

Scaling-Up Adolescent High-Intensity Interval Training Programs for Population Health

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LUBANS, D.R., N. EATHER, J.J. SMITH, M.W. BEETS, and N.K. HARRIS. Scaling-Up adolescent high-intensity interval training programs for population health. *Exerc. Sport Sci. Rev.*, Vol. 50, No. 3, pp. 128–136, 2022. *High-intensity interval training (HIIT) has become a polarizing form of exercise. In this article, we argue that adolescent HIIT programs can have population health impact if they are (i) integrated into existing opportunities, (ii) designed to develop physical literacy, (iii) delivered in an engaging manner, and (iv) guided and supported by an implementation framework that addresses relevant barriers and facilitators.* **Key Words:** exercise, physical activity, intervention, implementation science, health promotion, physical education, health psychology

Key points

- Despite the clear benefits for a wide range of health outcomes, high-intensity interval training (HIIT) has become a polarizing form of exercise. Critics have suggested that HIIT has no value as a population health promotion strategy because it is a complex form of exercise that requires high levels of self-regulation to be effective.
- In this article, we present a multidisciplinary conceptual model consisting of four complementary yet overlapping tenets that we believe are fundamental to the successful scale-up of adolescent HIIT interventions.
- We argue that adolescent HIIT programs have the potential to improve population health if they are (i) integrated into existing opportunities (e.g., physical education and organized sport), (ii) designed to develop physical literacy (i.e., motivation, confidence, physical competence, and knowledge to be active across the lifespan), (iii) delivered in an engaging manner, and (iv) guided and supported by an implementation framework that addresses relevant barriers and facilitators.

INTRODUCTION

The health benefits of physical activity for youth (i.e., children and adolescents) are extensive (1). Importantly, when youth participate in physical activity of sufficient volume and

intensity to enhance health-related fitness (i.e., cardiorespiratory fitness (CRF), muscular fitness, and body composition), additional benefits are accrued (2,3). For these reasons, the World Health Organization recommends youth to do at least an average of 60 min·d⁻¹ of moderate-to-vigorous intensity physical activity (MVPA) across the week, comprised mostly of aerobic activities. As part of the 60 min, youth are encouraged to participate in vigorous-intensity aerobic activities and muscle and bone strengthening activities at least 3 d·wk⁻¹ (4). However, physical activity declines precipitously during adolescence (5), and globally, less than 20% of adolescents are sufficiently active (6). Innovative solutions are needed to address this public health challenge.

High-intensity interval training (HIIT) is a structured mode of exercise that has received substantial attention from both researchers and the lay public in recent years showing potential for promoting health via the accrual of vigorous-intensity activity. HIIT protocols generally involve relatively short, yet intense bouts of activity (i.e., typically >85% maximum heart rate), interspersed with periods of active rest or recovery. Although HIIT originated in the early 20th century, the popularity of HIIT has grown substantially in the past decade, ranking in the top five exercise trends each year since 2014 (7). The main appeal of this mode of exercise is that it can induce similar physiological benefits to that of moderate-intensity continuous training in a shorter time period.

In recent years, there also has been an exponential increase in the number of studies demonstrating the health benefits of HIIT for adolescents (see Fig. 1 for a summary of protocols that have been used with youth) (8). Logan and colleagues (9) published the first review of adolescent studies in 2014, providing initial support for the cardiometabolic health benefits of HIIT. Subsequent systematic reviews and meta-analyses (10–12) provided further evidence supporting HIIT as a safe, feasible, and time-efficient approach for improving CRF, body composition,

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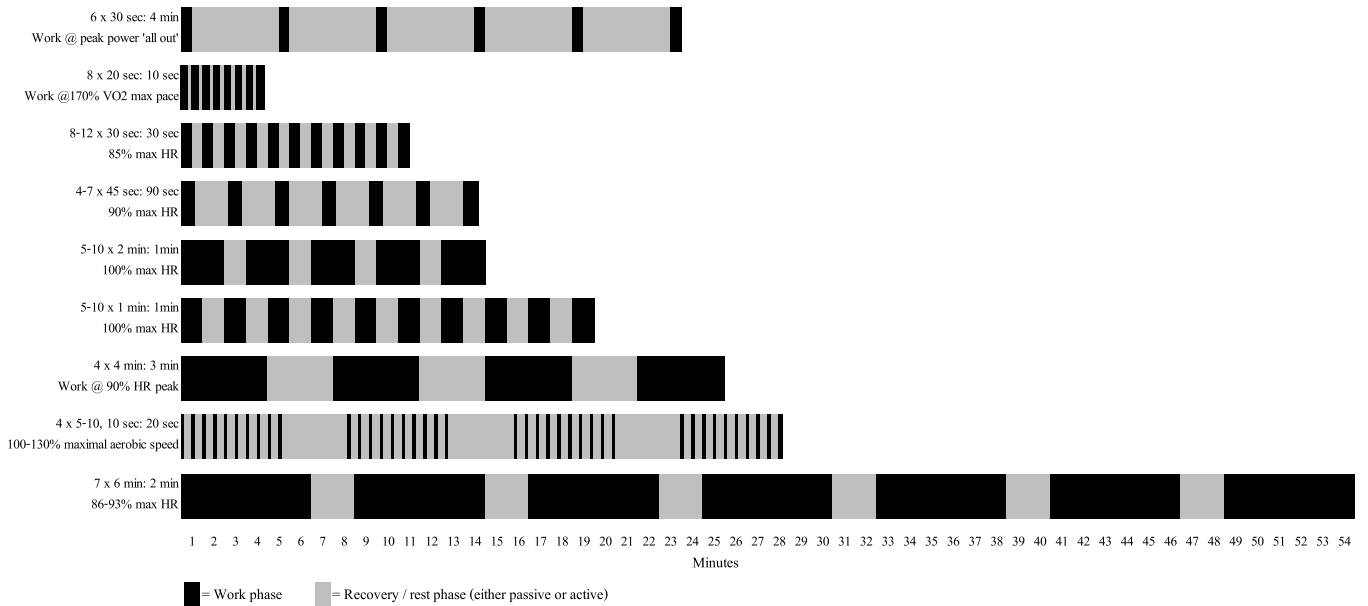


