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Feasibility of a mobile health intervention to motivate adolescent fitness and high-intensity exercise adherence (Motivating Adolescent Fitness (MOTAFIT)): protocol for a randomised controlled trial

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ABSTRACT

Introduction Most adolescents fail to achieve recommended levels of vigorous-intensity physical activity, despite the established benefits for cardiorespiratory fitness and vascular health. Supervised interventions can be effective, but are resource-intensive and lack scalability. Mobile health (mHealth) technologies may provide a cost-effective and accessible approach to support structured, individualised training for adolescents. The Motivating Adolescent Fitness (MOTAFIT) trial will assess the feasibility and acceptability of an mHealth-supported exercise intervention for adolescents to inform the design of a definitive randomised controlled trial (RCT).

Methods and analysis MOTAFIT is a three-arm feasibility RCT targeting 120 adolescents aged 13–16 years from the Okanagan Valley, British Columbia. Participants will be randomised (1:1:1) to: (1) MOTAFIT, (2) active control or (3) control group. The 12-week intervention targets ≥40 min/week of vigorous-intensity exercise (≥80% HRmax), co-designed with an exercise specialist and supported by mHealth technology. Primary outcomes for feasibility, including recruitment, retention, adherence, fidelity and acceptability, will be assessed as part of a process evaluation. Secondary measures (cardiorespiratory fitness, vascular health and blood pressure) will provide preliminary estimates to guide future sample size calculations.

Ethics and dissemination The study has received approval from the University of British Columbia Clinical Research Ethics Board (H22-03183) and the University of Victoria Human Research Ethics Board. Parental consent and adolescent assent will be obtained prior to participation. Findings will be disseminated via peer-reviewed publications, conferences and community engagement.

Trial registration number NCT06409793.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ First feasibility randomised controlled trial to deliver co-designed, individualised vigorous-intensity training to adolescents via mHealth with real-time feedback.
⇒ Three-arm design compares mHealth, standard intervention, active control and control, enabling robust assessment of feasibility.
⇒ Comprehensive feasibility outcomes with predefined progression criteria, supported by structured process evaluation.
⇒ Secondary outcomes provide preliminary effect estimates for cardiorespiratory fitness and vascular health.
⇒ Generalisability may be limited to one Canadian region, and blinding of participants and interventionists is not possible.

INTRODUCTION

Physical activity during childhood and adolescence is a key determinant for health throughout the lifespan.[1 2] Current guidelines recommend that adolescents accumulate an average of 60 min of moderate- to vigorous-intensity physical activity (MVPA) daily, with vigorous-intensity physical activity (VPA) on at least 3 days per week.[3] Despite these guidelines, >80% of adolescents globally fail to reach the recommended daily MVPA levels, and <25% of Canadian adolescents are sufficiently physically active.[4] As a result, creating adolescent-specific exercise and physical activity interventions, such as school-based programmes, community initiatives and structured exercise, has become a public health priority.

Within this context, there is increasing recognition that vigorous exercise offers disproportionately greater health benefits compared with low-intensity or moderate-intensity activity.[5–8] Practical methods to achieve these intensities include high-intensity interval training (HIIT), which alternates brief periods of vigorous exercise with recovery intervals.[9] This provides a time-efficient and effective way for adolescents to meet activity goals while enhancing cardiorespiratory fitness and overall well-being.[10]

Supervised exercise programmes for adolescents have been shown to successfully increase both vigorous and total exercise, as well as to improve cardiorespiratory fitness.[11 12] However, the effectiveness of such programmes outside controlled, laboratory environments is limited by logistical challenges and scalability issues.[13] Importantly, feasibility and sustainability must also be addressed to achieve meaningful improvements in fitness and health outcomes. Cost-effective and scalable interventions may reduce barriers to participation and improve access for adolescents unable to engage in resource-intensive supervised programmes. Consequently, there is a need to develop cost-effective, scalable interventions that bridge the gap between supervised programmes and current physical activity guidelines, offering adolescents effective support to engage in vigorous-intensity exercise.

The rise of mobile health (mHealth) technologies and wearable devices, such as activity trackers and heart rate monitors, enhances researchers' capacity to tailor interventions in real time and deliver personalised exercise prescriptions. mHealth initiatives can gather dynamic health-related data and provide intervention content directly within adolescents' daily environments, tackling logistical and scalability barriers associated with supervised training. Wearable devices, including pedometers or accelerometers, have been shown to increase daily physical activity levels in adolescents,[14] while heart rate monitoring offers an accurate way to track individual cardiovascular responses to exercise, providing objective, personalised data that accounts for age, sex, body composition and fitness level.[15] Despite these advantages, current evidence is limited by short intervention durations, a lack of process evaluation outcomes (such as adherence and fidelity) and low-quality outcome measures.[16–18]

Recent advances in mHealth enable pre-programmed exercise sessions to be stored within wearable devices, facilitating live coaching on session duration, structure (eg, work and rest periods) and prescribed intensity via personalised heart rate (HR) zones. This approach addresses the practical barrier of supervision and resource constraints, which previously required setting up satellite labs in schools,[19 20] and introduces behavioural strategies to improve adherence. By offering real-time feedback and guidance, mHealth can help adolescents develop exercise competence, boost autonomous motivation and align physical activity with personal preferences and schedules.[21] Unlike typical home-based programmes, this method incorporates feedback from healthcare professionals—a feature usually limited to supervised settings, potentially further improving adherence and engagement. Consequently, mHealth-based interventions are a feasible and scalable strategy to promote meaningful engagement in vigorous-intensity exercise and physical activity, supporting both immediate participation and long-term behaviour change.

