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Importance of perceived quality and usability of step tracker mobile apps for their use by adolescents

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ABSTRACT

The aims of the present research were to understand the reasons why adolescents stop using mobile applications and to discover the objective and subjective evaluation of mobile applications for physical activity by adolescents. A 10-week quasi-experimental design involving four experimental groups of adolescents who used mobile apps. A total of 240 adolescents aged 12–16 years participated in the research. The level of physical activity and the assessment of the apps used were recorded. The results showed an increase in physical activity after the intervention. The main reasons for not using the apps were that adolescents found the interface complex, or the apps did not work on their mobiles. Pokémon Go showed a greater entertainment and customization than the rest of the apps. It can be concluded that the abandonment of mobile app interventions is due to the fact that they are not designed for use in this population.

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Adolescents; assessment; mobile application; physical activity

Introduction

The use of technological devices to promote the practice of physical activity has gained special relevance in the last decade (Lee et al., 2019), with an increasing number of interventions using them to control or monitor progress (Hao et al., 2021; Vicianá et al., 2022). The devices used are diverse, but mobile phones and their applications stand out as providing the opportunity for tailored interventions to increase physical activity (Gal et al., 2018).

The use of mobile phones has acquired special relevance in the adolescent population, as this is the age at which they start to become dependent on them (Nikhita, 2015), and their inappropriate use could have a negative impact on the physical activity practiced (Xiao et al., 2022), as they tend to increase sedentary and screen time (Xiang et al., 2020). However, not everything they generate is negative, as recent studies show that the use of technological devices as a central axis of interventions, could be useful to increase physical activity, with notable benefits in body composition (Mateo-Orcajada et al., 2023), improved fitness (Yerrakalva et al., 2019), and the acquisition of healthy habits (Ringeval et al., 2020) observed with the use of mobile applications.

While the results of these studies are encouraging, the effectiveness of these interventions differs depending on the device used by adolescents (Creaser et al., 2021; Wang et al., 2024; Wang et al., 2022). Specifically, interventions with mobile applications have some strengths that facilitate monitoring, such as the inclusion of continuous notifications. However, mobile apps are not as effective as other technological devices that provide immediate feedback on achievement,

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such as wearables, might be (Creaser et al., 2021; Ridgers et al., 2016), making apps fewer effective devices for promoting improvements in physical activity (Flores Mateo et al., 2015).

The relevance of these findings comes from the fact that one of the main difficulties encountered in the use of mobile apps to promote physical activity in the adolescent population is the loss of adherence to the intervention (He et al., 2021). After the initial effect achieved by the novelty of the intervention, the use of the devices decreases over time (Seah & Koh, 2021), and the number of adolescents who complete the intervention is reduced (Egilsson et al., 2021). Recent research has attempted to solve this problem in two ways: a) by using mobile applications within the physical education subject during school hours (Gil-Espinosa et al., 2022; Zhu & Dragon, 2016); and b) by promoting the out of school use of mobile applications within the physical education subject, with a reward in the final grade (Mateo-Orcajada et al., 2023). Both methods force adolescents to use the applications, which increases the effectiveness of the intervention (Mateo-Orcajada, 2024). However, the use of these devices during school hours seems to be less effective, because the design and the interface of the apps are suited for their use during physical education classes (Alonso-Fernández et al., 2022), which makes it very difficult to integrate the apps into the curriculum.

Regarding the promotion of the extracurricular use of apps from the physical education class, previous research has shown their efficacy, with adolescents who covered the greatest distance obtaining the greatest benefits (Mateo-Orcajada et al., 2024). However, despite their efficacy, loss of adherence remains the main problem with these interventions (Egilsson et al., 2021; He et al., 2021), but the reasons for this are unknown. Knowing them is crucial for increasing the effectiveness of these interventions; the benefits exist, but the use of the applications needs to be continued over time, for at least three months (Romeo et al., 2019). No previous research has analysed the opinion of adolescents on the physical activity mobile applications currently available on the market, which is essential to begin to understand the reasons why interventions are no longer effective due to loss of adherence. For this reason, the objectives of the present research are a) to understand the reasons why adolescents stop using mobile applications during a period of mandatory use; and b) to discover the objective and subjective evaluation of adolescents with regard to mobile applications for physical activity, as well as the differences between the apps.

Based on previous scientific literature on the use and evaluation of mobile applications for nutritional or medical use (Adam et al., 2018; Lambrecht et al., 2021), the following research hypotheses are proposed: H1) the reasons for stopping the use of mobile applications will differ depending on the mobile application used; and H2) the objective and subjective evaluation will show significant differences between the applications.

Material and methods

Design

A 10-week study with a quasi-experimental design was carried out in which four mobile applications (Strava, Pacer, MapMyWalk, and Pokémon Go) were used to promote physical activity in adolescents. The sampling was non-probabilistic by convenience, selecting the schools with the largest number of adolescents in mandatory secondary education willing to participate in the Region of Murcia (Spain). In order for the sample to be representative of this geographical area, schools in the north, south, east, and west were contacted and the two schools with the largest number of students in these areas were selected. If the first centre did not agree to participate, the next centre with the largest number of students was contacted. Prior to the start of the intervention, the educational centre was contacted, and once approval was obtained, the procedure and objectives of the research were explained to the physical education teachers. Subsequently, a meeting was held with the adolescents interested in participating, as well as with their parents. Adolescents who finally agreed to participate gave written informed consent signed by them and their parents.

The study design followed the Consolidated Standards of Reporting Trials (CONSORT) (Schulz et al., 2011) guidelines, and approval was obtained from the institutional ethics committee of the Catholic University of Murcia (code: CE022102), in accordance with the guidelines of the World Medical Association and the Declaration of Helsinki.

Participants

According to the standard deviation (SD) of previous research (Lambrecht et al., 2021) that used the user version of the mobile application rating scale (uMARS) (SD = 0.7) the minimum sample needed to conduct the research, for an estimated error (d) of 0.22 and a 95% confidence interval (CI), was 40 participants per mobile app, with the total sample needed being 160 participants. The sample size was calculated using RStudio v.3.15.0 statistical software (RStudio Inc., U.S.A.).

A total of 400 adolescents (210 males and 190 females) aged between twelve and sixteen years old (13.94 ± 1.23 years old) from two compulsory secondary education schools in the Region of Murcia formed part of the initial research sample. The adolescents were divided into four experimental groups (100 per group), each using a mobile application for the practice of physical activity (Strava, Pacer, MapMyWalk, and Pokémon Go).

