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Protocol for a randomized controlled trial of a mobile app and wearable–based intervention promoted through physical education to enhance physical and psychological health in adolescents during out-of-school hours

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Abstract

Background The use of new technologies to promote physical activity among adolescents has gained particular relevance in recent years. However, the methodological designs, as well as the instruments used, make it difficult to compare the studies conducted.

Methods This protocol describes a single-blind, seven-arm randomized controlled trial designed to evaluate the effectiveness of mobile apps and wearable devices in promoting physical activity and improving physical and psychological health among adolescents aged 12 to 16. The intervention, conducted over two 12-week periods, is integrated into physical education (PE) settings to encourage device use during out-of-school hours. Participants will be randomly assigned to one of six experimental groups (EGs) or a control group (CG). During the intervention, EG adolescents must complete progressively increasing step goals (from 5,000 to 12,000 steps/session) at least three times per week. The primary outcomes include physical activity level, anthropometric and body composition, physical fitness, and psychological variables, while secondary outcomes include dietary habits, device usability, and participant satisfaction. Assessments will be conducted at three time points: baseline, post-test, and re-test.

Discussion This protocol addresses previous research limitations by ensuring methodological rigor, standardized procedures, and objective assessments. This standardized protocol for the use of mobile apps and wearables promoted in the field of physical education is expected to enable high-quality scientific research studies that truly observe the potential of these tools to improve the physical health of adolescents, since one of the main problems observed when using these technologies was the lack of standardization and attention to key aspects, which led to premature abandonment of the program.

Trial registration This study protocol has been reviewed and approved by the Catholic University of Murcia (code: CE022102). It is registered at ClinicalTrials.gov (ID: NCT06140225. Registration date: 11/14/2023). All participants will

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provide written informed consent before enrollment. The study will be conducted in accordance with the principles of the Declaration of Helsinki. Data may be made available upon reasonable request, in accordance with ethical and legal guidelines.

Keywords Anthropometric variables, Body composition, New technologies, Physical activity, Physical fitness, Psychological state, School, Teenagers

Background

Mobile apps and wearable devices have gained significant relevance as tools for promoting physical activity among adolescents [1, 2]. This is primarily due to their ability to continuously and accessibly record various health-related parameters, with physical activity level being one of the most prominent. Their interactive features, such as immediate feedback, reminders, and gamified design, make these tools both appealing and potentially effective for encouraging behavioral changes and promoting healthy physical activity habits in adolescent populations [3].

Despite their development and increasing use, most studies involving these devices exhibit notable methodological limitations. Among the most common are the short duration of the programs, the use of non-randomized designs, lack of standardization in physical activity criteria, and the heterogeneity of tools and tests used to assess intervention outcomes [4]. In this regard, numerous prior studies rely on assessment instruments with limited validity and reliability, which hinders accurate interpretation of results, limits the generalizability of findings, and complicates comparison with outcomes from other investigations [5].

Additionally, considerable variability exists in the protocols employed across studies, both in their structural design and in the criteria used to prescribe physical activity in terms of duration, volume, and intensity [6]. This heterogeneity makes it difficult to compare results and highlights the need for well-grounded methodological designs that incorporate objective measurement tools, define clear progression criteria, and ensure sufficient duration to generate meaningful changes in physical activity levels with potential impact on adolescent health.

Therefore, the present protocol aims to describe the design of an intervention based on the use of mobile apps and wearable devices, developed with a high level of methodological rigor and specifically tailored to the adolescent population. The protocol includes assessment instruments with strong validity and reliability for use in this age group, as well as progressive physical activity criteria grounded in the scientific literature. This design intends to serve as a robust and replicable framework for future research using these technologies, facilitating the generation of comparable results and enabling more definitive conclusions regarding the effectiveness of such interventions in adolescent populations.

Methods

Study design and setting

This study is designed in accordance with the recommendations of the Consolidated Standards of Reporting Trials (CONSORT) [7] and the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) statements [8]. It is registered at ClinicalTrials.gov (ID: NCT06140225. Registration date: 11/14/2023).

This protocol outlines a 26-week, seven-arm, parallel, single-blind randomized controlled trial (RCT) with blinded outcome assessors. Participants will be randomly assigned to one of the experimental groups (EGs) (Strava, Pacer, MapMyWalk, Pokémon Go, Xiaomi Smart Band, or Amazfit Band 7) or to a control group (CG). Adolescents in the EGs will participate in a 12-week intervention using their assigned mobile app or wearable device three times per week. In each session, they will be required to complete a target walking distance, which will be progressively increased on a weekly basis. Figure 1 presents the study design.

