Universidade de Évora - Instituto de Investigação e Formação Avançada

Programa de Doutoramento em Motricidade Humana

Tese de Doutoramento

Effects of a High-Intensity Interval Training program integrated in high-school Physical Education Classes, on physical fitness, physical activity and motivation in adolescents

André Filipe Paulino da Silva Bento

Orientador(es) | Armando Manuel Raimundo
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A tese de doutoramento foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor do Instituto de Investigação e Formação Avançada:

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Évora 2023

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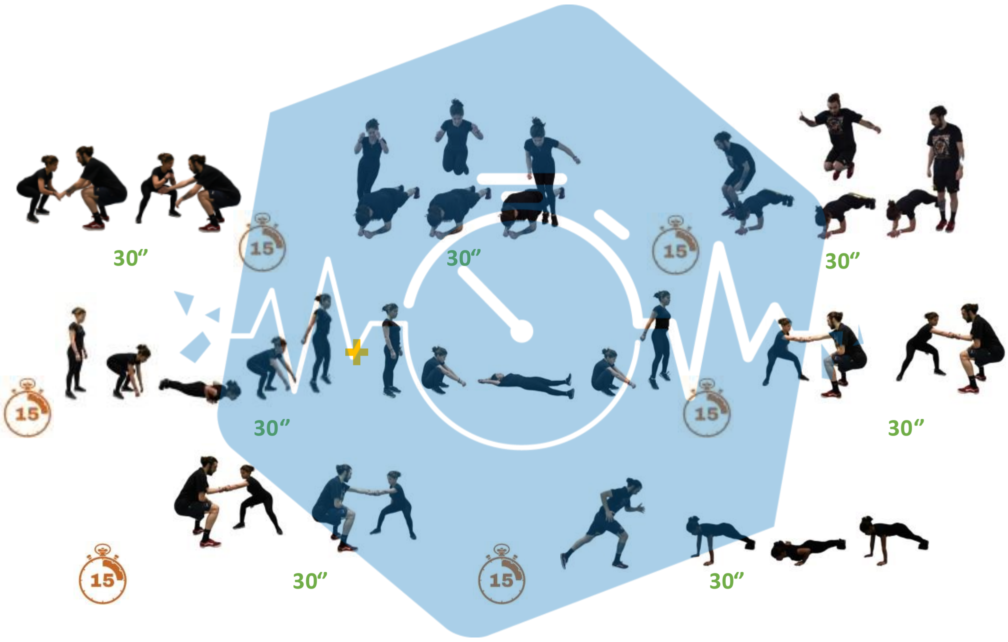

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Évora 2023

The work presented in this thesis was supported by the Portuguese national funding agency for science, research, and technology, Fundação para a Ciência e Tecnologia, with the grant number SFRH/BD/136869/2018.

Dedico este trabalho ao meu tio António Paulino (in memoriam), o primeiro a quem dei a notícia que me tinha sido atribuída uma bolsa de investigação, e que desejou este doutoramento mais do que eu.

Agradecimentos

Esta viagem foi de um enorme deslumbramento. Não exclusivamente pela imersão no mundo da investigação, pois a vontade e a paixão já existiam e as melhores expectativas confirmaram-se. Este privilégio de dedicação "exclusiva" ao estudo e à produção científica ofereceu-me muito mais do que ciência, e, numa fase inicial, o acrónimo PhD não parecia fazer muito sentido na área científica a que me propunha a dar contributo. O que superou as minhas expectativas foi o ócio (não no sentido em que o concebemos atualmente) e o mundo que se me apresentou extra academia.

Ainda que não me sinta completamente pacificado com eventual falta de produtividade para enriquecimento do CV académico (meu e dos que apostaram em mim), esta experiência trouxe-me, também ou principalmente, mundo e humanidade. Paralelamente ao sonho da investigação tornado realidade, foi a oportunidade de mergulhar e explorar outro lado do mundo das artes e literatura que mais me deslumbrou. A lírica mais do que a sonoridade, a história mais do que a semântica. A música, através do intervencionismo cantado pelo Bob Dylan, Joana Baez ou Patti Smith, ou os dramas existenciais do Bruce Springsteen; a literatura desde a mais clássica como o Santo Agostinho e as suas dissertações sobre o tempo que me conduziram até Sócrates e Platão, à historiografia da Terra Santa de Jerusalém e até aos ensaios de José Saramago; elucidaram sobremaneira este acrónimo: philosophiae doctor.