The inclusion criteria were a) aged between twelve and sixteen years old; and b) enrolment in compulsory secondary education. The exclusion criteria were a) not starting the intervention with mobile applications; b) transferring schools during the intervention period; c) not completing the uMARS after the period of use of the mobile applications; and d) not having one's own mobile phone with which to carry out the intervention.

Of the 100 adolescents who were part of each experimental group at the beginning of the research, 67 finished with Strava, 59 with Pacer, 55 with MapMyWalk and 59 with Pokémon Go, resulting in a final sample of 240 adolescents. The dropout rate was different between the apps (Strava: $n = 33$; Pacer: $n = 41$; MapMyWalk: $n = 45$; Pokémon Go: $n = 41$). The sample selection flowchart and reasons for dropout are shown in [Figure 1](#).

Instruments

The Physical Activity Questionnaire for Adolescents (PAQ-A) was used to assess the physical activity level of adolescents (Kowalski et al., 1997). This questionnaire has an adequate validity and reliability for use with adolescents, as well as an intraclass correlation coefficient of 0.71 for the final score of the questionnaire (Martínez-Gómez et al., 2009). This questionnaire is composed of nine items, of which the first eight are completed using a Likert scale of 1 to 5 points. The last item is a dichotomous question (yes or no) that allows us to establish whether there was any impediment that prevented normal physical activity in the previous week. The arithmetic mean of the scores of the first eight items represents the level of physical activity of the adolescents in the previous week (Kowalski et al., 1997). This questionnaire allows to classify the adolescents, being those with a score equal to or higher than 2.75 the one that determines a practice of more than 60 minutes of moderate to vigorous intensity physical activity (Benítez-Porres, 2016).

Mobile apps were rated by adolescents using the 'User Version of the Mobile Application Ratings Scale (uMARS)' (Stoyanov et al., 2016). This scale is composed of 26 items that allow rating the quality of apps objectively and subjectively. The original version it has an excellent internal consistency ($\alpha = 0.90$), which is maintained in the Spanish-language version ($\alpha = 0.89$) (Martin-Payo et al., 2021). The objective part of the questionnaire is completed using a Likert scale of 1 to 5 points (1=inadequate; 5=excellent) that allows the evaluation of four dimensions: engagement ($\alpha = 0.80$), functionality ($\alpha = 0.70$), aesthetics ($\alpha = 0.71$), and information ($\alpha = 0.78$). The subjective part includes 10 questions scored using a Likert scale of 1 to 5 points, in which usability and perceived impact are evaluated (Stoyanov et al., 2016).

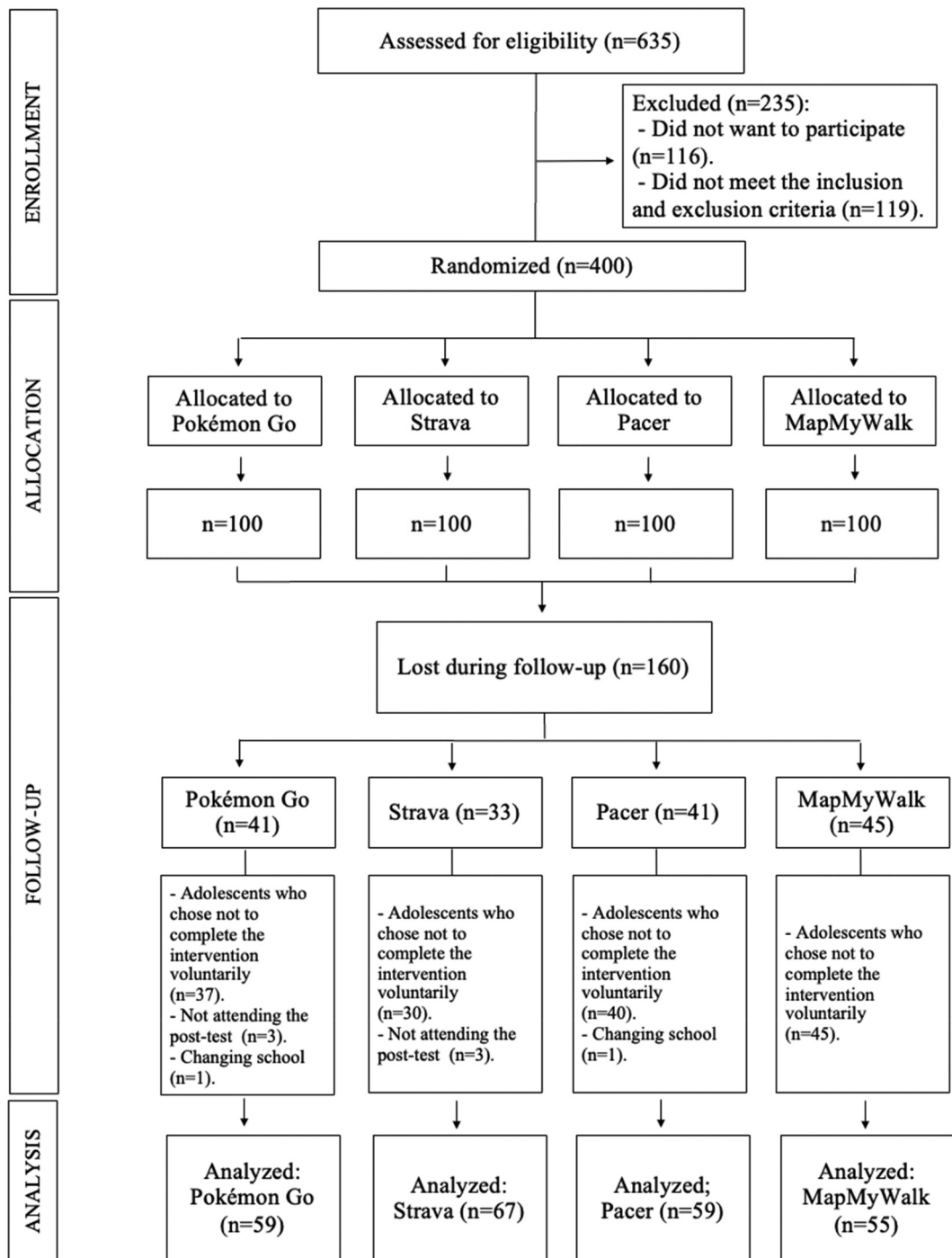


Figure 1. Sample selection flowchart.