Ethics approval

The study will be conducted in accordance with the recommendations of the Declaration of Helsinki and the World Medical Association. The Institutional Ethics Committee of the Catholic University of Murcia approved the protocol design and procedures (code: CE022102).

Adolescents interested in participating will provide written informed consent, signed by both themselves and their legal guardians, authorizing the collection and scientific use of relevant data. Participants will be informed that they may withdraw from the study at any time, and that all data collected up to that point will be deleted.

Sample size

The sample size was calculated using the standard deviation (SD = 8.65) reported in previous studies aiming to increase physical activity levels in adolescents through technological devices [9]. Based on an estimated error (d) of 2.53 and a 95% confidence interval (CI), the minimum required sample size per group is 60 adolescents.

Therefore, at least 78 adolescents from secondary schools will be included in each study group, ensuring a balanced representation of males and females. This decision accounts for the high dropout rate (approximately

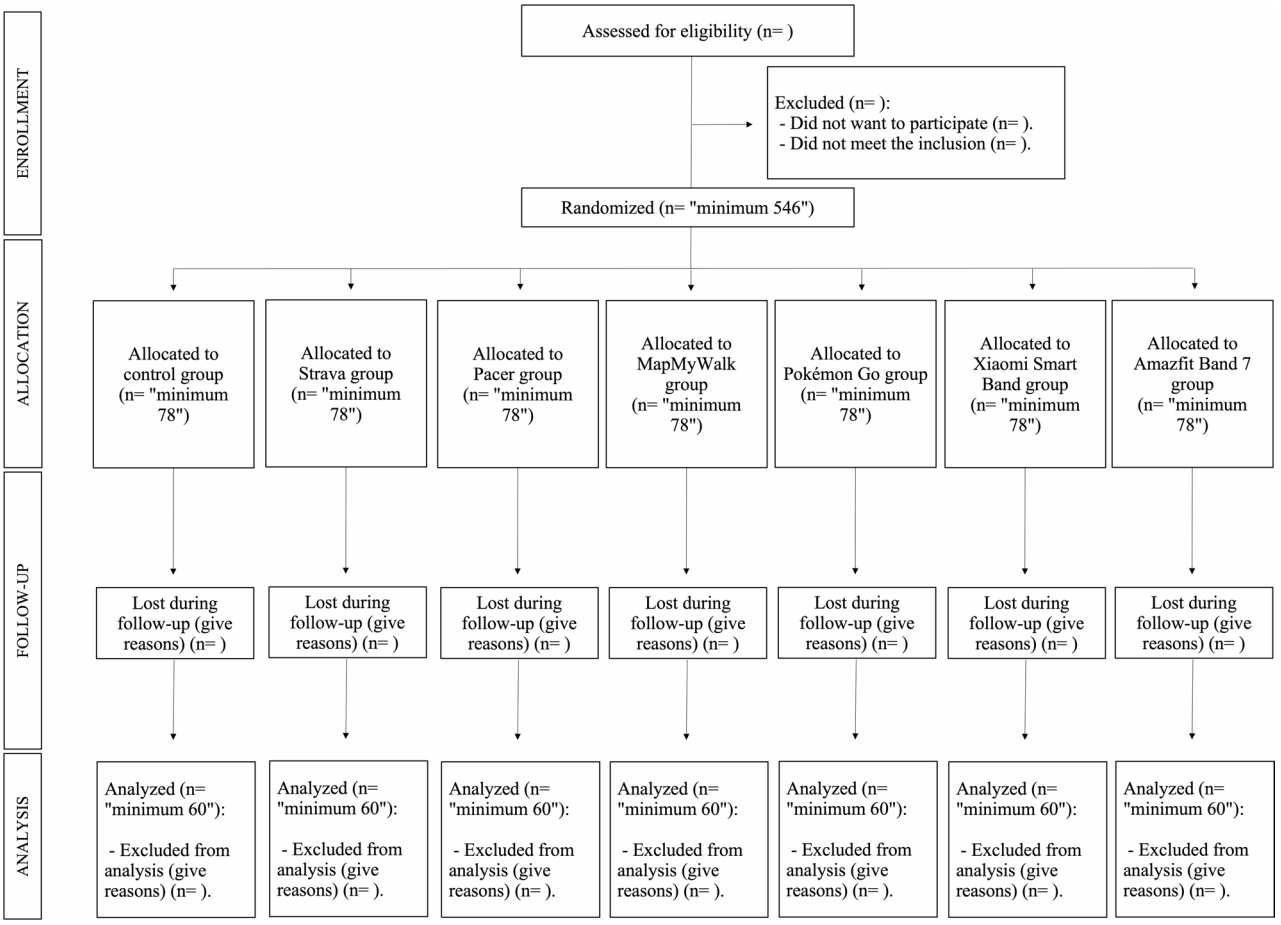

Fig. 1 Study flowchart

30%) observed in previous interventions involving technological devices among adolescents [10].

Recruitment

Participants will be recruited by convenience sampling from secondary schools that express interest in participating. Initially, school administrators will be contacted and provided with detailed information regarding the study, including its objectives and procedures. Upon their approval, the physical education staff will be informed, as they will be responsible for presenting the study to the students. An informational meeting will then be held with the adolescents who express interest in participating, along with their parents or legal guardians. During this meeting, the study's objectives, procedures, and data confidentiality measures will be explained, and any questions or concerns regarding the study will be addressed.

Eligibility criteria

Inclusion criteria for the study will be as follows: (a) age between 12 and 16 years; (b) enrollment in compulsory secondary education; (c) absence of any disabling condition that may prevent participation; (d) completion of all questionnaires, anthropometric assessments, and physical fitness tests in full; and (e) participation in all measurement sessions: baseline (T1), post-intervention (T2), and re-test (T3).

Exclusion criteria will include: (a) missing more than 20% of the scheduled physical education classes during the academic year; (b) not owning a mobile device; (c) transferring to another school during the intervention period; and (d) initiating or ceasing regular physical activity during the intervention, including gym attendance or participation in specific sports, as well as increasing daily step count on days when the app or wearable is not used, any of which could affect physical activity levels independently of the intervention.

Randomization and allocation