Para muitos, estes parágrafos são de catarse ou autocomiseração por todos os sacrifícios ou sacrificados implicados no processo de obtenção do grau de doutor. Eu, de facto, fui um privilegiado e estes foram os 4 anos em que pude dedicar mais tempo à família… e ao ócio.

Rezei pouco.

Obrigado

A Deus, que todo este empreendimento seja para Sua maior honra e glória.

À minha comunidade neocatecumenal pela caridade, correcção e discernimento.

À Filomena e nossos 6 filhos, pela perseverança.

Ao orientador Professor Doutor Armando Raimundo, não apenas pela orientação inexcedível, mas por acreditar e fazer acontecer este projecto ainda antes de assim poder ser chamado. A bolsa que me foi atribuída leva o seu selo.

Ao coorientador Professor Doutor Luis Carrasco pelo abraço logo no primeiro momento em que nos conhecemos, pela ciência e positividade com que sempre me animou, e claro, pelas cervejas. E sim, o Paul McCartney é um senhor.

À comissão de avaliação do projecto de tese, Professores Doutores Hugo Folgado, José Marmeleira, Nuno Batalha e Orlando Fernandes pela lição de humildade.

À comissão de acompanhamento do projecto de tese, Professores Doutores Hugo Folgado e Orlando Fernandes por sempre pautarem este processo com observações pertinentes e desbloqueadoras.

Aos meus pais pelo dom da vida.

Ao CPSS, direcção e colaboradores, pela paciência e confiança em me libertarem mais uma temporada para outro capricho: estudar.

À Escola Secundária D. Manuel I em Beja na pessoa dos seus Directores, os Professores Maria José Chagas e Pedro Martinho, pela ousadia em abraçar um projecto desta complexidade.

À equipa de Professores de Educação Física que disponibilizaram as suas turmas para o ensaio: Noémia Jorge, Fernando Damásio, Susana Lemos, António Castilho, Carolina Tavares, Helena Gonçalves, Gilberto Pato, Cristóvão Amaral e João Lourenço. Foi comovente a forma como me acolheram como um de vós. A vossa dedicação às crianças e à Educação Física é inspiradora e não vem versada em manuais.

Aos colegas João Carvalho e Madalena Pereira pela recolha e compilação fotográfica do programa de HIIT.

Acknowledgements

This journey was one of great wonder, not exclusively for the immersion in the world of research, as the will and passion already existed, and the best expectations were confirmed. This privilege of “exclusive” dedication to study and scientific production offered me much more than science, and at an early stage, the acronym PhD did not seem to make much sense in the scientific area to which I proposed to offer my contribution. What exceeded my expectations was leisure (not in the sense how we currently conceive it) and the world that has opened to me outside academia.

Although I do not feel entirely pacified with a possible lack of productivity to enrich the academic CV (mine and of those who bet on me), this experience brought me, also or mainly, world and humanity. Alongside the research dream come true, the opportunity to delve into and explore another side of the world of arts and literature was what fascinated me the most. The lyrics, more than the sound, the story, more than the semantics. Music, through interventionism sung by Bob Dylan, Joana Baez or Patti Smith, or the existential dramas of Bruce Springsteen; literature from the most classical, such as Saint Augustine and his dissertations on Time that led me to Socrates and Plato, to the historiography of the Holy Land of Jerusalem and the essays of José Saramago; all they clarified this acronym: *Philosophiae* Doctor.

For many, these paragraphs are of catharsis or self-pity for all the sacrifices or the sacrificed involved in attaining the doctoral degree. I, in fact, was privileged, and these were the four years in which I was able to devote more time to my family… and leisure.

I did not pray much.

Thanks

To God, may this whole enterprise be for His greater honor and glory.

To my neocatechumenal community, for its charity, correction and discernment.

To Filomena and our six children, for their perseverance.

To the supervisor Professor Armando Raimundo, not only for his invaluable supervision but for believing in and making this project happen even before it could be called that. The grant awarded to me bears his seal.

To the co-supervisor Professor Luis Carrasco, for the hug right in the first moment we met, for the science and positivity with which he always encouraged me, and of course, for the beers. And yes, Paul McCartney is a lord.

To the thesis project assessment committee, Professors Hugo Folgado, José Marmeleira, Nuno Batalha and Orlando Fernandes, for their lesson in humbleness.

To the thesis project monitoring committee, Professors Hugo Folgado and Orlando Fernandes, for always guiding this process with relevant and unblocking observations.

To my parents, for the gift of life.

To CPSS, management and collaborators, for their patience and trust in freeing me up another season for another whim: studying.

