gaming and use of social media among boys and girls?—a mixed methods approach. Int J Environ Res Public Health 18:1–13. https://doi.org/10.3390/ijerph18116085
López-Bueno R, Calatayud J, Andersen LL et al. (2021) Correction to: cardiorespiratory fitness in adolescents before and after the COVID-19 confinement: a prospective cohort study. Eur J Pediatr 180:2295. https://doi.org/10.1007/s00431-021-04107-x
López-Bueno R, López-Sánchez GF, Casajús JA, et al. (2020) Health-related behaviors among school-aged children and adolescents during the Spanish Covid-19 confinement. Front Pediatr 8: https://doi.org/10.3389/fped.2020.00573
Lubans DR, Plotnikoff RC, Miller A et al. (2015) Using pedometers for measuring and increasing physical activity in children and adolescents: the next step. Am J Lifestyle Med 9:418–427. https://doi.org/10.1177/1559827614537774
MacKinnon DP (2011) Integrating mediators and moderators in research design. Res Soc Work Pract 21:675–681. https://doi.org/10.1177/1049731511414148
Marcenaro–Gutierrez O, Lopez–Agudo LA, Ropero-García MA (2018) Gender differences in adolescents' academic achievement. Young 26:250–270. https://doi.org/10.1177/1103308817715163
Martínez-Gómez D, Martínez-de-Haro V, Pozo T et al. (2009) Fiabilidad y validez del cuestionario de actividad física PAQ-A en adolescentes españoles. Rev Esp Salud Publica 83:427–439
Mateo-Orcajada A, Abenza-Cano L, Albaladejo-Saura M, Vaquero-Cristóbal R (2023a) Mandatory after-school use of step tracker apps improves physical activity, body composition and fitness of adolescents. Educ Inf Technol (Dordr). In press:1–32. https://doi.org/10.1007/s10639-023-11584-0
Mateo-Orcajada A, Abenza-Cano L, Vaquero-Cristóbal R et al. (2021) Influence of gender stereotypes, type of sport watched and close environment on adolescent sport practice according to gender. Sustainability 13:1–14. https://doi.org/10.3390/su132111863
Mateo-Orcajada A, González-Gálvez N, Abenza-Cano L, Vaquero-Cristóbal R (2022) Differences in physical fitness and body composition between active and sedentary adolescents: a systematic review and meta-analysis. J Youth Adolesc 51:177–192. https://doi.org/10.1007/s10964-021-01552-7
Mateo-Orcajada A, Vaquero-Cristóbal R, Abenza-Cano L (2023b) Mobile application interventions to increase physical activity and their effect on kinanthropometrics, body composition, and fitness variables in adolescent aged 12 to 16 years old: an umbrella review. Child Care Health Dev. In press
Matsudo VKR, Matsudo SM, de Rezende LFM, Raso V (2014) Handgrip strength as a predictor of physical fitness in children and adolescents. Rev Brasileira de Cineantropometria e Desempenho Hum 17:1–10. https://doi.org/10.5007/1980-0037.2015v17n1p1
Melinder C, Hiyoshi A, Hussein O et al. (2015) Physical fitness in adolescence and subsequent inflammatory bowel disease risk. Clin Transl Gastroenterol 6:e121–8. https://doi.org/10.1038/ctg.2015.49
Micozzi MS, Albanes D (1988) Three limitations of the body mass index. Am J Clin Nutr 48:691–692. https://doi.org/10.1093/ajcn/48.3.691
Morales-Vives F, Camps-Ribas E, Dueñas-Rada JM (2020) Predicting academic achievement in adolescents: the role of maturity, intelligence and personality. Psicothema 32:84–91
Morency C, Demers M, Lapierre L (2007) How many steps do you have in reserve? Transp Res Rec 1:1–6. https://doi.org/10.3141/2002-01
Mota J, Esculcas C (2002) Leisure-time physical activity behavior: structured and unstructured choices according to sex, age, and level of physical activity. Int J Behav Med 2(9):111–121
Nagata JM, Singh G, Sajjad OM et al. (2022) Social epidemiology of early adolescent problematic screen use in the United States. Pediatr Res 92:1443–1449. https://doi.org/10.1038/s41390-022-02176-8
Nikhita CS, Jadhav PR, Ajinkya S (2015) Prevalence of mobile phone dependence in secondary school adolescents. J Clin Diagn Res 9:VC06–VC09. https://doi.org/10.7860/JCDR/2015/14396.6803
Nobari H, Fashi M, Eskandari A et al. (2021) Effect of COVID-19 on health-related quality of life in adolescents and children: a systematic review. Int J Environ Res Public Health 18:4563. https://doi.org/10.3390/ijerph18094563
Pechtl S, Kim L, Jacobsen K (2022) Physical inactivity and sedentariness: languorous behavior among adolescents in 80 countries. J Adolesc Health 70:950–960
Pitlović V, Sarić G, Pitlović H et al. (2013) A correlation of peak height velocity and olecranon apophysis ossification assessed by ultrasound. Coll Antropol 37:1285–1289
Poortmans JR, Boisseau N, Moraine JJ et al. (2005) Estimation of total-body skeletal muscle mass in children and adolescents. Med Sci Sports Exerc 37:316–322. https://doi.org/10.1249/01.MSS.0000152804.93039.CE
Richter A, Adkins V, Selkie E (2022) Youth perspectives on the recommended age of mobile phone adoption: survey study. JMIR Pediatr Parent 5:1–10. https://doi.org/10.2196/40704
Rúa-Alonso M, Rial-Vázquez J, Nine I et al. (2022) Comparison of physical fitness profiles obtained before and during covid-19 pandemic in two independent large samples of children and adolescents: DAFIS project. Int J Environ Res Public Health 19:1–15. https://doi.org/10.3390/ijerph19073963
Rudroff T, Kelsey MM, Melanson EL et al. (2013) Associations between neuromuscular function and levels of physical activity differ for boys and girls during puberty. J Pediatrics 163:349–354. https://doi.org/10.1016/j.jpeds.2013.01.014
Rusek W, Baran J, Leszczak J et al. (2021) Changes in children's body composition and posture during puberty growth. Children 8:1–12
Schmidt SCE, Anedda B, Burchartz A et al. (2020) Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. Sci Rep. 10:1–12. https://doi.org/10.1038/s41598-020-78438-4
Schulz KF, Altman DG, Moher D (2011) CONSORT 2010 statement: updated guidelines for reporting parallel group randomised trials. Int J Surg 9:672–677. https://doi.org/10.1016/j.ijsu.2011.09.004
Shin Y, Kim SK, Lee M (2019) Mobile phone interventions to improve adolescents' physical health: a systematic review and meta-analysis. Public Health Nurs 36:787–799. https://doi.org/10.1111/phn.12655
Slaughter MH, Lohman TG, Boileau R et al. (1988) Skinfold equations for estimation of body fatness in children and youth. Hum Biol 60:709–723
Steene-johannessen J, Hansen BH, Dalene KE et al. (2020) Variations in accelerometry measured physical activity and sedentary time across Europe – harmonized analyses of 47, 497 children and adolescents. Int J Behav Nutr Phys Act 17(1):14
Sun X, Haydel KF, Matheson D et al. (2023) Are mobile phone ownership and age of acquisition associated with child adjustment? A 5-year prospective study among low-income Latinx children. Child Dev 94:303–314. https://doi.org/10.1111/cdev.13851
Tapia-Serrano MA, Sánchez-Oliva D, Sevil-Serrano J et al. (2022) 24-h movement behaviours in Spanish youth before and after 1-year into the covid-19 pandemic and its relationship to academic performance. Sci Rep. 12:1–10. https://doi.org/10.1038/s41598-022-21096-5
van de Kop JH, van Kernebeek WG, Otten RHJ et al. (2019) School-based physical activity interventions in prevocational adolescents: a systematic review and meta-analyses. J Adolesc Health 65:185–194. https://doi.org/10.1016/j.jadohealth.2019.02.022
Weihrauch-Blüher S, Schwarz P, Klusmann JH (2019) Childhood obesity: increased risk for cardiometabolic disease and cancer in adulthood. Metabolism 92:147–152. https://doi.org/10.1016/j.metabol.2018.12.001
Wells JCK (2007) Sexual dimorphism of body composition. Best Pr Res Clin Endocrinol Metab 21:415–430. https://doi.org/10.1016/j.beem.2007.04.007
Wunsch K, Eckert T, Fiedler J et al. (2020) Effects of a collective family-based mobile health intervention called "SMARTFAMILY" on promoting physical activity and healthy eating: protocol for a randomized controlled trial. JMIR Res Protoc 9:1–16. https://doi.org/10.2196/20534
Yerrakalva D, Yerrakalva D, Hajna S, Griffin S (2019) Effects of mobile health app interventions on sedentary time, physical activity, and fitness in older adults: systematic review and meta-analysis. J Med Internet Res 21:e14343. https://doi.org/10.2196/14343