After recruitment and selection of the adolescents, the principal investigator will use a computer-generated random number table in the presence of other investigators not involved in the study to assign adolescents to one of the EG or the CG. All students belonging to the same class within the same educational center will be assigned to the same study group. Baseline measurements will

be performed after randomization. All assessors will be blinded to the participants' group allocations and their prior evaluations.

Study procedure

The procedure for the intervention with mobile apps and wearable devices is outlined in Fig. 2. This design was chosen to align with the main objective and to facilitate the interpretation of both intragroup and intergroup data.

Two intervention periods of 12 weeks each will be conducted. This duration was chosen based on previous research indicating it is optimal for achieving changes in such interventions [11]. The first period, occurring between baseline and post-test measurements, will be mandatory for students, with device use promoted through physical education classes. Students who complete the entire intervention will receive a bonus on their final physical education grade. The second intervention period, between post-test and re-test measurements, will be voluntary and not promoted by the physical education curriculum. This period aims to encourage autonomous use of the devices by students, allowing assessment of adherence generated during the first intervention period.

Baseline, post-test, and re-test measurements will be conducted during the students' weekly physical education classes, ensuring they take place at the same time (between 8:00 and 14:00), on the same day of the week, always in the sports pavilion and under consistent conditions. The measurement protocol, similar across baseline, post-test and retest, will be: (1) on the first day of evaluation, participants will complete the questionnaires in random order, followed by the assessment of anthropometric variables. A subsample will also wear an accelerometer to objectively measure physical activity levels. Finally, all participants will undergo a familiarization session with the physical fitness tests to ensure proper understanding and execution; (2) on the second day, participants will begin with the sit-and-reach flexibility test, performed once prior to the warm-up, as previous studies have reported that warm-up activities may influence performance on this test [12]. Subsequently, they will complete a general warm-up consisting of five minutes of joint mobility exercises targeting the main joints involved in the fitness assessments, followed by ten minutes of progressive running. After the warm-up, participants will perform the physical fitness tests. These will include two repetitions of the following assessments: handgrip strength, countermovement jump (CMJ), standing broad jump (SBJ), curl-up, push-up, and 20-m sprint. Tests will be conducted in randomized order, with two minutes of rest between repetitions of the same test and five minutes between different tests. The 20-meter shuttle run test will be carried out once at the end of the session, due to the high fatigue it produces. This testing sequence is based on recommendations from the National Strength and Conditioning Association (NSCA), which considers the fatigue associated with each test and the predominant metabolic pathways involved [13].