To *Escola Secundária D. Manuel I* in Beja, in the person of its Directors, Professors Maria José Chagas and Pedro Martinho, for daring to embrace a project of such complexity as this one.

To the team of Physical Education Teachers who made their classes available for the trial: Noémia Jorge, Fernando Damásio, Susana Lemos, António Castilho, Carolina Tavares, Helena Gonçalves, Gilberto Pato, Cristóvão Amaral and João Lourenço. It was touching how you welcomed me as one of you. Your dedication to children and Physical Education is inspiring and does not come in textbooks.

To my colleagues João Carvalho and Madalena Pereira for the collection and photographic compilation of the HIIT (High-Intensity Interval Training) program.

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Figures and Tables

Abbreviations

BMI – Body Mass Index

CRF – Cardiorespiratory fitness

ES – Effect size

HR – Heart rate

HIIT – High-Intensity Interval Training

MICT – Moderate-Intensity Continuous Training

MVPA – Moderate-to-vigorous physical activity

MVPE - Moderate-to-vigorous physical e exercise

PA – Physical activity

PACER – Progressive Aerobic Cardiovascular Endurance Run

PEC – Physical Education Classes

MAS – Maximal Aerobic Speed

VO_2 max – Maximal oxygen consumption

RPE – Rating perceived exertion

SDT – Self-Determination Theory

WHO – World Health Organization

ABSTRACT

This thesis aims to investigate whether 16 weeks of High-Intensity Interval Training (HIIT) implemented in Physical Education classes (PEC), compared to 16 weeks of usual PEC, can improve body composition (BC) and physical fitness (PF) in high-school adolescents. A systematic review (Study 1) aimed to evaluate the utility of HIIT programs integrated into PEC and concluded that HIIT is presented as a powerful stimulus on cardiorespiratory fitness (CRF). HIIT in the school context has great potential in improving PF and physical activity (PA) in adolescents. Study 2 details a protocol for a randomized controlled trial examining the effect of HIIT in PEC. In Study 3 we aimed to investigate the relationship between PA and health-related PF in adolescents and analyze whether the associations of PA with BC in adolescents are mediated by PF or energy intake (EI). These results suggest that PA of at least a moderate intensity is relevant to BC and health-related PF in adolescents, regardless of the EI. Study 5 aimed to assess whether PF had an indirect effect on exercise intensity (through motivation) and concluded that the absence of an indirect effect suggested that high or low values of motivation did not increase or decrease volitional high-intensity exercise. The idea that public health gains will be greater if we help the least active become more active, or will be higher if we help the least motivated become more motivated due to the lack of sufficient motivation to participate in moderately intense exercise or PA, is being challenged. Study 4 aims to investigate whether 16 weeks of HIIT implemented on PEC can improve PF in high-school adolescents. Post-intervention measures revealed a significant difference between groups in CRF, and girls from HIIT-G increased their CRF with a significant difference between female groups and a medium to large effect size.

Keywords: adolescents, body composition, cardiorespiratory fitness, health, muscular fitness,

RESUMO

Esta tese procurou investigar se 16 semanas de Treino Intervalado de Alta Intensidade (HIIT) nas aulas de Educação Física (AEF), em comparação com as AEF habituais, podem melhorar a composição corporal (CC) e a condição física (CF) dos adolescentes. Uma revisão sistemática (Estudo 1) teve como objectivo avaliar a utilidade de programas HIIT integrados nas AEF e concluiu que o HIIT se apresenta como um forte estímulo na melhoria da aptidão cardiorrespiratória (ACR). O HIIT no contexto escolar tem grande potencial na melhoria da CF e actividade física (AF) em adolescentes. O estudo 2 detalha um protocolo para um estudo controlado randomizado examinando o efeito do HIIT nas AEF. No Estudo 3, investigámos se a relação entre AF e CF relacionada com a saúde em adolescentes e as associações da AF com a CC em adolescentes são mediadas pela CF ou ingestão calórica (IC). Esses resultados sugerem que AF de intensidade pelo menos moderada é relevante para CC e CF relacionada à saúde em adolescentes, independentemente da IC. O estudo 5 teve como objetivo avaliar se a CF teve efeito indireto na intensidade do exercício (através da motivação) e concluiu que a ausência de efeito indireto sugere que valores altos ou baixos de motivação não aumentam ou diminuem o exercício volitivo de alta intensidade. A ideia de que os ganhos em saúde pública serão maiores se ajudarmos os menos activos a serem mais activos, ou se ajudarmos os menos motivados a se motivarem devido à falta de motivação suficiente para participar de exercícios de intensidade moderada ou AF, está sendo desafiada. O estudo 4 procurou investigar se 16 semanas de HIIT implementado nas AEF podem melhorar a CF em adolescentes do ensino secundário. Os resultados pós-intervenção revelaram uma diferença significativa entre os grupos na ACR, potenciado pelas raparigas do HIIT-G que aumentaram ACR com diferença significativa entre os grupos femininos.