Aims and objectives

The Motivating Adolescent Fitness (MOTAFIT) trial aims to examine the feasibility of implementing an exercise training programme in adolescents using mHealth technology, integrating individualised biometric-informed feedback and coaching into a structured home-based exercise and physical activity programme. The objective of the trial is to inform the design of a full randomised controlled trial (RCT) by establishing the feasibility and acceptability of the intervention and generating preliminary outcome data. More specifically, the trial objectives are to:

1. Determine the recruitment rate for adolescents eligible and willing to take part in the intervention from the Okanagan Valley of British Columbia, Canada (ie, recruitment rate).
2. Determine the feasibility, retention and adherence to the intervention programme.
3. Evaluate whether the intervention was implemented as intended through a process evaluation framework to assess fidelity and acceptability of the intervention.[22]
4. Estimate the precision of secondary outcome measures to inform the sample size estimations for a future RCT. The secondary outcome measures include cardiorespiratory fitness, peripheral and cerebrovascular function, blood pressure and body composition.

METHODS

Study design

This study is a feasibility RCT, with participants randomised (1:1:1) to one of three groups: (1) MOTAFIT, an mHealth group who receive an individualised digital exercise programme with real-time feedback via a wearable device; (2) an active control group, who receive the same programme without mHealth delivery or the biometric feedback or (3) a control group, who receive no intervention and are instructed to maintain their habitual physical activity. Participants will only be informed of their group allocation following completion of all baseline pre-intervention assessments. The trial protocol adheres to the Consolidated Standards of Reporting Trials (CONSORT) extension to pilot and feasibility trials[23] and Template for Intervention Description and Replication[24] guidelines.

As part of the MOTAFIT trial, data will be collected during the intervention to investigate the implementation of the intervention, inclusive of the feasibility, adherence and fidelity of the exercise programme. Secondary outcomes of pre-intervention, mid-intervention and post-intervention measures will be conducted as detailed below, with the primary aim to be used to inform future sample size calculations. A protocol schematic detailing an overview of the intervention is shown in figure 1.

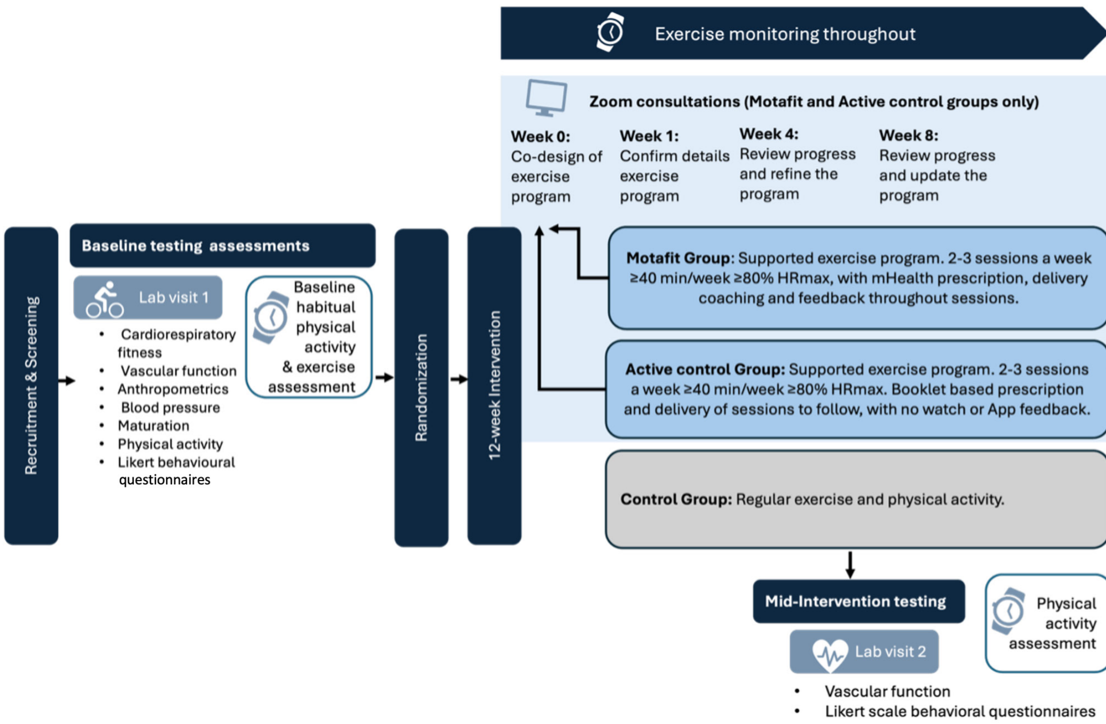

Figure 1 Protocol schematic of the MOTAFIT feasibility trial. mHealth, mobile health; MOTAFIT, Motivating Adolescent Fitness.