The CG will not participate in the intervention with mobile apps or wearable devices but will undergo the same measurements as the EG (T1, T2, and T3). Like the EG, adolescents in the CG will attend their regular physical education classes and continue their usual physical

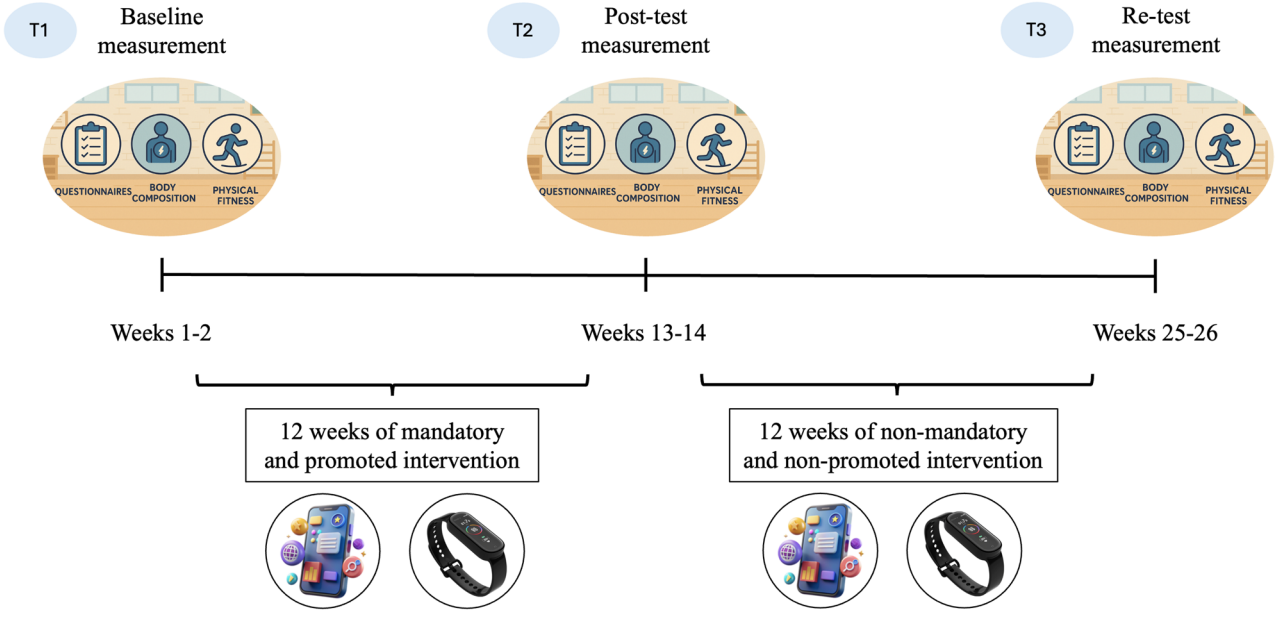

Fig. 2 Study procedure

activities. After the intervention and completion of the T3 measurements, these students will be offered the opportunity to use the mobile apps and wearable devices, with an explanation of their functionality.

Mobile app and wearable devices intervention

For adolescents assigned to the EGs, an explanatory session will be conducted prior to the start of the first intervention. During this session, participants will receive instructions on how to install the mobile app (Strava, Pacer, MapMyWalk, or Pokémon Go) or configure the wearable device (Xiaomi Smart Band or Amazfit Band 7), as well as how to activate it to begin recording their sessions. This session will be delivered by researchers from the project who are not directly involved in subsequent measurements or data analysis.

The mobile apps Strava, Pacer, and MapMyWalk were selected due to their inclusion of a high number of behavior change techniques, which have been shown to be critical in promoting changes in physical activity levels [14]. Pokémon Go, being a game, incorporates a gamification component, which has been demonstrated to be effective in increasing physical activity levels and daily step counts among children, adolescents, and adults [15].

The Xiaomi Smart Band was selected due to its user-friendliness for this population [16], and because it demonstrates good criterion validity and moderate to high accuracy in step counting when compared with ActiGraph accelerometers [17]. Similarly, the Amazfit Band was included as it is one of the wearables that shows adequate validity and reliability for step measurement [1].