Palavras-chave: adolescentes, composição corporal, aptidão cardiorrespiratória, saúde, aptidão muscular.

CHAPTER 1

1. General Introduction

The adolescent population is progressively showing signs of insufficient physical activity (PA), overweight and obesity, poor diet, low cardiorespiratory fitness (CRF), hypertension, chronic inflammation, and dyslipidemia (Logan et al., 2014). One of the most important methods for lowering inflammatory processes and, as a result, cardiovascular events is exercise (Kargarfard et al., 2016). Over 50% of obese children will grow up to be obese adults, increasing their chance of having asymptomatic illnesses like those already mentioned (Dias et al., 2016).

Children and adolescents spend far too much time in sedentary activities in the majority of Western nations, a problem that worsens every ten years (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Health Behavior in School-Aged Children (HBSC) data link headaches, sadness, irritability, and nervousness to a sedentary lifestyle (Marques et al., 2015). Additionally, as they become older, adolescents tend to become less active (Bluher et al., 2017). Lack of motivation to engage in PA, limited access to facilities, and limited free time are typically cited as obstacles to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019).

High-Intensity Interval Training (HIIT) is characterized by relatively short periods of very intense exercise, interspersed with periods of pause or low-intensity exercise (Fisher et al., 2011; Gibala & Jones, 2013; Logan et al., 2016). The purpose of HIIT is to allow overloading physiological systems with exercises of higher intensity than those achieved during a gradual maximal test (Stuckey et al., 2012). Therefore, HIIT is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Logan et al., 2014; Zhang et al., 2017), as it leverages the number of exercise participants, resulting in health outcomes improvements, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017).

Due to feelings of incompetence, intense efforts have been considered inappropriate and demotivation for the general/sedentary population (Biddle & Batterham, 2015; Hardcastle et al., 2014). However, children and adolescents have expressed a clear preference for time efficiency and pleasure, and the “stop-start” nature of HIIT seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). Despite the widespread interest in the advantages that the HIIT methodology offers, there is a lack of randomized controlled studies investigating the impact on adolescents, mainly approaching adolescents’ environments, such as schools (Harris et al., 2017; Logan et al., 2016; Logan et al., 2014).

It seems to be a lack of research specifically reporting Physical Education Classes (PEC) contributions to increasing PA. Studies conducted in the context of schools underrepresent adolescents, particularly older ones (Leahy et al., 2019). It is known that school and PEC are privileged spaces, promoters of positive changes for the rest of life (Mura et al., 2015), and HIIT is a powerfull stimulant for improving body composition and lowering adult cardiometabolic risk (Sim et al., 2015). Preliminary studies carried out with adolescents have shown promising results on body composition and cardiometabolic health, and more effective and time-efficient intervention for improving blood pressure and aerobic capacity levels (Bluher et al., 2017; Costigan et al., 2015; Eddolls et al., 2017; Garcia-Hermoso et al., 2016; Herget et al., 2016).

In an attempt to broaden knowledge about evidence that relates to the variables mentioned above, this thesis was based on the following research question: what are the effects of a HIIT program integrated into high-school PEC (students aged 10-19 years) on physical fitness, PA, and motivation for exercise?

This thesis aims to investigate whether 16 weeks of HIIT implemented on PEC, compared to 16 weeks of usual PEC, can improve body composition and physical fitness in high-school adolescents. More precisely, we intend to study how these variables are associated, allowing us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people. Exploring the mechanisms or processes that mediate the effects of HIIT on physical fitness is crucial for developing effective interventions in PEC.

1.1. Structure of the Thesis

The current thesis is written in a contemporary style and is organized into chapters that provide a review of the literature on the topic and the original data collected during the experimental method and published in papers. A literature review (Chapter 2) and general discussion (Chapter 7) were carried out to contextualize this investigation, which resulted in five research studies (submitted in peer-reviewed journals with an established ISI Impact Factor or SCImago journal rank), and they provided an overview and some insights regarding the key findings from these studies (Chapters 2.7, 3.10, 4-6).

Chapter 2 includes an extensive literature review regarding a general background of the topic of exploring and developing the pillars for conducting this thesis. This literature review addresses the potential effects of a HIIT program integrated into high-school PEC (students aged 10-19 years), on physical fitness, PA, and motivation for exercise.