Following the methodology of previous research (Galvim et al., 2019), the dropout instrument consisted of two open questions, the first one provided information on whether the mobile applications were used, while the second one provided information on the reasons for not using the application in cases where it was not used. For this second question, three options were provided in the questionnaire ('interface was complex to use', 'I did not know how to use it', 'I did not find it interesting'), but the possibility was given to include other reasons.

Variables assessed

The PAQ-A was used to measure the perceived level of physical activity of the adolescents, which made it possible to establish whether the intervention with mobile applications had been effective in promoting physical activity.

The engagement dimension was composed of five items (entertainment, interest, customization, interactivity, and target group) that allowed us to discover if the application was fun, interesting, customizable, interactive, and had prompts.

The distance covered with the use of the mobile application by each adolescent was recorded as a covariate. This is because previous research (Mateo-Orcajada et al., 2023, 2023a, 2023b) has shown significant differences in physical fitness and body composition variables according to the level of use of mobile applications. Therefore, adolescents with a higher level of use of mobile applications could show a different objective and subjective perception than those who used these devices to a lesser extent, because they would have experimented with the mobile applications for a longer period of time. For the measurement of this variable, a researcher was in charge of recording weekly the distance travelled by the adolescents using the mobile applications. To do this, the adolescent participants were included in a group within the mobile application from which the researcher could record weekly the distance travelled by each adolescent. In addition, at the end of the intervention and at the time of the post-test measurements, the distance travelled by each adolescent was checked in the app from the user's mobile phone.

Gender was also included as a covariate, as previous research has shown differences in preferences for the use of mobile applications, as well as in the time invested by males and females (Klenk et al., 2017; Mateo-Orcajada et al., 2023a), so that the objective and subjective perception of physical activity mobile applications currently available in the market could be different.

Randomization

Randomization was carried out to assign the mobile apps to each adolescent. Adolescents belonging to the same class group were assigned to the same app. This randomization was carried out by the principal investigator, together with other researchers who did not participate in the research, using a computer-generated random number table. No randomization by gender was necessary as the classes were evenly distributed between males and females. The researchers were blinded to the mobile application that was assigned to each adolescent.

Procedure

After obtaining the informed consent of the adolescents, the correct functioning of each of the mobile applications was explained to each class group. Prior to the intervention, the adolescents completed the PAQ-A questionnaire. A classroom in the school was used for this purpose, isolated from noise that could interfere with the completion of the questionnaires. During the intervention, adolescents were obligated to use the mobile applications at least three times a week, to complete the minimum distance established for each week. The physical education teachers encouraged the adolescents to make use of these devices, and those who fully completed the intervention were rewarded with a point in the final grade of the subject. At the end of the intervention, the

adolescents completed the PAQ-A, the uMARS and the dropout questionnaires. The conditions for completing the questionnaires were similar to those prior to the start of the intervention. The researchers did not interfere with the adolescents' responses and only resolved questions, if any.

Mobile app intervention

The intervention lasted 10 weeks, as previous studies has shown that the use of the apps for less than three months seems to be more effective than longer durations (Romeo et al., 2019). For each of the 10 weeks of intervention with the mobile applications, the adolescents were given a goal of minimum steps/kilometres to be covered each time they used the application. This distance had to be completed at least three times per week. The distance was increased incrementally each week, following the principle of progression.

The minimum distance to be covered was 5000 steps or 3.19 km on the first week, as this is the minimum distance needed to stop being considered sedentary (Lubans et al., 2015). The conversion of steps to kilometres was calculated considering previous research (Morency et al., 2007), in which it was indicated that in the adolescent population, 1 km corresponds to 1565 steps, approximately. The distance was increased weekly at a rate of 600 steps per week, ending with 12,000 steps on the last week, each day the application was used, with this being the minimum distance recommended to reach moderate to vigorous intensity of physical activity (Adams et al., 2013).

The apps used in the present study (Strava, Pacer, MapMyWalk, and Pokémon Go) were selected because they have been included in previous research and have been effective in increasing physical activity in other populations (Gonze et al., 2020; Petersen et al., 2020). Strava, Pacer and MapMyWalk act as pedometers, recording steps and distance travelled while using the app. These apps include numerous behaviour change techniques (Bondaronek et al., 2018), as well as physical activity reminders and rewards (Liu & Willoughby, 2018; Yang et al., 2020). In addition, Pokémon Go has an added incentive in that it is an active videogame in which adolescents must walk through different rural and urban areas to find different Pokémon that they can catch (Chong et al., 2018; Paavilainen et al., 2017). In addition, as they travel longer distances, they obtain rewards, which is a motivating factor. Its effectiveness has been demonstrated in previous research (Khamzina et al., 2020).

Adolescents who did not complete the full distance of the intervention were not excluded from the investigation and were measured in the post-test. This made it possible to establish the differences according to the distance covered with the application.

Data analysis

The Kolmogorov-Smirnov test was used to analyse the normality of the data, as well as skewness and kurtosis. Since the data followed a normal distribution, parametric tests were used for the analysis. First, the chi-square test (χ^2) was used to establish differences in the reasons for dropping out of the intervention between the different mobile apps. The corrected standardized residuals were used to determine significance, establishing the value of ± 1.96 as the reference value. As this is a 4×4 table, the contingency coefficient was used to establish the statistical value of the differences. 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). Two ANOVAs were carried out. The first one to establish the differences in the objective evaluation of each app, and the second one to establish the differences in the subjective evaluation. Four ANCOVAs were also carried out. The first one to establish the influence of the variable distance covered with the app, on the objective evaluation; the second one to establish the influence of the variable gender on the objective evaluation; the third one to establish the influence of the variable distance covered with app, on the subjective evaluation; and the fourth one to establish the influence of the variable gender, on the subjective evaluation. A Bonferroni post-hoc analysis was used to determine where the differences were found, between which mobile apps. Partial eta squared (η^2) was used to

calculate the effect size and was defined as small: $ES \geq 0.10$; moderate: $ES \geq 0.30$; large: $ES \geq 1.2$; 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 using the SPSS statistical package (v.25.0; SPSS Inc., IL).

Results

The intervention with mobile applications was effective in increasing the level of physical activity of adolescents, as significant differences were found between the pre- and post-test (pre: 2.61 ± 0.68 ; post: 2.81 ± 0.62 ; pre-post diff: -0.20 ± 0.52 ; $p < 0.001$; effect size: 0.57), with these adolescents reaching a moderate to vigorous intensity level of physical activity. There were no significant differences between the applications, as all of them showed significant effects on the level of physical activity (Strava: $p = 0.002$; Pacer: $p = 0.038$; MapMyWalk: $p = 0.041$; Pokémon Go: $p = 0.024$).