During the two 12-week periods, adolescents will be required to use the assigned mobile app or wearable device during out-of-school hours, at least three times per week [18]. In the first week of the intervention, participants must complete a minimum of 5,000 steps each time they use the app or wearable device, as this is the minimum threshold to no longer be classified as sedentary [19]. The ultimate goal of the intervention is for students to reach a target of 12,000 steps per session by the final week; a level associated with moderate-to-vigorous physical activity intensity [20]. To achieve this, the weekly step goal will increase by 684 steps each week. The progression can be found in Table 1.

Table 1 Progression of training volume per session according to the intervention week using mobile apps and wearable devices

Week	Steps per session	Km per session	Weekly volume (Steps)	Weekly volume (km)
1	5000	3.19	15,000	9.58
2	5684	3.63	17,051	10.90
3	6367	4.07	19,102	12.21
4	7051	4.51	21,153	13.52
5	7735	4.94	23,204	14.83
6	8418	5.38	25,255	16.14
7	9102	5.82	27,305	17.45
8	9785	6.25	29,356	18.76
9	10,469	6.69	31,407	20.07
10	11,153	7.13	33,458	21.38
11	11,836	7.56	35,509	22.69
12	12,520	8.00	37,560	24.00

Since some technological devices provide distance data in kilometers rather than step counts, Table 1 includes the conversion from steps to kilometers, based on prior research recommendations for adolescents (1 km = 1,565 steps) [19].

Outcomes

The primary and secondary outcome variables of the study, as well as the instruments or tests used for their measurement, are presented in Table 2. Adolescents participating in the study, both in the EG and the CG, will receive a report at the end of each assessment session. This report will include the values for each variable as well as the progression observed across the different measurement points.

Physical activity level

Participants' physical activity, including daily step counts and intensity levels under free-living, non-structured conditions, will be monitored using the tri-axial ActiGraph wGT3X-BT accelerometer (ActiGraph, LLC, Pensacola, FL, USA), worn on the non-dominant wrist. Device setup, data retrieval, wear time validation, and processing will be performed with ActiLife software (v6.13.3), using a 30 Hz sampling rate and 15-second epochs [21]. A valid day will require ≥ 600 min of wear time; non-wear time will be defined as ≥ 60 consecutive minutes of zero counts, allowing brief interruptions of up to two minutes. Step counts will be estimated using internal algorithms. Time in moderate-to-vigorous (MVPA) and total physical activity will be classified using Evenson's thresholds, validated for adolescents [22]. The ActiGraph has demonstrated strong validity for assessing step counts and activity intensity in adolescents.

Self-reported physical activity will be assessed using the Spanish-validated Physical Activity Questionnaire for Adolescents (PAQ-A) [23], which shows acceptable reliability (ICC = 0.71). The questionnaire comprises nine items: the first eight assess physical activity during the previous week on a 5-point Likert scale (1 = very low; 5 = very high), and the ninth identifies any limiting circumstances via a yes/no response. The mean of items 1–8 will determine overall activity level, with scores >2.75 classified as active and ≤ 2.75 as inactive [24].

Table 2 Study outcomes

Outcome	Category	Variables	Protocol or Test	Instrument
Primary	Physical activity level	Objective measure of physical activity level	-	Accelerometer wGT3X-BT
		Subjective measure of physical activity level	-	Physical Activity Questionnaire for Adolescents (PAQ-A)
Primary	Anthropometric and Body Composition Variables	Body mass	ISAK protocol	TANITA DC 430-SMA
		Height	ISAK protocol	SECA 213 stadiometer
		Sitting height	ISAK protocol	SECA 213 stadiometer
		Skinfolds	ISAK protocol	Harpenden caliper
		Girths	ISAK protocol	Lufkin W606 PM tape
Primary	Physical Fitness	Flexibility	Sit and reach test	Acuflex Tester III box
		Upper body strength	Handgrip strength test	Takei Tkk5401 digital handheld dynamometer
		Upper body strength	Push-up test	Mat
		Lower body power	Countermovement jump	Force platform
		Lower body power	Standing broad jump	Tape
		Abdominal strength and endurance	Curl up	Mat
		Sprint speed	20-m sprint	Single-beamed photocells
		Cardiorespiratory fitness	20-m shuttle run test	Speaker
Primary	Psychological variables	Basic psychological needs	-	Satisfaction and frustration of basic psychological needs
		Satisfaction with life	-	Satisfaction with life scale (SWLS)
Secondary	Eating habits	Adherence to the Mediterranean Diet	-	KIDMED
Secondary	Training volume	Distance covered with the electronic device	-	Electronic device (app or wearable)
Secondary	Mobile and internet experiences	User experiences related with mobile phone	-	Questionnaire of Experiences Related to Internet use (CERI)
		User experiences related with internet	-	Questionnaire of Experiences Related to Mobile phones (CERM)
Secondary	User satisfaction	Satisfaction with the app	-	Mobile Application Rating Scale: user version (uMARS)
		Satisfaction with the wearable	-	Participant experience questionnaire evaluating the use of wearable activity trackers
		Dropout level	-	Dropout open questions