Study setting and recruitment plan

The recruitment target is to obtain expressions of interest from approximately 120 participants from the Okanagan Valley of British Columbia, Canada. Recruitment commenced in August 2024 and will last for 18 months. This will be achieved through several recruitment methods: (1) advertisement through flyers in the University and school newsletters, (2) posting to the local online news and (3) through a third-party recruitment service (WayTurn.com), which primarily uses social media platforms to target adolescents and parents in the Kelowna and Okanagan Valley regions.

Eligibility criteria

Participants will be eligible to take part in the trial if they are healthy, aged between 13 and 16 years old and comfortable communicating in English. Participants will initially be contacted by the research team via telephone to discuss the project requirements and eligibility. Participants will be asked screening questions (eg, discussing their medical history) and will be excluded at this point if they meet any of the exclusion criteria detailed below. Written parental consent and adolescent assent will either be collected electronically or when participants first visit the laboratory prior to commencing the trial, depending on their preference.

Exclusion criteria:

- Inability to increase the present level of activity or exercise due to time commitments or activity/sport training requirements.
- Not having access to a smartphone, or having no data plan or access to Wi-Fi.
- Have congenital cardiac abnormalities (eg, tetralogy of Fallot).
- Have a known respiratory disease (eg, asthma).
- Have a known metabolic disease (eg, type 1 diabetes).
- Are pregnant.

Randomisation and blinding

Participants will be randomised in a 1:1:1 ratio to 'MOTAFIT', 'active control' or 'control' using an online randomisation service (https://ctrandomization.cancer.gov/tool/). Randomisation will be stratified by sex (male or female) and performed prior to completion of all baseline assessments. It is not possible to blind the researchers or the participants during the intervention, but analysis of secondary outcomes will be performed blinded to both the interventional group to which the participant was assigned and the time point at which the measurement was taken, for example, the vascular outcomes and cardiorespiratory fitness assessments.

Grounding theories

The MOTAFIT trial will be implemented based on two grounding theories. The theory of expanded, extended and enhanced opportunities states that more physical activity can be accrued if participants are provided with more opportunities, more time for these opportunities and higher quality opportunities for routine physical activity.[25] In line with this theory, MOTAFIT aims to enhance physical activity and exercise opportunities by making these workouts available to adolescents at any time and facilitated by mHealth technologies and the online app training platforms. Additionally, by co-creating workouts and upskilling on using the fitness watch to target high-intensity physical activity, MOTAFIT could enhance participant engagement throughout the intervention as well as the quality of physical activity opportunities. The MOTAFIT programme also includes components that support the Theory of Planned Behaviour[26] which is comprised of components including: (1) attitude about exercise; belief about and evaluation of the consequences of the behaviour, (2) subjective norms; belief about what others want one to do and motivation to comply and (3) perceived behavioural control; belief about the amount of control one has to successfully perform the behaviour. These components are delivered as embedded, theory-informed exercise counselling and motivational supports within the intervention, rather than as a standalone behavioural change programme. Through the use of personalised workouts, real-time heart rate feedback, supportive text messages, planned sessions and exercise counselling, the intervention aims to promote motivation, self-efficacy and adherence. Together, these two theories underpin the design of the trial and aim to support meaningful opportunities for exercise and physical activity while fostering engagement and sustained behaviour change.

Intervention

The primary aim of the active intervention groups (MOTAFIT and active control) is to increase participants' overall physical activity levels, with a specific focus on achieving 40 min of vigorous-intensity exercise at or above 80% of their maximum heart rate (HRmax) . The use of three experimental groups will allow us to discern the impacts of mHealth components specifically compared with a regular exercise programme (ie, active control) and compared with the typical changes that occur during growth and development in adolescence (ie, control).

Participants allocated to the MOTAFIT and active control groups will co-design an individualised exercise programme during online video consultations (Zoom Video Communications, 2016) with an exercise specialist (table 1). These Zoom sessions will involve collaborative discussion of preferred activity types (eg, running, sport, home workouts), preferred exercise environments (eg, home, gym, outdoors) and scheduling. Programmes will be designed to be progressive and modifiable over time, with adjustments made based on participant feedback, preferences and exercise behaviours. The differences in provision between the two intervention groups are detailed below.

Table 1 Overview of exercise counselling meetings

	Time point	Details
Meeting 1	Prior to intervention commencing	First meeting to explore the participant's current exercise habits and preferences, views towards exercise and barriers, inclusive of injury and physical limitations to exercise. Inform the participant which group they have been randomised to. Agree on a SMART (specific, measurable, achievable, relevant and time-bound) plan.
Meeting 2	Prior to intervention commencing	Co-creation of personal exercise programme for participant with the exercise specialist. The participant will also be educated on the intensity of the exercise they should be aiming for and the use of any technologies (for the mHealth group).
Meeting 3	End of 4 weeks	Participant feedback and programme refinement to progress the programme if appropriate.
Meeting 4	End of 8 weeks	Participant feedback and programme refinement to progress the programme if appropriate.

mHealth, mobile health.