The reasons in relation to the mobile application for which the adolescents did not complete the intervention are listed in Table 1. For Strava (50.5%), Pacer (51.5%) and MapMyWalk (57.8%), the main reason for not using the application was that the adolescents considered the interface of these applications to be complex. In addition, a considerable percentage of adolescents in the Pacer group (24.3%) did not use it because they did not know how to make correct use of it. In the Pokémon Go group (45.2%), they did not use it because the app did not work on their mobile devices. It is worth noting that with respect to the four apps used, a small percentage of participants (8–16%) did not find the apps interesting.

Table 2 and 3 shows the differences in the objective evaluation made by the adolescents of each mobile application, also considering the covariates distance covered and gender. Regarding the objective evaluation, without considering the covariables, significant differences were only found in entertainment ($p = 0.019$) and customization ($p = 0.028$). The post-hoc analysis showed that adolescents indicated a significantly higher entertainment in Pokémon Go as compared to Pacer ($p = 0.030$), as well as higher customization in Pokémon Go compared to Strava ($p = 0.023$).

When considering the covariate distance covered, differences were significant between applications in the engagement dimension ($p = 0.008$), as well as in entertainment ($p = 0.031$), customization ($p = 0.003$), interactivity ($p = 0.012$), navigation ($p = 0.018$), quality of information ($p = 0.027$), and credibility of source ($p = 0.038$). A subsequent post hoc analysis showed that with Pokémon Go, adolescents showed higher engagement ($p = 0.027$), entertainment ($p = 0.023$) and interactivity ($p = 0.043$) results as compared to Pacer, as well as higher customization ($p = 0.020$) as compared to Strava. However, it was observed that adolescents who used Pokémon Go rated navigation being worse as compared to MapMyWalk ($p = 0.041$), as well as credibility of source as compared to Strava ($p = 0.039$) and MapMyWalk ($p = 0.030$). It was also observed that the quality of information was better in MapMyWalk than in Pacer ($p = 0.045$). Regarding the covariate gender, significant

Table 1. Differences in the reasons for not performing the intervention with the different mobile applications.

	Pokémon Go (n = 37)	Adj. Res.	Strava (n = 30)	Adj. Res.	Pacer (n = 40)	Adj. Res.	MapMy Walk (n = 45)	Adj. Res.	χ^2 ; p;	contingency coefficient
Interface was complex to use	14 (38.7%)	-2.0	13 (50.0%)	-0.6	18 (51.5%)	0.2	26 (57.8%)	1.3	29.127; 0.004	0.442
I did not know how to use it	0 (0.0%)	-1.8	4 (4.2%)	-0.9	10 (24.3%)	3.3	5 (11.1%)	-0.3		
I did not find it interesting	7 (16.1%)	0.3	5 (16.6%)	1.2	6 (12.1%)	0.1	4 (8.9%)	-1.1		
The application was not working on my mobile	16 (45.2%)	3.3	8 (29.2%)	0.5	6 (12.1%)	-2.5	10 (22.2%)	-0.6		

Table 2. Objective evaluation of each application considering the covariates distance covered and gender.

	Objective evaluation							Objective evaluation* distance covered with app			Objective evaluation* gender		
	Pokémon Go (n = 59)	Strava (n = 67)	Pacer (n = 59)	MapMyWalk (n = 55)	F	p	η ²	F	p	η ²	F	p	η ²
Engagement	3.88 ± 0.75	3.73 ± 0.65	3.52 ± 0.83	3.71 ± 0.64	2.158	0.094	0.030	3.571	0.008	0.064	2.012	0.094	0.037
Entertainment	3.61 ± 1.09	3.48 ± 1.04	3.03 ± 1.05	3.51 ± 0.93	3.394	0.019	0.046	2.723	0.031	0.050	2.643	0.035	0.048
Interest	3.65 ± 0.99	3.72 ± 0.78	3.34 ± 1.11	3.61 ± 1.00	1.768	0.154	0.025	1.748	0.141	0.033	1.514	0.199	0.028
Customization	3.93 ± 1.00	3.33 ± 0.99	3.53 ± 1.22	3.41 ± 1.10	3.083	0.028	0.042	4.135	0.003	0.074	3.495	0.009	0.063
Interactivity	3.98 ± 0.88	3.85 ± 0.96	3.61 ± 1.05	3.61 ± 1.22	1.584	0.194	0.022	3.291	0.012	0.060	1.220	0.303	0.023
Target group	4.22 ± 0.87	4.27 ± 0.83	4.10 ± 1.05	4.39 ± 0.70	0.914	0.435	0.013	1.983	0.098	0.037	0.713	0.584	0.014
Functionality	3.93 ± 0.75	3.92 ± 0.65	4.00 ± 0.83	4.06 ± 0.74	0.201	0.778	0.005	1.803	0.130	0.034	1.358	0.250	0.025
Performance	3.83 ± 1.08	3.91 ± 0.83	3.97 ± 0.98	3.90 ± 1.16	0.171	0.916	0.002	0.735	0.569	0.014	0.932	0.446	0.018
Ease of use	4.15 ± 0.92	4.15 ± 0.86	4.20 ± 0.89	4.20 ± 0.90	0.056	0.983	0.001	0.395	0.812	0.008	0.766	0.548	0.015
Navigation	3.78 ± 0.81	3.82 ± 0.83	3.93 ± 1.05	4.15 ± 0.96	1.419	0.238	0.020	3.052	0.018	0.055	3.193	0.014	0.058
Gestural design	3.98 ± 0.80	3.81 ± 0.97	3.90 ± 0.98	4.00 ± 0.71	0.533	0.660	0.008	1.838	0.123	0.034	0.414	0.798	0.008
Aesthetics	3.98 ± 0.73	3.94 ± 0.69	3.86 ± 0.86	3.94 ± 0.69	0.245	0.865	0.004	0.840	0.501	0.016	0.565	0.688	0.011
Layout	3.98 ± 0.88	3.99 ± 0.90	4.05 ± 0.94	3.98 ± 0.85	0.089	0.966	0.001	0.781	0.539	0.015	0.793	0.531	0.015
Graphics	4.04 ± 0.73	4.12 ± 0.75	4.07 ± 1.00	4.10 ± 0.83	0.087	0.967	0.001	1.389	0.239	0.026	0.842	0.500	0.016
Visual appeal	3.91 ± 1.15	3.70 ± 0.92	3.46 ± 1.10	3.76 ± 0.92	1.794	0.149	0.025	1.349	0.253	0.025	1.351	0.252	0.025
Information	3.82 ± 0.88	3.93 ± 0.69	3.86 ± 0.94	4.01 ± 0.82	0.456	0.713	0.007	2.972	0.070	0.054	1.150	0.334	0.022
Quality of information	4.02 ± 1.06	3.97 ± 0.74	3.88 ± 1.05	4.12 ± 1.01	0.538	0.657	0.008	2.793	0.027	0.051	0.647	0.629	0.012
Quantity of information	3.91 ± 1.03	3.93 ± 0.84	3.85 ± 1.13	4.12 ± 0.84	0.678	0.566	0.010	1.436	0.223	0.027	1.014	0.401	0.019
Visual information	3.85 ± 0.97	3.97 ± 0.90	3.98 ± 1.23	3.93 ± 1.13	0.169	0.917	0.002	2.266	0.063	0.042	2.484	0.055	0.046
Credibility of source	3.50 ± 1.15	3.87 ± 1.06	3.75 ± 1.07	3.88 ± 1.10	1.242	0.295	0.018	2.595	0.038	0.048	0.970	0.425	0.018