Anthropometric and body composition variables

Body composition and anthropometric variables will be assessed according to ISAK standards [25] by level 3 and 4 certified anthropometrists. Measurements will include three basic measurements (body mass, height, and sitting height); three skinfolds (triceps, thigh, calf); and five girths (relaxed arm, waist, hips, thigh, calf). Each measurement will be taken twice, with a third if discrepancies exceed 1% for basic variables and girths or 5% for skinfolds. Mean will be used when only two measurements are required, while median will be used when three measurements are required.

Validated and reliable instruments, calibrated before each session, will be used and include: Lufkin W606 PM tape (0.1 cm) (Lufkin, Missouri) for girths, Harpenden caliper (0.2 mm) (Burgess Hill, UK) for skinfolds, TANITA DC 430-SMA scale (100 g) (TANITA, Tokyo) for body mass, and SECA 213 stadiometer (0.1 cm) (SECA, Hamburg) for height and sitting height. Intra- and inter-rater error will be calculated in a subsample.

Based on the collected anthropometric data, the following derived variables will be computed: body mass index (BMI = body mass (kg)/height (m)^2), muscle mass [26], fat mass [27], the sum of three skinfolds (triceps, thigh, and calf), the corrected girths for the arm [arm relaxed girth – (π × triceps skinfold)], thigh [thigh girth – (π × thigh skinfold)], and calf [calf girth – (π × calf skinfold)], and waist-to-hip ratio (waist girth/hips girth).

Maturity offset will be estimated using the Mirwald et al. [28] sex-specific equation, and biological maturation calculated as chronological age minus maturity offset, indicating age at peak height velocity (APHV). This method shows strong validity (R^2 = 0.89–0.92 for boys; 0.88–0.91 for girls).

Physical fitness variables

Flexibility of the hamstrings and lower back will be measured using the sit-and-reach test, a valid tool for adolescents [29]. Participants will sit with legs extended, feet hip-width apart against the Acuflex Tester III box (Novel Products, USA) and reach forward maximally with extended knees and arms [30].

Upper-body strength will be assessed with handgrip and push-up tests. Handgrip strength will be measured using a Takei Tkk5401 dynamometer with the elbow fully extended for optimal force output [31]. In the push-up test, participants will start in a prone position with hands shoulder-width apart and toes on the floor. Maintaining a straight body line, they will perform as many push-ups as possible in 60 s, bending the elbows to 90° and fully extending them. Only repetitions with correct form will be counted, and the test will end either when time is up or form cannot be maintained [32].

Lower-body power will be assessed using the CMJ and SBJ. In the CMJ, participants will jump vertically from a standing position on a force platform (200 Hz). From this stance, they will perform a quick downward movement by flexing the knees to approximately 90°, immediately followed by an explosive upward extension to execute the jump. Throughout the entire movement, participants will maintain an upright trunk posture, keep the knees and ankles fully extended during the airborne phase, and ensure that the hands remain on the hips [33]. In the SBJ, participants will jump forward from a shoulder-width stance behind a starting line, swinging their arms and extending hips, knees, and ankles. The distance will be measured from the take-off line to the nearest point of contact, usually the heels [34].

Abdominal strength and endurance will be assessed using the curl-up test. Participants will lie in a supine position with their knees flexed at a 90° angle and feet flat on the floor. Arms will be positioned crossed over the chest. From this position, participants will be instructed to perform as many trunk flexions as possible. A repetition will be considered valid when the upper back fully lifts off the floor [35].