## Acknowledgements

The authors would like to thank the schools, management teams, teachers, students, and research assistants who made it possible to carry out the measurements for this project.

This research has been financed by grants for the Ministry of Science and Innovation of the Spanish Government, in the program knowledge generation (Title: "Promotion of Daily Physical Activity recommended for the Health of Adolescents through Mobile Apps, Wearables and a Gamified TAC"/Call: 2022/Reference code: PID2022-140245OA-I00). This work is part of the doctoral thesis of Adrián Mateo-Orcajada. Mateo-Orcajada, Adrián's participation in this research is funded by Séneca Foundation–21409/FPI/20. Fundación Séneca. Región de Murcia (Spain).

## Author contributions
Conceptualization, RV-C and LA-C; data curation, AM-O and RV-C; formal analysis, AM-O and RV-C; funding acquisition, AM-O, RV-C, and LA-C; investigation, AM-O, RV-C, and LA-C; methodology, AM-O; project administration, RV-C; supervision, L A-C; writing—original draft, AM-O and RV-C; writing—review and editing, A M-O, R V-C, and LA-C All authors have read and agreed to the published version of the manuscript.

## Competing interests
The authors have no competing interests.

## Ethical approval
Prior to the start of the study, the ethics committee of the Catholic University of Murcia approved the study design (code: CE022102), and the recommendations from the Declaration of Helsinki were followed throughout the study.

## Informed consent
Participation was voluntary for all the adolescents, who provided informed consent signed by them and their parents prior to the start of the study.

## Additional information
**Correspondence** and requests for materials should be addressed to Raquel Vaquero-Cristóbal.



Adrián Mateo-Orcajada[1], Raquel Vaquero-Cristóbal[2]✉ & Lucía Abenza-Cano[1]

[1]Facultad de Deporte, UCAM Universidad Católica de Murcia, Murcia, Spain. [2]Department of Physical Activity and Sport, Faculty of Sport Sciences, University of Murcia, Murcia, Spain. ✉email: raquel.vaquero@um.es