Table 3. Bonferroni post hoc analysis of the variables of the objective evaluation that showed significant differences.

	Pokémon Go – Strava			Pokémon Go – Pacer			Pokémon Go – MapMyWalk			Strava – Pacer			Strava – MapMyWalk			Pacer – MapMyWalk		
	Mean Diff.	p	95% CI	Mean Diff.	p	95% CI	Mean Diff.	p	95% CI	Mean Diff.	p	95% CI	Mean Diff.	p	95% CI	Mean Diff.	p	95% CI
Objective evaluation																		
Entertainment	0.13 ± 0.20	1.000	−0.39; 0.66	0.58 ± 0.20	0.030	0.04; 1.12	0.09 ± 0.22	1.000	−0.49; 0.69	0.44 ± 0.18	0.100	−0.05; 0.93	−0.04 ± 0.20	1.000	−0.58; 0.51	−0.48 ± 0.21	0.141	−1.04; 0.08
Customization	0.61 ± 0.21	0.023	0.06; 1.16	0.41 ± 0.21	0.333	−0.16; 0.98	0.52 ± 0.23	0.157	−0.09; 1.14	−0.20 ± 0.19	1.000	−0.71; 0.32	−0.09 ± 0.21	1.000	−0.66; 0.49	0.11 ± 0.22	1.000	−0.48; 0.70
Objective evaluation * distance covered																		
Engagement	0.15 ± 0.14	1.000	−0.21; 0.51	0.41 ± 0.14	0.027	0.03; 0.78	0.17 ± 0.15	1.000	−0.24; 0.58	0.26 ± 0.13	0.286	−0.09; 0.60	0.02 ± 0.14	1.000	−0.35; 0.40	−0.23 ± 0.15	0.671	−0.62; 0.16
Entertainment	0.13 ± 0.20	1.000	−0.40; 0.66	0.60 ± 0.20	0.023	0.05; 1.14	0.10 ± 0.22	1.000	−0.49; 0.69	0.47 ± 0.19	0.078	−0.03; 0.96	−0.03 ± 0.20	1.000	−0.58; 0.51	−0.50 ± 0.21	0.113	−1.06; 0.06
Customization	0.61 ± 0.20	0.020	0.06; 1.15	0.48 ± 0.21	0.146	−0.08; 1.04	0.52 ± 0.23	0.142	−0.09; 1.13	−0.13 ± 0.19	1.000	−0.64; 0.39	−0.08 ± 0.21	1.000	−0.65; 0.48	0.04 ± 0.22	1.000	−0.54; 0.62
Interactivity	0.13 ± 0.19	1.000	−0.39; 0.64	0.44 ± 0.20	0.043	−0.09; 0.97	0.37 ± 0.22	0.132	−0.21; 0.95	0.31 ± 0.18	0.515	−0.17; 0.80	0.24 ± 0.20	1.000	−0.29; 0.78	−0.07 ± 0.21	1.000	−0.62; 0.48
Navigation	−0.04 ± 0.17	1.000	−0.50; 0.42	−0.09 ± 0.18	1.000	−0.57; 0.39	−0.36 ± 0.19	0.041	−0.88; 0.16	−0.05 ± 0.16	1.000	−0.48; 0.39	−0.32 ± 0.18	0.439	−0.80; 0.16	−0.28 ± 0.19	0.832	−0.77; 0.22
Quality of information	0.05 ± 0.18	1.000	−0.43; 0.53	0.21 ± 0.19	1.000	−0.28; 0.71	−0.10 ± 0.20	1.000	−0.64; 0.44	0.16 ± 0.17	1.000	−0.29; 0.61	−0.15 ± 0.19	1.000	−0.64; 0.35	−0.31 ± 0.19	0.045	−0.82; 0.20
Credibility of source	−0.37 ± 0.21	0.039	−0.92; 0.18	−0.18 ± 0.21	1.000	−0.75; 0.39	−0.38 ± 0.23	0.030	−0.99; 0.24	0.19 ± 0.19	1.000	−0.33; 0.71	−0.01 ± 0.21	1.000	−0.58; 0.56	−0.20 ± 0.22	1.000	−0.79; 0.39
Objective evaluation * gender																		
Customization	0.66 ± 0.21	0.010	0.11; 1.21	0.47 ± 0.21	0.165	−0.09; 1.04	0.60 ± 0.23	0.065	−0.02; 1.22	−0.19 ± 0.19	1.000	−0.70; 0.32	−0.06 ± 0.21	1.000	−0.63; 0.51	0.13 ± 0.22	1.000	−0.45; 0.71
Navigation	0.02 ± 0.17	1.000	−0.44; 0.49	−0.08 ± 0.18	1.000	−0.56; 0.40	−0.27 ± 0.20	0.048	−0.80; 0.25	−0.10 ± 0.16	1.000	−0.53; 0.33	−0.30 ± 0.18	0.593	−0.78; 0.18	−0.20 ± 0.18	1.000	−0.69; 0.29

differences were observed in customization ($p = 0.009$) and navigation ($p = 0.014$), with Pokémon Go scoring higher than Strava in customization ($p = 0.010$), and lower than MapMyWalk in navigation ($p = 0.048$).