Exercise prescription criteria

For both exercise groups (MOTAFIT and active control), exercise programmes will be co-designed between each participant and the exercise specialist across two initial consultations. In the first session, adolescents will discuss their preferences, goals, available facilities and prior exercise experience. This information will be used to collaboratively develop a personalised 12-week exercise programme, which will be refined and explained in a second consultation. All programmes are designed to be flexible in mode, setting and scheduling, allowing participants to choose activities that suit their lifestyle while meeting core prescription criteria. The primary criteria are set to accumulate a minimum of 40 min per week at ≥80% of HRmax, primarily through HIIT or sprint interval sessions. HIIT sessions will be defined as structured workouts in which at least 50% of the total session duration is spent performing high-intensity work intervals (rate of perceived exertion (RPE) ≥7 or ≥80% HRmax), interspersed with recovery periods. Sessions will typically include 10–15 min of accumulated high-intensity effort, with total session length, structure and activity/exercise type tailored to the individual's preferences.

The post-doctoral research fellow (PhD in Exercise Physiology) on the trial will be the exercise specialist for the duration of the study for all participants. They have received extensive training on how to implement the mobile health intervention from one of the exercise training specialists in the MOTIVATE-T2D trial, which used the same mobile health technology to train individuals who had recently been diagnosed with type 2 diabetes.[27]

MOTAFIT group

There are three mHealth components used to support the delivery of the MOTAFIT intervention: online coaching platform (Polar Flow for Coach, www.polar.com/coach), for the exercise specialist, a smartphone app for the participant (Polar Flow, www.polar.com/) and the fitness watch (Polar Ignite 2, Polar Electra). Participants in the MOTAFIT group will receive their programme through the Polar activity watch and the online PolarFlow app. The exercise specialist will programme the mutually agreed on frequency and duration of sessions and required individualised intensity (via heart rate zone) via the Polar Online coaching platform (Polar Flow for Coach, www.polar.com/coach), which will sync to the watch via the Polar smartphone app (Polar Flow-Sync & Analyse). The exercise specialist will use the data from the cardiorespiratory fitness test completed in the laboratory to set the individualised intensity of the sessions. The preset exercise sessions will then be available for the participant to follow on the watch and will include a warm-up and a cool-down phase. After completing the session, participants will be asked to provide feedback on the session, including a rating of perceived exertion (CR-10 scale[28]) and written comments. This information, along with daily physical activity and their exercising heart rate, will be used by the exercise specialist to modify and progress the exercise programme if necessary. Participants will also be educated in the meetings with the exercise specialist about exercise intensity, and how to use the heart rate zones in the watch to check they are working at the correct intensity during their workouts. The fitness watch will coach the participant through the workout and provide visual and haptic (vibration) alerts indicating the live heart rate zone in which the participant is currently working, to ensure they are in the correct zone for each section of the workout. Participants will be able to record additional activities on the watch. Participants will initially receive daily individualised pre-scripted text messaging and after 4 weeks, the frequency of the text messages decreases to weekly messaging. The content of these text messages will be informed via a decision tree of pre-scripted messages tailored based on each participant's exercise adherence (number of completed sessions, duration of sessions and time spent in the prescribed heart rate zone) as recorded by the fitness watch and synced to the Polar Online Platform. Participants will have the opportunity to respond to these messages and ask questions, but it is not a requirement to respond.

Active control group

Participants in the active control group will receive an individualised, co-designed exercise programme in the form of a booklet, detailing the exercise sessions (duration, intensity (RPE), activities and workout structure) and weekly prescription based on the sessions designed in the exercise counselling sessions. The individualised booklet will also contain examples of exercises they could perform as part of their training and instructions with photographs on how to perform them. Participants will be asked to record the exercise sessions on the activity watch (Polar Ignite 2, Polar Electra) and sync these with the app, but they will not be provided with any information in regard to what target heart rate they should be achieving during the sessions, and will not receive live coaching through the exercise session. Participants will use RPE-based prescription of exercise intensity. As with the MOTAFIT group, participants will receive weekly pre-scripted text messages based on whether they are meeting the exercise goals or not. The text messages target the three components of self-determination theory: autonomy, competence and relatedness.[21] Similarly to the MOTAFIT group, participants will not be required to respond to text messages.

Control group

The control group will be encouraged to maintain their normal exercise habits and will not be given a programme by the research team. They will be given a Polar activity watch (Polar Unite) to record their normal exercise and daily activities, but they will not have access to the Polar app (Polar Flow). The researchers will sync the watch to gather the data at the 6 weeks visit and the post-intervention visit (12 weeks). The active control group will not receive regular text messages from the exercise specialist. They will only receive scheduled messages at 4 and 8 weeks to check in with them to ensure they are still regularly wearing the watch. Participants in the active control will still meet briefly with the exercise specialist at the same time points outlined in table 1 but the content of meetings 2–4 will simply be to check in with the participant to keep them engaged in the study and wearing the Polar device to ensure measurement of exercise and physical activity in this group. After completion of the trial, all participants in the active control group will be offered a tailored 12-week exercise programme.

Study withdrawal

The primary outcomes of this trial are participant recruitment rate and retention rate. A full CONSORT diagram will be produced by keeping record of the number of potential participants approached, reasons for not participating, the number completing each assessment time-point and the number dropping out during the intervention with the reasons for not completing the study. Participants will be free to withdraw from the study at any time, and this will be explained to them during the consent process. Reasons for withdrawal will be documented for reporting in the CONSORT diagram. All data collected up to withdrawal will be included, unless participants specifically ask for this to be removed. Participants who withdraw during the intervention will be invited back for the mid-intervention and follow-up testing.