Figure 1. Summary of high-intensity interval training (HIIT) protocols used with youth. [Adapted from Smith *et al.* (8). Copyright © 2020 Taylor and Francis. Used with permission.]

and cardiometabolic health in youth. There is also emerging evidence for the positive effects of HIIT on affect, mental health, and cognitive function in youth (13).

Despite the clear benefits of HIIT for a wide range of health outcomes, HIIT has become an increasingly polarizing form of exercise (14,15). More specifically, it has been argued that HIIT does not have potential as a population health promotion strategy because it is a complex form of exercise that requires high levels of self-regulation to be effective (14). One of the major criticisms of HIIT is that the unpleasant feelings associated with vigorous or high-intensity exercise (16) might have a negative effect on future physical activity (17). Others have argued that once warm-ups and cool-downs are included, HIIT is not particularly time-efficient (15).

In this article, we argue that HIIT is neither a pariah nor a panacea for the global physical inactivity pandemic. Alternatively, we believe

well-considered HIIT programs can contribute to the global challenge of physical inactivity by providing adolescents with (i) a potent, time-efficient and enjoyable dose of vigorous physical activity, and (ii) the motivation, confidence, physical competence, and knowledge to participate in HIIT (as part of a smorgasbord of physical activity options (18)) across the lifespan. We present a conceptual model that outlines key considerations for the design, delivery, and scale-up of HIIT programs for nonclinical populations based on our collective adolescent HIIT research (10,13,19–24). We provide evidence from our *Burn 2 Learn (B2L)* study and other relevant school- and sport-based HIIT programs to support the utility of our proposed model.

Conceptual Model

Our conceptual model (Fig. 2), informed by exercise psychology, physical education (PE), exercise science, and implementation

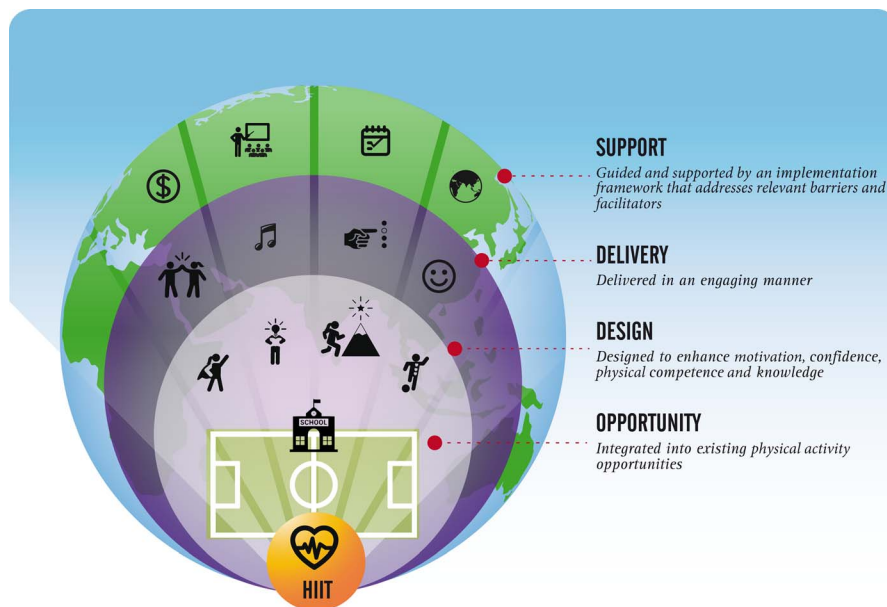


Figure 2. Conceptual model outlining key considerations for the design, delivery, and scale-up of youth high-intensity interval training (HIIT) programs.

science, includes four complementary, yet overlapping tenets that represent foundational design and delivery considerations that are likely prerequisites for successful scale-up. First, we suggest that incorporating HIIT into existing physical activity opportunities maximizes time efficiency and minimizes dependence on adolescents' self-regulation. Second, we propose that HIIT interventions should be designed to develop dimensions of physical literacy (*i.e.*, motivation, confidence, competence, and knowledge to be active). Third, we highlight the importance of delivering HIIT in an engaging manner. Finally, we argue that the adolescent HIIT programs should be guided and supported by an implementation framework that addresses relevant barriers and facilitators.