The subjective evaluation of the applications is shown in Table 4. No significant differences were found in the subjective quality ($p > 0.05$) or perceived impact ($p > 0.05$), nor when the covariates distance covered ($p > 0.05$), and gender ($p > 0.05$) were considered.

Discussion

Barriers and difficulties encountered in the use of mobile apps by adolescents

The first objective of the present research was to understand the reasons why adolescents stop using mobile applications during a period of mandatory use. The results showed that although the intervention was effective in increasing physical activity level, a high percentage of adolescents dropped out, which is similar to the results of previous research (Egilsson et al., 2021). The majority of adolescents in the apps that acted as pedometers (Strava, Pacer and MapMyWalk) indicated that they did not follow the intervention because the apps' interface was complex. Previous research has shown that the design of mobile apps has become more relevant in recent years, surpassing even the importance shown by efficiency, as it influences the user's emotions and perception of quality (Bhandari et al., 2017). A possible explanation for these results could be that the perception of app design is completely different between app designers and the users who finally use the app, resulting in difficulties in its use (Cata & Martz, 2015). This could be due to the fact that app designers have more advanced knowledge about the use of apps than the common user, including complex functionalities and interfaces without considering the user's needs, which would hinder the use of apps (Gao & Lee, 2019). As indicated in previous research, this is a highly relevant aspect that should be considered when designing mobile applications (Cata & Martz, 2015), even more so when designing mobile applications aimed at the adolescent population, as the results show that this could be the main reason for not using apps in this population. Therefore, when designing mobile apps to promote physical activity, it is necessary to involve researchers and professionals from different disciplines, in addition to consulting end users, so that the integration of the app is more effective (Gao & Lee, 2019; Simões et al., 2018).

As for Pokémon Go, a large percentage of teens who did not use it indicated that it was because the app did not work properly on their device. These results are similar to those of previous research conducted with this video game in university students, in which the first reason for not using it was that they did not like the theme of the video game, with the next reason being that the application did not work on their device, as the mobile phone was not compatible, it required too much data, or the app kept crashing the phone (Vaterlaus et al., 2019). Therefore, although the results of the present research and previous research have shown that Pokémon Go is a useful app for promoting physical activity in adolescents (Khamzina et al., 2020; Mateo-Orcajada et al., 2023b), it is necessary to consider that this app may not work on all devices (Gao & Lee, 2019). This is an aspect to consider, as it adds to the problems encountered by other augmented reality games or exergames, whose implementation has been complicated in the adolescent population.

If in addition to the difficulties encountered for their use in the school environment, such as the lack of support from the school administration, space limitations, curricular conflicts, or budget shortages (Gao & Lee, 2019), we find difficulties for their use outside school hours, as shown in this research, no matter how useful these tools are for promoting physical activity (Mateo-Orcajada et al., 2023; Xu et al., 2022), they will no longer be viable. These results are relevant for the design of future gamified applications, as it would be more important for them to work on as many devices as possible and have a simple interface, even if this means reducing the number/type of graphics or functionalities.

Table 4. Subjective evaluation of the applications used according to the covariates distance covered and gender.

	Subjective evaluation							Subjective evaluation* distance covered with app			Subjective evaluation* gender		
	Pokémon Go (n = 59)	Strava (n = 67)	Pacer (n = 59)	MapMyWalk (n = 55)	F	p	η ²	F	p	η ²	F	p	η ²
Subjective quality	3.11 ± 0.84	3.24 ± 0.62	3.17 ± 0.75	3.24 ± 0.73	0.378	0.769	0.005	0.875	0.480	0.017	0.283	0.889	0.005
Would you recommend this app?	3.72 ± 1.21	4.07 ± 0.97	3.73 ± 1.14	3.98 ± 1.08	1.522	0.210	0.021	1.836	0.123	0.034	1.151	0.334	0.022
Do you think you would use this app in the next 12 months?	3.24 ± 1.25	3.42 ± 0.87	3.32 ± 1.06	3.37 ± 1.07	0.277	0.842	0.004	1.587	0.179	0.030	0.685	0.603	0.013
Would you pay for this app?	1.83 ± 1.12	1.73 ± 0.96	1.95 ± 1.09	1.78 ± 0.94	0.495	0.686	0.007	0.981	0.419	0.019	0.371	0.829	0.007
What is your overall (star) rating of the app?	3.65 ± 0.90	3.75 ± 0.82	3.68 ± 0.90	3.83 ± 0.83	0.380	0.768	0.005	1.431	0.225	0.027	0.680	0.607	0.013
Perceived impact	3.27 ± 1.00	3.14 ± 0.90	3.12 ± 0.97	3.11 ± 0.95	0.293	0.831	0.004	0.222	0.926	0.004	0.230	0.921	0.004
Awareness	3.39 ± 1.18	3.13 ± 1.04	3.17 ± 1.09	3.10 ± 1.18	0.659	0.578	0.009	0.837	0.503	0.016	0.862	0.487	0.016
Knowledge	3.17 ± 1.02	3.09 ± 1.07	3.05 ± 1.12	3.10 ± 1.22	0.110	0.954	0.002	0.089	0.986	0.002	0.266	0.900	0.005
Attitudes	3.28 ± 1.13	3.13 ± 1.11	3.14 ± 1.11	3.17 ± 1.09	0.199	0.897	0.003	0.252	0.909	0.005	0.152	0.962	0.003
Intention to change	3.20 ± 1.09	3.19 ± 0.99	3.15 ± 1.03	3.05 ± 1.09	0.197	0.899	0.003	0.163	0.957	0.003	0.190	0.943	0.004
Help seeking	3.11 ± 1.27	2.97 ± 1.13	2.97 ± 1.10	2.88 ± 0.98	0.317	0.813	0.005	0.301	0.877	0.006	0.660	0.620	0.013
Behaviour change	3.48 ± 1.24	3.30 ± 1.10	3.25 ± 1.15	3.37 ± 1.14	0.364	0.779	0.005	0.354	0.841	0.007	0.374	0.827	0.007

Based on the results of the present research, the first research hypothesis, which stated that the reasons for stopping the use of mobile applications will differ depending on the mobile application used, can be partially accepted. This is because it does not seem to be that the mobile application is what is important, but rather the type of application used. The apps that acted as pedometers and were similar to each other, were found to have a complex interface, while the difficulty with the gamified app (Pokémon Go), was that it did not work on all devices. However, future research is needed to analyse the reasons for abandonment of interventions with mobile physical activity apps, as this is a completely unexplored area.