Table 2 A priori criteria for the assessment of feasibility

Feasibility outcome	Definition	Criteria for success
Recruitment rates	The enrolment of referred and eligible participants.	≥50% of all contacted participants recruited.
Retention	The completion of the programme and end-of-programme assessment.	≥70% of participants completing an end-of programme assessment.
Attendance	The frequency of exercise (number of sessions recorded) and percentage of prescribed sessions completed.	≥70% of the prescribed workouts completed.
Adherence	Fidelity of the intervention (average HR, peak HR and time spent above 80% HRmax).	≥50% of time above 80% HRmax.
Training drop-off	The week in which participants no longer completed any training sessions.	≥70% of weeks with completed training sessions.

HR, heart rate; HRmax, maximal heart rate.

Serious adverse event reporting and monitoring

In the unlikely event of a serious adverse event occurring, it will be reported, and the severity of the event will be classified by the research team. An independent clinician will determine causality of the event. Records will also be kept of all non-serious adverse events, and these will be followed until resolution.

Intervention outcomes

Primary outcomes

Feasibility will be assessed such that at least three of the five a priori criteria shown in table 2 are fulfilled.

Exercise adherence and habitual physical activity

The adherence and fidelity to the exercise programme will be measured using two different methods

1. Device-derived assessment of exercise sessions: optical heart rate monitoring (photoplethysmography) will be used to track completion, intensity and duration of all recorded exercise sessions. Participants' maximum heart rate will be determined during the baseline cardiorespiratory fitness assessment. Heart rate data will be used to assess intervention fidelity through average and peak heart rate attained per session, the percentage of sessions above 80% of maximum heart rate, and the percentage of time spent in higher intensity zones (>80% and >90% HRmax). The MOTAFIT group will receive their individualised exercise programme via the Polar Ignite 2 watch and Polar Flow app, including live heart rate feedback, whereas the active control and control groups will use Polar watches to record sessions but will not receive live coaching or app-based feedback. This design allows assessment of whether guided, real-time heart rate feedback provides additional benefit over unguided exercise programmes.
2. Device-derived physical activity levels: the GENEActiv (Activinsights, Cambridge, UK) tri-axial wrist-worn accelerometer will be worn continuously on their non-dominant wrist for 7 days at baseline/prior to starting the intervention and in the final 7 days of the intervention period. The research team will programme the accelerometer to start and stop recording on the required dates before giving to the participant. The manufacturers' software will be used to extract the data and the open-source GGIR software package (http://cran.r-project.org) in R (R Core Team, Vienna, Austria) will be used to process the data. Paediatric-specific cut points will be used to calculate time spent in different exercise intensities.[29] Average minutes per day of light, moderate, vigorous, moderate to vigorous and total physical activity, minutes of inactivity (sedentary plus standing) time and device wear time will be reported. The Polar watches will also provide steps per day and daily caloric expenditure as indicators of physical activity throughout the intervention. Assessment of habitual physical activity will be used as an outcome variable to determine differences between groups and over time.

Process outcome evaluation

The process evaluation of the intervention implementation will be guided by the Framework for Effective Implementation developed by Durlak and DuPre,[22] which is specific to youth and adolescents. The intervention reach and number of participants contacted about the study will be tallied to inform the recruitment rate of the programme. The number of workouts prescribed by the exercise specialist and completed by participants will be recorded to inform the dosage delivered and received (adherence). Heart rate will be recorded to assess fidelity to reach the target high intensity of the workouts. Heart rate and number of exercise sessions completed will also be used to monitor the active control and control group. Any adaptations and modifications to the exercise prescription and completion will be recorded by the exercise specialist. Enjoyment,[10] self-efficacy, perceived behaviour control,[30] and positive and negative affect[31] will be recorded to understand participant responsiveness to the programme delivered via Likert scale questionnaires.

Pre-intervention and post-intervention outcome measures

Data will be collected on a variety of secondary outcomes at baseline and following the 12-week intervention as detailed below and in table 3. These data will primarily be used to inform sample size calculations for future studies. All participants will have these outcomes assessed

Table 3 Overview of secondary outcomes conducted at baseline and following the intervention

Outcome	Time point	Measurement technique(s)	Detailed outcomes
Cardiorespiratory fitness	Pre-intervention and post-intervention	Ramp incremental cardiopulmonary exercise test to exhaustion on cycle ergometer with metabolic cart	Peak oxygen uptake Peak power output
Anthropometrics	Pre-intervention, mid-intervention and post-intervention	Laboratory assessment	Stature, seated height, body mass and body composition (fat mass, fat free mass, body fat percentage)
Resting blood pressure	Pre-intervention, mid-intervention and post-intervention	Automated device	Systolic and diastolic blood pressure
Exercising blood pressure	Pre-intervention and post-intervention	Manual assessment	Systolic and diastolic blood pressure
Resting vascular outcomes	Pre-intervention, mid-intervention and post-intervention	Duplex ultrasound Flow mediated dilation	Internal carotid artery and vertebral artery blood flow and shear rate (global cerebral blood flow) Endothelial function of the superficial femoral artery
Exercising vascular outcomes	Pre-intervention and post-intervention	Transcranial Doppler	Cerebral blood velocity of the middle cerebral artery and posterior cerebral artery
Maturation	Pre-intervention and post-intervention	Questionnaire Verbal reporting Sex-specific regression equations.[54] Saliva samples and ELISA kits	Tanner staging Menstrual cycle stage Age in years from peak height velocity Testosterone, progesterone, oestradiol and dehydroepiandrosterone
Questionnaires	Pre-intervention, mid-intervention and post-intervention	Paper copies completed in the laboratory	Positive and negative affect scales Physical activity enjoyment scale Physical activity enjoyment scale (for HIIT) Self-efficacy for behaviour scale Perceived behavioural control scale

HIIT, high-intensity interval training.

at baseline (Week 0) and post-intervention (Week 12). A subsample of the outcomes will also be measured after 6 weeks of training (Week 6).