Integrated into existing physical activity opportunities

Despite decades of research effort, interventions aimed at increasing physical activity in school-aged youth have been largely ineffective. Prior interventions have typically assumed that changes in theory-informed intrapersonal (*e.g.*, motivation) and interpersonal (*e.g.*, social support) factors will lead to physical activity behavior change. However, meaningful effects on these hypothesized mediators are rarely demonstrated, and even when they are, change in physical activity often fails to follow. In response, there have been recent calls to adopt a more pragmatic approach focused on the primacy of the “Opportunities” for youth to be physically active.

In their description of the Theory of Expanded, Extended and Enhanced Opportunities for youth physical activity promotion (also known as “TEO”), Beets and colleagues (25) suggest that the provision of regular, structured opportunities to be active (*e.g.*, PE lessons, school recess breaks, out-of-school time) is the only reliable way to achieve improvements in youth physical activity. The TEO paradigm recognizes the challenges of relying on youth to self-regulate their physical activity, particularly as adults control many of the opportunities young people have to be physically active.

We view the TEO philosophy as especially relevant for promoting vigorous physical activity. Evidence from exercise psychology demonstrates a reliable decline in affective valence (*i.e.*, feeling of displeasure) when individuals move from moderate to vigorous intensity during an acute exercise bout (16). However, there is also evidence supporting a “rebound” toward positive affect after cessation of such a bout (24,26). Nevertheless, the suspicion that most people either *can't* or *won't* engage in HIIT has been a key criticism of the idea of HIIT for public health for some time (14), and this critique has some merit. We therefore argue that to have any meaningful impact at scale, opportunities for HIIT sessions that do not rely on young people's motivation and self-regulation are required. This means embedding engaging HIIT within structured, regularly occurring periods of the week, situated in the settings with greatest reach into the population (*e.g.*, schools and organized sports clubs). This time-efficient approach may also help overcome a common criticism leveled at PE and organized sport (*i.e.*, low levels of MVPA during lessons and training sessions) (27,28) and optimize the public health benefits of these existing opportunities.

Designed to enhance motivation, confidence, physical competence, and knowledge

Program design is an important consideration for the effective scale-up of youth HIIT programs. Specifically, we argue that HIIT should contribute more to youth development than just a “dose” of physical activity. Instead, we suggest that HIIT

programs for this population should have an explicit goal of supporting physical literacy. Although different definitions of physical literacy exist, Whitehead's seminal definition is probably the most widely accepted, this being the “motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life” (29). Framing the design of HIIT programs through the lens of physical literacy will, if done thoughtfully, result in a more nuanced and meaningful experience for youth with the potential to support lifelong health and well-being.

The strenuous and intermittent nature of HIIT makes it a uniquely different exercise experience compared with something like the “daily mile” (*i.e.*, school program that requires students run or walk outside for 15 min (~1 mile) at a self-selected pace each day), for which participation among most students is possible with minimal instruction. Alternatively, adolescent HIIT programs will generally require at least some instruction and supervision to be safe and effective. Moreover, adolescent HIIT programs should be designed specifically to support the development of new exercise skills, the confidence to perform such skills, and knowledge about the health and performance benefits. Adolescents should also be provided with opportunities to design and run their own HIIT sessions.

Focusing on these important elements of physical literacy will serve three important functions. First, decision makers (*e.g.*, school principals and sport administrators) will be more likely to adopt adolescent HIIT programs if they align with their core businesses of learning (schools) and engagement (community sport). Second, delivery agents (*i.e.*, teachers and coaches) responsible for implementing HIIT programs will view such programs more positively if they address affective and educational outcomes (including motor skill competency), rather than the enhancement of fitness alone. Finally, adolescents will be more likely to view HIIT as meaningful if it is enjoyable, and they experience the development of new knowledge, skills, and confidence.

Delivered in an engaging manner

As advocates of HIIT, we take seriously the responsibility to promote thoughtful delivery of adolescent HIIT programs. We emphasize the importance of creating a positive exercise experience in the provision of HIIT. This requires consideration of more than just “what,” “how,” “when,” and “where” opportunities for HIIT are provided. Our position is that opportunity is necessary but not sufficient for enabling the effective scale-up of HIIT for youth. The rationale for this is both pragmatic and ethical, in that we accept “forcing” exercise on youth is neither an effective strategy for promoting adherence nor a morally defensible one given the potential for psychological harm. For example, negative childhood experiences in school PE are readily recalled even in adulthood, and may have the potential to influence physical activity-related cognitions and behavior well beyond the schooling years (30). By consequence, individuals may be more willing to expend effort avoiding negative emotional states than they are in seeking to “feel good” (31).