Strengths and issues to consider in the design of future physical activity apps for adolescents

The second objective of the present research was to discover the objective and subjective evaluation of the mobile applications for physical activity by the adolescents, as well as to find the differences between the apps. In terms of the objective evaluation, adolescents who used Pokémon Go showed greater entertainment and customization results as compared to the apps used as pedometers (Pacer and Strava, respectively). These results follow previous research, in which users of augmented reality apps showed a greater engagement in physical activity, as their perception was modified by a story line or narrative that dissociated them from exertion (Farič et al., 2021). Furthermore, previous research has shown that Pokémon Go has other strengths to consider, such as game enjoyment or player customization options (Hamari et al., 2019; Qin, 2021), which is supported by the results of the study. The ability to customize and personalize the content according to the user's needs is fundamental to maintain adherence to the programme (Jakob et al., 2022). Similarly, entertainment becomes relevant for the continuity of app use, since when an app is considered fun, adherence also increases (Yang et al., 2020). In addition, it is worth noting that customization and entertainment are related through other psychological constructs, since the possibility of customization increases the perception of autonomy and control, which explains part of entertainment (Kim et al., 2015). Therefore, as recommended in previous studies, users should be able to customize the app and its accounts to improve their satisfaction with the mobile apps they use for physical activity promotion (Seah & Koh, 2021).

Another relevant finding of the present research was that adolescents showed a higher engagement, entertainment, customization, and interactivity in Pokémon Go, as compared to Pacer and Strava, when considering the covariate distance covered. The fact that a greater distance covered in Pokémon Go is related to the possibility of catching more Pokémon, receiving more rewards, and climbing up the levels may justify the findings of the present research. Previous studies have shown that in these types of gamified games, the effort directed towards an aim, in this case catching new Pokémon, plays an important role in translating the desire to reach the aim into the achievement of the goal (Kwak et al., 2021). In addition, previous studies have shown that exploration is one of the aspects of the game that improves the effectiveness of the intervention (Lindqvist et al., 2018), which could explain the greater entertainment and engagement of the adolescents who used the app the most. However, little is known about the most determinant aspects of Pokémon Go from the user's perspective, and future research should consider aspects such as whether adolescents used Pokémon Go for the first time or were long-time users. This may be a relevant aspect, as previous research has shown that new users are motivated by features directly related to Pokémon, such as catching all Pokémon and reaching higher levels, while old users highlight the quality of the game in general and the challenges the game offers to them (Rasche et al., 2017). This may be a determinant factor for the time spent playing the game, distance travelled, or app rating, but future research is needed to corroborate this.

However, in Pokémon Go, the navigation and credibility of source ratings were worse than in Strava and MapMyWalk, respectively, when considering the covariate distance travelled. No previous research is known to have compared the use of augmented reality mobile apps, such as Pokémon Go, with mobile apps that act as pedometers, such as Strava, Pacer, and MapMyWalk. One possible

explanation for these differences is that the pedometer apps in this study include a large number of behaviour change techniques that increase users' knowledge of different habits that can lead them to healthier behaviours, including the possibility of goal setting and planning, feedback and monitoring, social support, the comparison of behaviour, social rewards, and the credible source (Bondaronek et al., 2018; Middelweerd et al., 2014). The effectiveness of these techniques for behavioural change could be determined by the increased use of the applications, as users would discover the true potential of the application the more they use it. However, this has not been previously demonstrated, and future research is needed to discover whether it is the increased use of the app that leads to the discovery of new features, or whether it is the discovery of new features that leads to increased use of the app. Pokémon Go, on the other hand, does not provide any health-related content or information, as aspects such as playing, having fun, nostalgia, social ties or interest in Pokémon are the main drivers (Baranowski & Lyons, 2020; Marquet et al., 2017). The app bases the increased physical activity on these, which would justify the differences found between the apps.

The covariate gender was also shown to influence the results of the objective evaluation, more specifically in Pokémon Go, where differences were found with respect to Strava in customization, and with respect to MapMyWalk in navigation. Previous research has shown that interventions based on mobile apps should be gender-specific, since the motives that drive their use, as well as their final use, differ between males and females (Klenk et al., 2017; Mateo-Orcajada et al., 2023a). The results of the present research follow the line of these previous investigations, as they would indicate that the objective evaluation of mobile apps differs according to gender, which would be fundamental for discovering which apps can be the most useful in a given population. As one of the strong characteristics of Pokémon Go is the possibility of customizing the player (Hamari et al., 2019; Qin, 2021), the results found are especially important, as there would be differences according to gender in this aspect, and future studies are needed to provide more information. Therefore, this research highlights the need to consider the characteristics of the target population in order to choose the application that best suits their needs, as previous research also points out (Simões et al., 2018). However, further studies are needed to establish the aspects that are most relevant when selecting the most appropriate mobile apps for each group.

It is worth noting that no differences were found between the mobile apps in the subjective evaluation made by the adolescents, nor when the covariates distance covered, and gender were considered. The results show that adolescents would recommend the mobile app, as they rate it positively, and believe that they would continue to use it for the next 12 months, although later results showed that most of them did not continue to use it when its use was not promoted. In addition, they would not pay to use any of the apps used in this research. These results are similar to previous research conducted with mobile apps for medical patients, where the subjective rating was positive (Adam et al., 2018; Lambrecht et al., 2021). No previous studies are known to have conducted objective or subjective ratings of mobile physical activity apps, but the results found are encouraging due to the overall positive perception of these tools among adolescents. However, future studies are needed to gain a more in-depth understanding of the perception of these apps among different populations, as this will enable accurate recommendations to be made as to which may be most effective in each case.

Based on the results obtained in this research, the second research hypothesis, which stated that the objective and subjective evaluation would show significant differences between the applications, can be partially accepted. This is because significant differences were found between the apps in the objective evaluation, with Pokémon Go being the one in which most differences were found with respect to the rest of the apps, although no differences were found in the subjective evaluation made by the adolescents.

Lessons learned from the use of mobile applications among adolescents in this study

The use of physical activity apps currently available on the market is complex for a considerable part of the adolescent sample, which is similar to previous research in the field (Frontini et al., 2020;

Ribanszki et al., 2021). By complexity, users understand the difficulties encountered in using the different functions of the app, such as activating the physical activity log, configuring the user account, accessing the settings, or activating other functionalities present in the app. In addition, the initial complexity can also be a determining factor, since difficulties in the initial login, or the existence of many menus that distract the user's attention, can affect the use of this device (Frontini et al., 2020; Ribanszki et al., 2021).