Adolescents' speed will be assessed using the 20-meter sprint test, initiated voluntarily by participants [36]. Sprint time will be recorded via single-beam photocells (Polifemo Light, Microgate, Italy) placed at hip height to reduce arm-triggered timing errors [37].

Cardiorespiratory fitness will be evaluated using the 20-meter shuttle run test [38], where participants run back and forth following progressive audio cues until exhaustion or two consecutive missed lines. VO_2 max will be estimated using Léger's equation. This test is validated and reliable in adolescent populations.

To ensure consistency, each evaluator will be assigned specific tests and will conduct both familiarization and measurements for those tests in all sessions.

Psychological variables

Basic psychological needs satisfaction (competence, autonomy, relatedness) will be assessed using the Basic Psychological Needs Satisfaction scale (BPNs) [39], which shows good validity and internal consistency (competence $\alpha = 0.80$; autonomy $\alpha = 0.69$; relatedness $\alpha = 0.73$). It includes 18 items rated on a 6-point Likert scale, with scores per dimension ranging from 6 to 36, where higher scores indicate greater need satisfaction. The Psychological Need Frustration Scale in Exercise will be used to assess the frustration of basic psychological needs during physical activity. The instrument consists of 12 items rated on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree), grouped into three subscales: autonomy, competence, and relatedness frustration. Higher scores indicate greater psychological need frustration. The scale shows acceptable internal consistency ($\alpha = 0.70–0.71$) [40].

Life satisfaction will be measured using the "Satisfaction with Life Scale" (SWLS) [41], a reliable tool ($\alpha = 0.84$) consisting of five items rated on a 5-point Likert scale, with total scores from 5 to 25; higher scores indicate higher life satisfaction.

Eating habits

Adolescents' adherence to the Mediterranean diet (AMD) will be assessed using the KIDMED questionnaire [42], a valid and reliable tool for evaluating dietary habits in adolescents. It includes 16 yes/no items, with 12 positive and 4 negative questions, scoring from 0 to 12 based on nutritional impact.

Training volume

A designated member of the research team will be responsible for recording weekly the distance covered, in both steps and kilometers, for each participant in the EG. This systematic tracking will serve to monitor adherence to the weekly intervention goals and ensure that participants are meeting the prescribed physical activity targets throughout the study period.

Mobile and internet experiences

These variables will assess whether the intervention with mobile apps and wearables changes adolescents' attitudes and behaviors toward phone and internet use. Problematic use will be measured with the validated Questionnaire of Experiences Related to Internet use (CERI) and Questionnaire of Experiences Related to Mobile phones (CERM) [43], each with 10 items rated 1–4. Reliability is acceptable ($\alpha = 0.77$ for CERI, $\alpha = 0.80$ for CERM). Scores

Table 3 Variables that will be collected in each group during the study

	Baseline			Post-test			Re-test		
	C	M	W	C	M	W	C	M	W
Demographic variables	X	X	X	X	X	X	X	X	X
Physical activity level	X	X	X	X	X	X	X	X	X
Physical fitness	X	X	X	X	X	X	X	X	X
Psychological variables	X	X	X	X	X	X	X	X	X
Eating habits	X	X	X	X	X	X	X	X	X
Training volume					X	X		X	X
Mobile and internet experiences	X	X	X	X	X	X	X	X	X
Device user satisfaction					X	X		X	X

C: control; M: mobile apps; W: wearable

will classify adolescents as having problematic use, occasional problems, or no problems.

User satisfaction

The quality of the mobile apps will be evaluated by EG adolescents using the User Version of the Mobile Application Rating Scale (uMARS) [44], a 26-item tool assessing objective (engagement, functionality, aesthetics, information) and subjective aspects on a 5-point Likert scale. The scale shows excellent reliability ($\alpha = 0.90$).

Wearables will be assessed through a 17-item questionnaire [45] covering usage patterns, satisfaction, willingness to purchase, perceived usefulness, ease of use, attitude, intention, and actual use.

Following previous studies [46], dropout will be evaluated with two open-ended questions about app usage and reasons for non-use, offering options such as "interface too complex", "did not know how to use it" and "not interesting" plus room for additional reasons.

Data collection

All information collected from participants will be completely anonymous. Personal names will not be included under any circumstances, as each participant will be assigned a code. The information collected will be used and made available only to the research team. The variables to be collected in each group are presented in Table 3.