This has clear implications for promoting HIIT to youth, as the forms of HIIT described within much of the research literature would likely be aversive to the majority of adolescents (*i.e.*, repeated maximal “sprints” on an exercise bike or running track) (10). This said, there are evidence-based strategies that can be applied to the delivery of HIIT to counterbalance the

negative affective states this mode of exercise might provoke (e.g., use of carefully selected music). For a start, this involves offering “versions” of HIIT that differ from those used within seminal laboratory-based research, which it must be recognized were focused on understanding the acute and chronic effects on human physiology. Second, this requires more careful consideration of how HIIT can best be “packaged” to be more appealing to youth that are typically unmotivated by the benefits of exercise for cardiovascular and metabolic disease risk. Indeed, “pedagogy” is often overlooked in the design and delivery of health promotion interventions (32), but we view pedagogy (i.e., the “how” of delivery) to be just as core to an intervention's effectiveness as the content and format.

Self-Determination Theory (33) and Achievement Goal Theory (34) are two prominent psychological theories of motivation that have been applied extensively to physical activity interventions in school (35) and organized sport contexts (36). The former posits that satisfying individuals' basic psychological needs for autonomy, competence, and relatedness will support autonomous motivation, behavioral engagement, and psychological well-being (37). The latter (34) focuses on the importance of goal “framing” in achievement contexts, suggesting that goals based on personal mastery will support long-term motivation and commitment, whereas those based on comparative performance will elicit feelings of pressure, judgment, and threat among all but a high-performing minority. Although we do not expect the operationalization of basic psychological needs satisfaction or mastery goal framing within HIIT interventions to result in all young people self-selecting to engage in HIIT in their leisure time (in the short term), this does not mean that these concepts are irrelevant to the delivery of HIIT programs. Indeed, thoughtful consideration of these psychological constructs could be the difference between young people viewing school- and sport-based HIIT as something worthwhile versus something to be endured, objected to, or avoided altogether.

Guided and supported by an implementation framework that addresses relevant barriers and facilitators

In our final section, we describe the importance of using implementation science to guide and support the design, delivery, and scale-up, of youth HIIT programs. HIIT is a relatively complex form of exercise, and program drift (i.e., deviation from manualized protocols in the real-world delivery of interventions) (38) is a challenge to the successful scale-up of youth HIIT programs. “Scale-up” or “scaling up” has been defined as the “deliberate effort to increase the impact of successfully tested health interventions to benefit more people” (p. 2) (39). It is well known that physical activity interventions rarely progress beyond the efficacy stage, and we are unaware of any HIIT-based interventions that have been implemented at-scale. Indeed, the majority of youth HIIT studies have been delivered by researchers and designed to establish efficacy — with little consideration of how they will work in the “real world.”

For adolescent HIIT interventions to have population health impact, they need to be designed with scale-up in mind. This will help prevent the “voltage drop” (i.e., reduced intervention benefits) that typically occurs as interventions progress from efficacy to effectiveness to dissemination (38). For example, the authors of a recent systematic review concluded that scaled-up community-based physical activity interventions achieve less than 60% of their prescale effect size (40). Delivery agent (i.e.,

individual responsible for delivering an intervention) and level of implementation support are two major factors that influence intervention fidelity and effectiveness (41). Although teachers and coaches are ideally placed to deliver school- and community-based HIIT programs, they need to be provided with adequate training and ongoing support. As noted by Beets and colleagues, changes in delivery agent (i.e., from researcher to practitioner) and the removal of implementation support as interventions move from small-scale pilot studies to larger-scale effectiveness trials are major factors contributing to voltage drop.

It is not our intention to provide a detailed discussion of implementation and scale-up considerations. Instead, we direct readers to existing guidelines, reviews, and conceptual articles on this topic (42–44). For example, the PRACTIS guide (PRACTical planning for Implementation and Scale-up) (42) provides researchers with four steps that outline how best to plan the dissemination, implementation, and scale-up of interventions. These include the following: (i) characterize the parameters of the implementation settings (i.e., schools or sport clubs), (ii) identify and engage key stakeholders across multiple levels within the delivery system, (iii) identify contextual barriers and facilitators to implementation (the use of an implementation framework can assist in the process), and (iv) address potential barriers to effective implementation.

In summary, HIIT has utility as a population physical activity strategy, especially if it can be formally embedded within existing opportunities and delivered by existing personnel (i.e., teachers and coaches). For adolescent HIIT programs to achieve their potential, they need to be designed with scale-up in mind, which includes the establishment of partnerships with key stakeholders (e.g., departments of education and sporting organizations), the identification of barriers, and the development of resources, training, and support packages that recognize the real-world challenges and constraints that teachers and coaches may face when delivering HIIT.