Cardiorespiratory fitness

Peak oxygen uptake ($\dot{V}O_{2peak}$) will be assessed through an incremental exercise test to exhaustion on a cycle ergometer[32] at baseline and after 12 weeks of training to allow evaluation of any changes in cardiorespiratory fitness from the intervention. A Quark PFT system (COSMED, Rome, Italy) will be used to measure expired pulmonary gases breath by breath, before converting to 10 s averages to determine $\dot{V}O_{2peak}$ which will be the highest 10 s average. Following a 2 min warm-up with no resistance on the bike, the resistance will incrementally increase until volitional exhaustion, despite strong verbal encouragement. The ramp rate (10–25 W/min) will be determined by the research team based on the participants' stature, body mass and current exercise habits to elicit a test duration of between 8 and 12 min. Heart rate will also be monitored throughout the test with a Polar heart rate monitor (H10, Finland) and a 3-lead echocardiogram (ADI Bioamp ML132, ADInstruments). Exercising blood pressure will be taken manually every ~2 min, as close as possible to thresholds and at the end of the test. Participants will complete a 5 min cool down at 20 W. The $\dot{V}O_{2peak}$ will be used as a secondary outcome measure to examine differences between groups and over time following the intervention. Additionally, ventilatory threshold one and two will be identified and used in combination with the $\dot{V}O_{2peak}$ and heart rate data to prescribe the intensity of the exercise sessions for the mHealth group.

Anthropometrics and blood pressure

At baseline, after 6 weeks of training and after 12 weeks of training, stature and seated height will be measured with participants barefoot using a stadiometer (Seca Portable, Seca, Hamburg, Germany). Body mass and composition will be assessed using electronic scales (Tanita body composition analyser TBF-410, Tanita Corp, Arlington Heights, Illinois, USA) with participants wearing light clothing (eg, shorts and a t-shirt). Resting blood pressure will also be assessed using an automated blood pressure monitor (OMRON BP769CAN, OMRON HEALTHCARE, Co. Ltd, Kyoto, Japan). These assessments will be used as a covariate to determine differences based on body mass or composition and resting blood pressure.

Vascular outcomes

Cerebral blood velocity responses to incremental exercise

Cerebral blood velocities (CBv) will be continuously recorded during a 5 min resting baseline and throughout the maximal exercise test to exhaustion ($\dot{V}O_{2peak}$). CBv will be assessed in the right middle cerebral artery and the left posterior cerebral artery using a 2 MHz transcranial Doppler ultrasound (Spencer Technologies, Seattle, Washington, USA). Paediatric-specific headbands will be used and respective arteries insonated through the transtemporal window using standardised methods.[33] Data will be collected and stored for later offline analysis using an analogue-to-digital converter (PowerLab16/30, ADInstruments, Colorado Springs, Colorado, USA). Blood velocity will be assessed as a secondary outcome variable to compare responses between groups and over time following the intervention.

Resting cerebral blood flow

Artery diameter and blood velocity of the internal carotid artery will be assessed at baseline, after 6 weeks of the intervention and after 12 weeks of training using a 15 MHz multi-frequency linear array Doppler ultrasound probe (Terason, uSmart 3300, TeraTech, Burlington, Massachusetts, USA). B-mode imaging will be used to measure the arterial diameter while simultaneous pulse wave will concurrently record peak blood velocity. The vessel will be imaged at least 1.5 cm distal to the common carotid bifurcation to avoid turbulent and retrograde flow and non-uniform shear patterns. These assessments will be made in accordance with published technical recommendations.[34] All recordings will be taken as a resting 2 min baseline for assessment of resting cerebral blood flow. Videos will be screen captured and stored as video files for subsequent offline analysis. Analysis of artery diameter and peak blood velocity at 30 Hz will be performed using custom-designed edge-detection and wall-tracking software (BloodFlow Analysis, V.5.1), which is largely independent of investigator bias.[35] This is a software programme written using National Instruments to analyse scans by researchers at the University of Western Australia and is not commercially available, and only used for academic research purposes, and shared freely among the vascular research community. The research team has used this coded programme for over 10 years, with no possibility of commercialisation of the programme, and no conflicts of interest with the research team. Recent papers contain detailed descriptions of the analysis approach.[36] From synchronised diameter and velocity data, blood flow (the product of lumen cross- sectional area and Doppler velocity) will be calculated at 30 Hz. Shear rate (an estimate of shear stress without viscosity) will be calculated as four times mean blood velocity/vessel diameter. Reproducibility of diameter measurements using this semi-automated software is significantly better than manual methods, reduces observer error significantly and possesses an intra-observer coefficient of variation of 6.7%.[37] Measurement of cerebral blood flow will be used as a secondary outcome assessment to examine differences between groups and over time.