Statistical analysis

Data will be entered into the database by one researcher and verified by a second to ensure accuracy. Normality will be assessed using the Kolmogorov-Smirnov test, as well as skewness and kurtosis analyses. Mean (M) and standard deviation (SD) will be reported as descriptive statistics. For parametric variables, repeated-measures ANOVA will be used to analyze within-group (intragroup) differences between baseline, post-test, and re-test in all the groups. In addition, one-way ANOVA will be performed to evaluate between-group (intergroup) differences at each time point (baseline, post-test, re-test), in order to compare the effects of each app and/or wearable device versus each other and the CG. For non-parametric variables, Kruskal-Wallis ANOVA will be used to assess intergroup differences, while Friedman's ANOVA, followed by the Wilcoxon signed-rank test, will be used for intragroup comparisons. Gender, physical activity level, BMI, maturation status, and training volume will be included as covariates in the analysis. Bonferroni post-hoc tests will be used to determine specific group differences when significant effects are found. Effect sizes will be calculated using partial eta-squared (η^2p) and interpreted as follows: small (≥ 0.10), moderate (≥ 0.30), large (≥ 1.2), and very large (≥ 2.0) [47]. Categorical variables will be analyzed using the chi-square test (χ^2) to identify differences in dropout reasons or device ratings. Corrected standardized residuals (± 1.96) will be used to determine significance, and the contingency coefficient will indicate the strength of association (maximum expected value = 0.707): $r < 0.3$ = low, $r < 0.5$ = moderate, $r > 0.5$ = high [48]. A significance level of $p < 0.05$ will be established for all analyses. Statistical procedures will be performed using SPSS software (version 25.0; SPSS Inc., IL).

Discussion

This protocol is designed for RCT studies assessing the effectiveness of various mobile apps and wearable devices in promoting changes in physical activity levels, body composition, physical fitness, and psychological well-being among secondary school adolescents aged 12 to 16. The use of these technologies is encouraged through physical education classes for application in out-of-school hours.

Its relevance lies in addressing the inconsistency of previous studies, which often used heterogeneous methodologies, tools, and study designs, hindering comparability and limiting conclusions about effectiveness. In contrast, this protocol follows robust research standards, incorporating a randomized controlled design, validated fitness tests, body composition assessments, and reliable questionnaires tailored for adolescent populations.

To address the commonly observed issue of low adherence in past interventions, the study includes two 12-week phases. The first promotes and incentivizes use via physical education classes to foster engagement, while the second phase removes academic incentives to examine autonomous use of the devices.

It also improves upon prior limitations such as reliance on self-report questionnaires for physical activity or small sample sizes in EG. However, challenges remain, including accurately assessing activity intensity via apps and wearables, lack of control over nutritional intake, and usability issues faced by some adolescents.

This protocol aims to serve as a reference model for future interventions involving mobile apps and wearables in adolescent populations, particularly when use is promoted through PE and the goal is to assess impacts on physical activity and health-related outcomes. It is expected that the data obtained in different scientific investigations can be published in high-impact journals, as well as in books and other scientific documents, due to the methodological rigor and standardization provided by this protocol.

Abbreviations

ANOVA	Analysis of variance
APHV	Age at peak heigh velocity
BMI	Body mass index
CG	Control group
CI	Confidence interval
CMJ	Countermovement jump
EG	Experimental group
M	Mean
MVPA	Moderate-to-vigorous physical activity
PE	Physical education
RCT	Randomized controlled trial
SD	Standard deviation
SBJ	Standing broad jump
T1	Baseline
T2	Post-intervention
T3	Re-test
VO_2 max	Maximal oxygen consumption

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None.

Authors' contributions
AMO, LAC and RVC conceived the study and led the development of the study design. AMO and RVC contributed to the methodological framework and drafted sections of the protocol. AMO, LAC and RVC contributed to the design of data collection instruments and ethical considerations. All authors contributed to the writing and critical revision of the protocol, approved the final manuscript, and agree to be accountable for all aspects of the work.

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Data availability
Not applicable.

Declarations

Ethical approval and consent to participate
The Institutional Ethics Committee of the Catholic University of Murcia approved the protocol design and procedures (code: CE022102). Adolescents interested in participating will provide written informed consent, signed by both themselves and their legal guardians if they are minors (under 18 years of age), authorizing the collection and scientific use of relevant data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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