School- and Sport-Based HIIT Programs for Youth

In the following section, we describe the B2L program, which was designed using the conceptual framework presented in this article. B2L was first evaluated in a small-scale feasibility study (19) before progressing to an effectiveness cluster randomized controlled trial involving 20 schools ($n = 670$ students) (23). The intervention resulted in greater improvements in CRF, muscular endurance, steps per day, HIIT self-efficacy, and reductions in hair cortisol concentrations, compared with the control group at the primary end point of the study (6 months). No notable group-by-time effects were found for mental health and cognitive function outcomes in the full study sample. However, improvements in perceived stress, internalizing problems, and working memory were observed among students who were classified as overweight or obese at baseline. Intervention effects for fitness and mental health were not sustained once teacher facilitated sessions were no longer being delivered at the 12-month follow-up assessments. However, almost 70% of students reported their intention to participate HIIT in the future and improvements in HIIT self-efficacy were sustained at 12 months. In this section, we also discuss other school- and sport-based HIIT programs that have potential for scale-up (20,45–47). These programs were selected because they address some of the considerations outlined in our conceptual model. We provide a summary of these studies in Table 1.

TABLE 1. School- and sport-based high-intensity interval training (HIIT) programs for youth.

Study	Age/Population/Setting	Duration	HIIT Description	Key Findings
Lubans <i>et al.</i> (23) N = 670 Australia Cluster RCT	16.0 (0.4) yr Older adolescents School	12-months	F: 2–3 sessions per week I: 85% of HR _{max} T: 8–16 intervals of 30-s work with 30-s recovery T: A variety of different styles (e.g., sport HIIT) including a combination of aerobic (e.g., shuttle runs, dance sequences) and body weight resistance exercises (e.g., push-ups)	↑ CRF, muscular fitness (upper), steps per day at school, and HIIT self-efficacy ↓ Hair cortisol concentrations ↔ MVPA minutes per day, body composition, mental health, and cognitive function
Harris <i>et al.</i> (20) N = 84 New Zealand Cluster RCT	11.9 (0.8) yr Adolescents School	9 wk	F: 2 sessions per week I: 90% of HR _{max} T: Varied (e.g., ~10–15 min, with 30-s work with 30-s recovery) T: Body weight exercises stimulating both aerobic and muscular responses	↑ Muscular fitness, exercise enjoyment, and HIIT self-efficacy ↓ Psychological difficulties ↔ CRF, body composition, well-being, and resistance training skill competency
Wassenaar <i>et al.</i> (45) N = 18,261 England Cluster RCT	12–13 yr Adolescents School	12-months	F: 2 sessions per week I: 70–85% of HR _{max} T: 2 × 2 min during warm-up and 3 × 2-min fitness infusions T: warm-up activities (e.g., vigorous arm swings and running on the spot) and fitness infusions (e.g., fast arm rotations, squats, lunges, and sprinting on the spot)	↔ CRF, mental health, and cognitive function
Weston <i>et al.</i> (46) N = 101 England Nonrandomized trial	14.0 (0.3) yr Adolescents School	10 wk	F: 2–3 sessions per week I: 100% of HR _{max} T: 4–7 intervals of 45 s work with 90-s rest T: high-intensity basketball, boxing, dance, and soccer drills	↑ CRF, MVPA minutes ↓ Triglycerides and body composition ↔ Blood pressure, weight, and cholesterol
Aschendorf <i>et al.</i> (47) N = 24 Germany RCT	15.1 (1.1) yr Female adolescent basketball players Organized sport	5 wk	F: 2 sessions per week I: 90%–95% of HR _{max} T: 4 intervals × 4-min with 3-min recovery or 15 × 30 s with 15-s recovery T: high-intensity basketball drills containing fundamental skills (e.g., dribbling, passing, and shooting)	↑ CRF, sprint, and agility ↔ Muscular fitness

F, Frequency; HR_{max}, maximum heart rate; I, Intensity; MF, muscular fitness; RCT, randomized controlled trial; T, Time; T, Type; ↑, increase in outcome; ↓, decrease in outcome; ↔, no effect on outcome.

Burn 2 Learn

Opportunity

The B2L program was promoted to schools as a time-efficient intervention designed to improve older adolescents' physical, mental, and cognitive health during a challenging life stage (*i.e.*, the senior school years). Teachers allocated to the intervention group were asked to facilitate the delivery of 2–3 HIIT activity breaks per week during curriculum time in the first two phases of the intervention (in the final phase, there was no expectation for teachers to implement activity breaks).

Design

The program was designed to enhance students' physical literacy and HIIT sessions involved a combination of aerobic (*e.g.*, shuttle runs, jumping jacks, boxing, dancing) and body weight resistance (*e.g.*, push-ups, squat jumps, and walking lunges) exercise. The program included 11 different styles of HIIT designed to suit a variety of settings and student interests. The first phase focused on developing students' exercise skills and introducing students to the B2L smartphone app. The second phase of the program provided students with opportunities to design their own sessions. The final phase of the program was focused on developing students' physical activity independence.

Delivery

The program was developed using Self-Determination Theory (33) and designed to enhance students' autonomous motivation for vigorous physical activity within and beyond the school setting by satisfying their basic psychological needs for autonomy, competence, and relatedness. Teachers were taught to deliver the program using the “Supportive, Active, Autonomous, Fair, Enjoyable” (SAAFE) delivery principles (48). For example, students' need for autonomy was satisfied by providing them with opportunities for choice within sessions (*e.g.*, type of

activity, music playing, and training partner). Competence was satisfied using positive and specific feedback from teachers, thoughtful selection of exercises that were effective but not overly complex, and an explicit focus on effort rather than absolute performance (using heart rate feedback).