Peripheral vascular function—superficial femoral artery

Peripheral vascular function of the superficial femoral artery will be assessed following the international guidelines[38] at baseline, after 6 weeks of training and after 12 weeks of the intervention to monitor changes in lower limb endothelial function and arterial structure from training. The participants will rest supine for ~15 min before high-resolution ultrasound (Terason t3200TM, Teratech, Burlington, Massachusetts, USA) with a 10 MHz multifrequency linear array probe will be used to image the right superficial femoral artery ~3 cm below the bifurcation point. A rapidly inflatable pneumatic cuff will be placed ~5–10 cm above the knee joint but distal to the ultrasound probe and will be inflated to 50 mm Hg above resting systolic blood pressure.[39] Continuous recordings of both diameter and Doppler measurements of blood flow velocity of the superficial femoral artery will be captured for 1 min prior to cuff inflation. After 5 min of cuff inflation, the cuff will be rapidly deflated and continuous measurement of diameter and blood flow velocity will be recorded for a further 3 min to capture peak dilation.

As with the analysis of resting cerebral blood flow, the same semi-automated custom-designed edge-detection and wall-tracking software[40] will be used to analyse the superficial femoral artery diameter and blood flow velocity. The researcher will be blinded to both the intervention group and time point the measurement was taken. The software produces continuous, simultaneous measurements of arterial diameter, blood velocity, blood flow and shear rate, and a post hoc calculation of flow-mediated dilation (FMD). The FMD data will be presented as both an absolute (mm) and relative (%) increase from baseline diameter. The relationship between baseline diameter and FMD will be examined, and if significant, allometric scaling will be performed.[41 42] Post-deflation shear rate area under the curve (SR_{AUC}) will also be reported.[43 44] Measurement of superficial femoral artery FMD, diameter, blood flow and shear rate will be used as a secondary outcome assessment to examine differences between groups and over time.

Assessment of maturation

Several methods of assessment will be used to estimate the participants' maturation:

1. Tanner staging.
2. Menstrual cycle.
3. Age in years from peak height velocity.
4. Saliva samples for sex hormones.

Assessment of maturation will be completed at baseline and post-testing and used as a covariate in data analysis to discern and control for the changes in outcome measures that occur as part of normal growth and development compared with those from the MOTAFIT exercise intervention. Methods 1–3 are more commonly used in this population; however, inclusion of hormonal data may be more accurate and provide a more comprehensive understanding. Thus, the current study will pilot the feasibility of collecting saliva samples for sex hormone concentration analysis in this population as a secondary assessment. Additionally, oestrogen is thought to be atheroprotective,[45] so differing concentrations of oestrogen within and between participants could affect the vascular outcomes. Therefore, a direct measure will be valuable as a covariate when examining changes in the vascular outcomes in the trial.

Tanner staging

The participant will be asked to self-report the pubic hair and breast or genital development stage using the line drawings of the stages of secondary sexual characteristics.[46]

Menstrual cycle

We will not control for phase of the menstrual cycle because adolescents do not always have a regular, predictable cycle in the first few years of menstruating. However, we will collect information on the stage of the menstrual cycle they are in when they visit the laboratory for testing and the year that they had their first menstruation.

Age in years from peak height velocity

Age in years from peak height velocity will be calculated from validated sex-specific equations as an estimate of somatic (maturation) status.[47] Values of >−1 y indicate pre-peak height velocity, <−1 to <1 y indicates circa-peak height velocity and >1 y suggests post-peak height velocity.

Saliva samples for assessment of adrenal and gonadal hormones

Given that hormonal biomarkers begin rising at the onset of puberty and prior to the appearance of any physical changes assessed via Tanner staging,[48] measuring pubertal maturation with direct biomarkers is of importance in the current population to characterise maturational stage. Salivary sampling for the assessment of gonadal hormones will be used given its non-invasive nature and ability to reliably reflect hormone levels in adolescents.[49] Participants will be guided through the first sample collection process via the passive drool technique in the laboratory with a member of the research team and provided with supplies for a further two samples over the subsequent two mornings. This will be done due to the cyclic variability in hormones during maturation, to average the samples across a 3-day period in an effort to obtain more representative hormone levels. Samples will be taken according to best practice guidelines[50] following at least 1 hour fast prior to collection and avoidance of caffeine for 12 hours prior. To avoid contaminating the samples, participants will be asked to refrain from eating for 2 hours prior to sample collection and to not drink anything other than water for 30 mins before. Participants will place the samples in their freezer at home before participants will either return the samples to the laboratory themselves or a member of the research team will arrange to pick them up from a convenient location. All saliva samples will be initially frozen at −20°C and transferred to −80°C until data collection has been completed so they can be batch analysed using ELISA kits (Salimetrics LLC, California, USA).

Likert scales

Participants will be given a pack of questionnaires in the form of Likert scales to complete during the three visits to the laboratory (pre, mid and post intervention). These will include the positive and negative affect scale,[31] perceived behaviour control scale,[30] Physical Activity Self-Efficacy Scale and Self-Efficacy for Exercise Behaviour.[51] Additionally, they will complete the Physical Activity Enjoyment Scale for children and adolescents[52] and a modified version of this for high intensity exercise specifically, by editing the starting phrasing to 'when I am participating in high-intensity exercise'. Responses will be used to understand differences in enjoyment, confidence and behavioural control in relation to physical activity and exercise between groups and over time.