Another major difficulty was the fact that the application did not work on the smartphone. In the scientific literature surrounding the use of cell phones by adolescents, a great deal of debate has arisen around accountability (Moreno et al., 2019). This term refers to when an adolescent is ready to have his or her own mobile device, due to a deficit of responsibility and care for it (Moreno et al., 2019). This fact leads to many receiving their first phone when one of their parents acquires a new one (Moreno et al., 2019). This means that the phones received by adolescents are outdated in terms of software, which may explain why some of the most required apps do not work properly on their devices.

On the other hand, customization and entertainment seem to be two key elements that should be present in physical activity apps for adolescents. Previous research using mobile apps for the prevention and management of noncommunicable diseases indicated that the ability to customize and adapt the content to the user's needs was fundamental to maintain adherence to the programme (Jakob et al., 2022) as well as to satisfy individual preferences (Hilliard et al., 2014). Similarly, entertainment is critical for users to continue using the app, as seen in previous research where it was observed that making the app fun to use was one of the determining factors for continuity (Yang et al., 2020). Therefore, personalization and entertainment become key elements in generating app adherence, also in the adolescent population. This is probably due to the fact that both are related to each other, as well as to other psychological constructs, since the possibility of personalizing the character increases the perception of autonomy, control, and attachment to the character, which in turn explains a considerable part of the enjoyment and entertainment (Kim et al., 2015).

Another aspect to consider is that the design of the study makes the external reward, in this case the increase in the physical education grade, acquire a relevant role for the success of the intervention. However, the aim of this type of intervention is to modify lifestyle and instil healthy habits in the adolescent population, since this is a crucial stage that conditions later stages of life (Simmonds et al., 2016). By means of external rewards, the aim is to increase the extrinsic motivation of the participants to initially adhere to the intervention (Bear et al., 2017). By increasing this extrinsic motivation, it is intended to progressively increase and acquire intrinsic motivation on the part of the participants that will adhere them to the programme in the long term (Teixeira et al., 2012), as has been seen in previous research in which this transition between extrinsic motivation and intrinsic motivation has been sought (Amabile, 1996; Frey, 1997; Hennessey & Zbikowski, 1993). However, it seems that this is not proving effective in adolescents for two reasons: first, dropout rates are similar to those of previous studies (Egilsson et al., 2021), suggesting that a one-point increase in the physical education grade is not enough incentive to significantly increase extrinsic motivation; and second, many of the adolescents did not continue to use the app once the reward for its use ended. Therefore, future research should look for new sources of motivation that allow an easier transition to intrinsic motivation when using these devices.

Recommendations for the design of physical activity intervention with apps for the adolescent population

Based on the results obtained in the present study and the results of previous studies, future studies aimed at increasing the level of physical activity by means of mobile apps in the adolescent population should consider the following aspects: a) use mobile applications in which the opinion of experts in the subject matter is present, as this has been seen as a strong point for maintaining adherence, since users trust the information received from the app (Subhi et al., 2015); b) the app should not include excessively complex functionalities, i.e. apps with an excess of information in

which the teenager gets lost navigating through the menus should be avoided (Frontini et al., 2020). Sometimes, less is more, and you should look for an app that allows you to record the distance travelled and with which the adolescents receives small notions of healthy habits; c) the promotion of the devices from schools seems to be a key element in maintaining the adherence of adolescents; however, it is known that the interface and design of the apps is not optimal for use in this setting (Alonso-Fernández et al., 2022). Therefore, apps should be sought or designed in which their use from the school by the teacher is simple and can encourage the practice of physical activity, even as homework in the classroom; d) the selection of apps that include elements of customization and are fun and easy to use for the adolescent population also seems to be a key element due to its relationship with other psychological constructs that facilitate greater adherence to the intervention (Hilliard et al., 2014; Jakob et al., 2022; Kim et al., 2015); e) achieving a high level of motivation towards the intervention is key for adolescents to use the app, not only for the duration of the programme, but also to generate a healthy habit and maintain the practice of physical activity over time (Teixeira et al., 2012). This is a pending task for future research that should look for sources of extrinsic motivation that can transition to intrinsic motivation in a better way than increasing the physical education grade (Amabile, 1996; Hennessey & Zbikowski, 1993); and f) the lack of autonomy in the choice of apps could be an aspect that decreases adherence to the intervention programme (Teixeira et al., 2012), so future research should try to adapt to the tastes and preferences of adolescents when selecting the app, which could lead to better results in terms of intervention follow-up. Considering these issues, a large number of the factors indicated in previous research that may affect adherence to the intervention, such as psychological aspects, benefit seeking, user experience and functionality (Yang et al., 2020), can be addressed and serve as a guide for future research in this area.

Limitations of the present study

The present research is not without limitations. Firstly, the level of physical activity was measured by means of a questionnaire, which, although valid and reliable, measures the subjective perception of physical activity. Secondly, the uMARS was used for the evaluation of the mobile applications, as it is a valid and reliable instrument, but it is possible that in the adolescent population, some of the terms used in the scale pose an additional difficulty, so future research could use focus groups or interviews to obtain more information from adolescents on their perception of the different mobile apps for the promotion of physical activity. Thirdly, the mobile applications used were chosen by the researchers, not by the adolescents, which could condition their use by being 'imposed'. This could affect the autonomy of the participants and condition their positive assessment of the apps, giving only a negative view of them. And fourthly, the reasons for stopping using the app were collected through questionnaires, which could limit the information collected from the adolescents. Future research should use qualitative techniques such as interviews or focus groups to collect the reasons why the adolescents did not use the app, thus obtaining much more information that is not limited to the answers included in the questionnaire.

Conclusions

With the results obtained in the present research, it can be concluded that interventions with mobile apps for physical activity in adolescents have a considerable dropout rate not because they are not attractive or interesting for this population, but because the apps that currently exist on the market do not work properly or have an interface that is too complex for these users. In addition, the objective evaluation was different according to the apps used by the adolescents, with Pokémon Go providing a greater entertainment and customization capacity as compared to the rest of the apps. As for the covariates distance covered and gender, both seem to significantly influence the results. This makes it even more necessary to be aware of the target population in order to select the most

effective app, as well as to encourage the continued use of mobile apps. However, this is the first study in this area, and future research is needed to corroborate the results obtained.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, [LAC], upon reasonable request.

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