Support

Guided by the Consolidated Framework for Implementation Research (CFIR) (49), a range of strategies were used to support program implementation. Importantly, the program was designed in consultation with the local department of education and teachers attended a full-day professional learning workshop that was accredited with the local educational standards authority. Teachers were also provided with resources to deliver a B2L presentation to their school principal and colleagues to raise awareness about the importance of the program. Importantly, teachers were provided with ongoing support from the research team that included two school visits per teacher to observe sessions, provide feedback, and address implementation challenges.

Promising school- and sport-based HIIT programs

Opportunity

School- and sport-based HIIT programs often involve the integration of HIIT into existing PE lessons (20,45,46) or sport training sessions (47). This strategy represents an application of the “enhanced” TEO principle, as it involves making greater use of an existing physical activity opportunity. For example, the *Fit to Study* intervention (45) required teachers to integrate 10 min of HIIT-style activities (*e.g.*, fast arm rotations, squats, lunges, and sprinting on the spot) into PE lessons. This approach is highly scalable because it does not require additional resources or self-regulation from students to attend sessions. Similarly, *Project Fun Fast Activity Blasts (FFAB)* (46) involved

two HIIT sessions per week delivered during PE and a third session completed after school or during the school lunch break. Mean attendance was 77% ± 13%, but the authors did not report separate attendance rates for compulsory (*i.e.*, PE) and noncompulsory (*i.e.*, after school or break time) sessions. Aschendorf and colleagues (47) integrated high-intensity exercise into basketball training.

Design

Although none of the school-based programs specifically mentioned physical literacy or included an educational component focused on the benefits of HIIT for youth, all were designed to be engaging using formative research with relevant stakeholders. For example, the FFAB program (46) was designed to include high-intensity exercise integrated with sport (*i.e.*, boxing, basketball, and soccer) and dance-specific skills, based on focus group findings with adolescents. Although the research team did not quantify participants' satisfaction with the program, session fidelity (*i.e.*, compliance with heart rate targets) and attendance were high.

The basketball-based HIIT program designed by Aschendorf and colleagues (47) included important design elements aligned with the goal of physical literacy. Of note, all HIIT sessions included different high-intensity drills involving foundational basketball skills, such as dribbling, passing, and shooting. The integration of high-intensity exercise with relevant motor skills was found to have a positive effect on players' CRF and is likely to be highly enjoyable and relevant for athletes. This approach has the added advantage of requiring junior athletes to perform motor skills while also exercising at a high intensity.

Delivery

The school- and sport-based HIIT programs were delivered by members of the team (46,47) or teachers (20,45). For school-based programs, the use of teachers represents a scalable and sustainable option. The use of external providers to deliver programs in schools may represent an expedient option for busy teachers, but it also requires ongoing funding, and tenuous alignment to the curriculum may result in disenfranchisement among teachers. Teachers in the *Fit to Study* (45) and *Pau te Hau* (20) studies were provided with training to deliver their HIIT programs using teaching principles informed by Self-Determination Theory. In *Pau te Hau*, teachers were introduced to the SAAFE delivery principles in their professional learning workshop, and specific links between the HIIT sessions and curricula activity were identified. This "curriculum connection" enhanced the buy-in of the generalist teachers delivering the program. *Fit to Study* teachers were provided with a 2-h online or face-to-face training session to deliver the program, and additional support was offered to 30 intervention schools. However, 11% of PE teachers did not receive training to deliver the intervention, and it is not clear if schools utilized the additional support that was offered to them.

Support

None of the school- or community-based HIIT programs were guided by implementation science or cited a relevant framework (although an effectiveness trial of the *Pau te Hau* study, guided by the CFIR, is currently underway). As described previously, physical activity interventions should be designed with scale-up in mind, and the use of an implementation framework allows researchers to determine how the intervention will

work once they step back. The absence of an implementation framework is unlikely to have a negative effect on fidelity and efficacy in small-scale studies because these programs are typically delivered by members of the research team (46,47). Alternatively, large-scale studies require thoughtful consideration to identify potential barriers and strategies to support implementation. The failure to use an implementation framework in the *Fit to Study*, which involved 104 secondary schools ($N = 18,261$ adolescents), may explain why the intervention was unsuccessful. Although some training and support were provided for schools, the dose of HIIT delivered by teachers was much lower than prescribed (*i.e.*, only two schools reported delivering HIIT sessions in over 90% of lessons and 77% of teachers integrated HIIT into at least 50% of PE lessons).