Data analysis

To describe the population, descriptive statistics will be reported for each intervention arm (MOTAFIT, active control and control group) of the study separately. The implementation of MOTAFIT and the feasibility of the programme will be evaluated using the Framework for Effective Implementation[22] across eight components:

1. Programme reach—number of expressions of interest and consenting adolescents.
2. Dosage—the number of planned workouts delivered and completed.
3. Fidelity—adolescents' heart rate during the workouts.
4. Quality—variation in heart rate between groups.
5. Monitoring of control group—via heart rate.
6. Responsiveness—participants' enjoyment, motivation and perceived behavioural control.
7. Adaptation—modifications of the workouts by the exercise specialist.
8. Differentiation—uniqueness of study relating to aspects of mHealth.

For secondary analyses, to determine the effect of the mHealth intervention on cardiorespiratory fitness and vascular health, general linear models will be used to assess changes in the dependent variables with group (MOTAFIT, active control, control), timepoint (pre-intervention, post-intervention) and group×time interaction included as independent variables. To determine the effect of involvement in mHealth on individuals' motivation, enjoyment, self-efficacy, feelings and perceived behavioural control, generalised linear models will be used to assess changes in the dependent variable, with group (mHealth or not), timepoint and group×time interaction included as dependent variables. Potential covariates, such as sex, age, maturation, body mass index, baseline cardiorespiratory fitness, baseline physical activity levels, baseline physical activity enjoyment and baseline levels of the dependent variable will be identified using two-by-two tests and included in the model where appropriate. Results will be presented descriptively, with estimates of change and associated 95% CIs provided to inform the precision and direction of effects. These findings will guide the design and sample size calculations of an RCT.

Sample size

No formal sample size calculation has been performed since this is a feasibility trial. One of the primary aims of the trial is to estimate recruitment rates within the specified period. Based on previous experience with this population, targeting approximately 120 responses or expressions of interest is feasible for the research team and is expected to yield a final sample of around 60 participants. This aligns with guidance for feasibility studies, which typically recommend 24–50 participants to assess recruitment, retention, intervention fidelity and outcome variability.[53]

Trial management

JK and KJS will manage the day-to-day running of the study and will report back to AMM and KJS at regular intervals. Recruitment rates will be reported monthly either via email or during regular meetings to review the progress of the trial. A minimum of one meeting per year will be held. Data will be managed and stored according to the British Columbia's Freedom of Information and Protection of Privacy Act 2015. Data entry from paper files will be completed by one researcher, with at least 10% checked by a second researcher. Any errors will be corrected and records kept detailing these changes. All data will be stored on a password-protected and secure server.

Ethical considerations and study dissemination

The MOTAFIT trial has received approval from the Clinical Research Ethics Board of the University of British Columbia (H22-03183) and it was also reviewed and approved by the Human Research Ethics Board at the University of Victoria. Participants and their parents will be provided with detailed information about the study procedures and given adequate time to decide on whether they would like to take part in the trial. They will also have the opportunity to contact the research team to discuss any questions they have about the project. Copies of the parental information sheet and consent form (online supplemental file 1) and the adolescent information sheets and assent form (online supplemental file 2) are available in the supplementary files. The parental consent and adolescent assent forms will be signed either in person in the laboratory or returned via email to the researchers. The participant and their parent/guardian will receive a copy of the completed consent and assent form for their records, with the originals kept by the research team. It will be explained to the participant and their parent/guardian that they are able to withdraw from the study at any time without any negative consequences. All data will be anonymously stored on a secured server. The results of the trial will be disseminated through publications in peer-reviewed journals and conference presentations.

Patient and public involvement

No formal patient or public involvement framework was established for this study. However, adolescents contributed to the co-design of their individualised training programmes throughout the study period via Zoom meetings and reviewed participant-facing materials (eg, exercise sessions, app content and instructions) to enhance clarity and engagement.

DISCUSSION

This protocol describes the MOTAFIT intervention, a randomised feasibility trial investigating the use of mHealth technology to increase vigorous exercise and habitual physical activity in adolescents. The MOTAFIT trial includes the novel component of delivering co-designed, individualised training programmes through wearable devices with live coaching and real-time heart rate feedback. This approach removes the need for in-person supervision while maintaining the structure and fidelity of exercise sessions, offering a scalable solution for supporting VPA in youth.

In addition to feasibility outcomes, the trial will explore whether increased vigorous exercise translates into improvements in cardiorespiratory fitness and vascular health. Importantly, MOTAFIT will also evaluate implementation fidelity using a process evaluation framework. This is pertinent given that evidence on how mHealth interventions are adopted and maintained in adolescents remains limited, and understanding the link between implementation and outcomes is critical for developing effective, scalable exercise interventions.

Unlike previous adolescent exercise interventions that often rely on supervised laboratory sessions or satellite school laboratories, MOTAFIT leverages mobile technology to provide flexible, accessible and engaging opportunities for exercise. By examining feasibility alongside secondary health outcomes, the trial will provide valuable insight into whether digital health supported exercise training can bridge the gap between fully supervised interventions and real-world application.

Overall, the results of this feasibility trial will inform the design of a future RCT and contribute to the growing body of evidence on the meaningful implementation of mHealth-based exercise interventions in adolescents.

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