Limitations of our conceptual model

It is important to note some limitations to integrating HIIT into existing physical activity opportunities. First, PE is not offered in all school systems and is rarely mandatory for students in their final years of school. Also, not all youth attend out-of-school care, summer day camps, or participate in organized sports. The creation of "new" opportunities to be physically active may be necessary for adolescents in these circumstances. This could include the integration of HIIT into classroom activity breaks (as used in the B2L study), the provision of organized HIIT during school break times (*i.e.*, recess), or even the creation of entirely new periods of the school day intended solely for participation in physical activity. In addition, engaging HIIT might be embedded within community-based intervention programs targeting families as a means of leveraging parents' influence on health behaviors in the home environment. Second, HIIT prescription should allow for progressive increments in exercise dose, accommodating deconditioned individuals. Adolescents otherwise disengaged from regular physical activity may need several brief sessions of incrementally increasing intensity to adapt physiologically and psychologically to the effort levels inherent in HIIT. Finally, few studies have examined the impact of adolescent HIIT programs on objectively measured physical activity or explored important issues such as the acceptability and feasibility of such programs when delivered by teachers and coaches.

RECOMMENDATIONS

In this section, we provide a summary of our recommendations for the design, delivery, and scale-up of youth HIIT programs, including guidelines for frequency, intensity, time, and type in Table 2. The start of PE lessons and organized sport sessions is an ideal opportunity for the delivery of youth HIIT programs. This time-efficient approach may also help teachers and coaches achieve other objectives, such as team building, tactics, and motor skill development.

Based on our previous studies and review of the literature, we recommend HIIT be delivered two to three times per week in blocks (*e.g.*, 10-wk program). Blocks then may be intermittently redeployed, with iterative developments (*e.g.*, variation in exercises used and manipulation of session structure) to prevent boredom. Our recommendation for this approach is predicated partly on the proven efficacy of shorter-term programs in adolescent populations (9,10). It is also based on the premise that unpunctuated engagement in any singular exercise modality or program

TABLE 2. Summary of design, delivery, and scale-up considerations for youth high-intensity interval training (HIIT) programs.

Consideration	Description	Recommendations
Opportunity	Incorporated into existing supervised physical activity opportunities to maximize time efficiency and minimize dependence on young people's self-regulation.	Embed HIIT activities and programs within the following structured opportunities: <ul style="list-style-type: none"> • Schools, via PE lessons, recess periods, or classroom activity breaks. • Organized sports practice (within or beyond school). • Out-of-school time, via before/after school programs on school grounds or elsewhere (e.g., YMCA). • Summer day camps.
Design	Designed to develop young people's physical literacy by supporting their motivation, knowledge, confidence, and competence to participate in physical activity across the lifespan.	Apply appropriate exercise prescription (FITT), and make this information explicit to adolescents to support their knowledge and understanding of HIIT: <ul style="list-style-type: none"> • Frequency: Program HIIT sessions 2–3 times per week, ideally on nonconsecutive days in periodic blocks (e.g., 10 wk). Blocks may be intermittently redeployed, with iterative developments to maintain engagement. • Intensity: HIIT intervals should be performed at 85%–95% of maximum heart rate, or ≥8 on a 1–10 Rating of Perceived Exertion scale. Lower intensities may be used when first familiarizing adolescents to HIIT. • Time: Utilize a variety of work/rest ratios, involving intervals of between 20 and 90 s in duration. Total session duration should be 10–20 min (including organization and warm-up). Intervals with more rest relative to work may be preferable when first commencing. • Type: Incorporate a variety of aerobic- (e.g., shuttle runs) and resistance-based (e.g., push-ups) exercises. Sessions may include the integration of fundamental movement skills (e.g., catching), dance movements, and sport-specific skills (e.g., basketball dribbling and shooting). Exercise selection should be considerate of minimum movement competency within the group and setting-specific constraints (e.g., space and equipment available), but intended to contribute to general physical literacy (e.g., developing new exercise skills). Plan for teachable moments, and enable youth to apply learned knowledge during HIIT program delivery: <ul style="list-style-type: none"> • Ask questions regarding the health/performance benefits of exercise (or specific exercises). • Provide opportunities and reinforce importance of performing sport skills while fatigued. • Reinforce proper exercise technique using memorable cues. • Provide opportunities for youth to design and run their own HIIT sessions.
Delivery	Delivered in an engaging manner by appropriately trained facilitators (e.g., teachers and youth sport coaches).	Apply evidence-informed principles to support engagement, enjoyment, and ongoing adherence to HIIT programs. One useful example is the SAAFE framework: <ul style="list-style-type: none"> • Supportive: Create an environment in which adolescents feel safe, optimally challenged, and cared for (e.g., avoid controlling language, provide constructive feedback, build rapport and display empathy, avoid peer-comparisons of performance and promote self-reflection on progress). • Active: Commence sessions quickly and minimize instruction time (e.g., use a circuit with marker cones and exercise cards to organize adolescents quickly, develop an active as soon as possible routine, and communicate this with participants). • Autonomous: Provide regular opportunities for individual choice (e.g., choice of music, workout partner, exercises, work/rest interval duration, session name, etc.). • Fair: Ensure all participants have the opportunity to experience success (e.g., use heart rate monitoring and associate success with “effort” (% HR_{max} achieved) rather than absolute performance (total no. of laps or repetitions completed), select/adapt exercises to suit variability in movement competence/fitness). • Enjoyable: Apply strategies to promote enjoyment and distract from feelings of exertion (e.g., use high tempo popular music, offer a variety of exercises, use “themed” workouts, create a sense of community/camaraderie among the group).
Support	Guided and supported by an implementation framework that is considerate of identified barriers and facilitators, and contextually specific constraints.	Select an appropriate implementation framework and use this to guide the planning and delivery of the HIIT program. Specific attention should be paid to the following: <ul style="list-style-type: none"> • Resourcing, personnel, and other context-specific constraints that might impact adoption, implementation and maintenance. • Training of facilitators and continuity planning for if/when initial facilitator(s) are no longer available. • Provision of resources to support HIIT program delivery (e.g., hardcopy exercise cards, facilitator information/planning booklet, loose exercise equipment, etc.).

will conceivably introduce an element of contempt for routine. In addition, the intention of a relatively brief program block is to facilitate the confidence and knowledge to participate in HIIT as a physical activity option.

We recommend a target intensity of 85% to 95% of an individual's estimated maximal heart rate toward the end of most work intervals. In addition, or alternatively, a rating of perceived exertion may be employed, in which case a session rating of ≥8 on a scale of 1 to 10 is recommended. The lower end of this target is both achievable in “real-world” settings and sufficiently effective in promoting improvements in CRF. Greater intensity (“effort”) seems a potent physiological stimulus and allows for session brevity, but HIIT performed at the highest end of the intensity continuum, typically greater than our stated recommendations (i.e., sprint interval training involving supramaximal effort), is unlikely to be palatable for the general population. Further study of HIIT programs involving different

levels of intensity in real-world settings is needed to confirm this assumption.

Regarding type, adolescents should be provided with a balanced and varied selection of enjoyable and safe aerobic- and resistance-based exercises. The exercises should be considerate of the movement competency of the target group. For example, if delivered to a school class as part of a PE curriculum, options should be provided that concurrently facilitate success and minimize the risk associated with repetitive performance of movements that may not be correctly executed by all participants. It is possible to accommodate a broad range of capabilities by offering alternatives and derivatives of movements as needed. The integration of fundamental movement skills (e.g., catching, throwing), dance moves, and sport-specific skills (e.g., basketball free throws, soccer dribbling) might also enhance participant engagement and provide further connection to curricula and extracurricula components.

Regardless of structure and setting, HIIT sessions should always be delivered in a positive motivational climate (e.g., provision of social support, choice, etc.). More specifically, adolescent HIIT programs should be delivered by teachers and coaches using autonomy supportive instructional strategies. As noted by Su and Reeve (50), autonomy supportive teachers (i) provide meaningful rationales, (ii) acknowledge negative feelings, (iii) use language that is not controlling, (iv) offer choices, and (v) nurture inner motivational resources. As such, there are many ways that adolescents can experience autonomy during a HIIT session (e.g., they could choose the type of HIIT program, their training partner, the work to rest ratios, or the music being played).

Finally, adolescent HIIT programs should be designed with scale-up in mind. This includes the establishment of partnerships with key stakeholders, the identification of implementation barriers and facilitators, development of resources, and training and support packages that recognize the challenges of delivering HIIT in real-world settings.

FUTURE RESEARCH

The efficacy of a range of HIIT protocols for improving fitness in adolescent populations is well established (9–11). Research is now needed to explore how evidence-based HIIT protocols can be “scaled up” to improve population health. We therefore provide the following recommendations:

- Further studies should investigate the feasibility, acceptability, and effectiveness of youth HIIT programs aligned with our four tenets, including implementation studies examining the level of support required to optimize the delivery of HIIT in key settings.
- Further exploration of strategies should satisfy young people's basic psychological needs and autonomous motivation during HIIT (e.g., the impact of heart rate feedback during HIIT on participants' motivation, adherence and engagement).
- Further research should examine the utility and acceptability of different types and intensities of HIIT among adolescents.
- Studies should examine the medium- and long-term effects of adolescent HIIT programs on physical literacy and physical activity behavior (e.g., the effect of PE-based HIIT on participation beyond the school setting).
- Research should examine the effects of HIIT interventions that include cultural connections (e.g., the use of traditional indigenous narratives to underpin certain exercise sessions).
- Finally, the COVID-19 pandemic has contributed to a global decline in youth physical activity, and there is an urgent need for research that focuses on the delivery and impact of virtually delivered adolescent HIIT programs.

CONCLUSIONS

As a population health exercise option, HIIT is perceived with some skepticism and stigma. This is unfortunate given our clear imperative to determine opportunities that might better engage youth in health enhancing vigorous physical activity. Perhaps early versions of laboratory-based HIIT with athletic participants and protocols designed to push the boundary of effort tolerance have been pervasively formative in the general impression of HIIT. In this article, we have presented a conceptual model that outlines the key factors that need to be considered in the design, delivery, and scale-up of youth HIIT programs. We are not suggesting that HIIT is for everybody

all of the time. Alternatively, we argue that providing adolescents with the motivation, confidence, physical competence, knowledge, and opportunities to engage in HIIT may complement and perhaps enhance their participation in other types of leisure-time physical activity across the lifespan (18). We contend that the time has come to give well-considered, contemporary HIIT programs due chance.

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