A brief methodology is presented in **Chapter 3**, with an overall indication of the methodology used in each article. The five investigations carried out to address the research goals are described in **Chapters 2.7, 3.10 and 4** through **6**.

The general discussion in **Chapter 7** offers a summary and an in-depth discussion of the main inferences, limitations, and prospects that emerge from the research of the five studies that make up this thesis.

1.2. List of publications related to the thesis

Peer-reviewed articles published, submitted or under review.

Bento, A., Carrasco, L., & Raimundo, A. (2022). School-Based High-Intensity Interval Training Programs for Promoting Physical Activity and Fitness in Adolescents: A Systematic Review. *Journal of Teaching in Physical Education*, *41*(2), 288-300. https://doi.org/10.1123/jtpe.2020-0187

Bento, A., Carrasco, L., & Raimundo, A. (2021). High-intensity interval training in high-school physical education classes: Study protocol for a randomized controlled trial. *Contemporary Clinical Trials Communications*, *24*, 100867. https://doi.org/https://doi.org/10.1016/j.conctc.2021.100867

Bento, A., Carrasco, L., & Raimundo, A. (2022). The Mediating Effect of Physical Fitness and Dietary Intake on the Relationship of Physical Activity with Body Composition in High School Students. *International Journal Of Environmental Research And Public Health*, *19*(12), 7301. https://www.mdpi.com/1660-4601/19/12/7301

Bento, A., Carrasco, L., & Raimundo, A. (2022). High-Intensity Interval Training (HIIT) Program in Physical Education Classes for Promoting Fitness in Adolescents: A Randomized Controlled Trial **(under review)**

Bento, A., Carrasco, L., & Raimundo, A. (2023). Mediating Effect of Motivation on the Relationship of Fitness with Volitional High-Intensity Exercise in High-School Students. *Healthcare, 11*(6), 800. https://www.mdpi.com/2227-9032/11/6/800

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Bento, A., Carrasco Páez, L., & Raimundo, A. (2020). School-based high-intensity interval training (HIIT) programs for promoting physical exercise: a systematic review. Conference: XV Congresso da Sociedade Portuguesa de Ciências da Educação At: Porto, Portugal

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CHAPTER 2

2. Literature Review

Adolescence is a time of biological, social, and cultural transitions that are closely linked to the development of either good habits or health risks (Kjønniksen et al., 2008). Additionally, metabolic disorders and obesity-related issues brought on by academic stress, sleep deprivation, and a sedentary lifestyle are worrying aspects in a teen's development (You et al., 2021).

Insufficient physical exercise, but also other factors, such as overweight and obesity, and poor diet, are increasingly evident in the adolescent population, and could be decisive both for low CRF and the increasing incidence of different pathologies (Logan et al., 2014). Over 50% of obese children will become obese adults, with a significant increase in the risk of developing asymptomatic diseases, including cardiovascular diseases, cancer, and type 2 diabetes mellitus (Dias et al., 2016). Data related to HBSC associate a sedentary lifestyle with headaches, sadness, irritability, and nervousness (Marques et al., 2015). A school is a place where adolescents spend most of their day. It is known that the school and PEC are privileged spaces and promoters of positive changes for the rest of life (Chen et al., 2021; Domaradzki et al., 2022; Duncombe et al., 2022; Harris et al., 2021; Popowczak et al., 2022), in which time-efficient approach interventions have a prominent role.

There are several reasons why PEC should be taught in schools, but the effectiveness of current methods for PEC is frequently challenged notwithstanding this point of view (Lubans et al., 2022; McKenzie & Lounsbery, 2014). It has also been demonstrated that most PEC programs have difficulty attaining the full range of health and educational outcomes included in the PEC curriculum (Bailey et al., 2009; Popowczak et al., 2022). Professionals consistently cite an overloaded curriculum causing additional time pressures as a primary obstacle to attaining these concurrent educational and health goals in response to the criticism (Bossmann et al., 2022; Duncombe et al., 2022; Harris et al., 2021; Morgan & Hansen, 2008).

PEC teachers are expected to increase their students' ability to perform a variety of movement skills in addition to the objectives of PEC programs in terms of health and fitness (Bauer et al., 2022; Bossmann et al., 2022; Domaradzki et al., 2022; Dudley et al., 2021; Meng et al., 2022; Popowczak et al., 2022). By adding HIIT into secondary PEC programs, teachers may be able to reach their goal of allocating 30% of class time to these crucial instructional techniques without compromising the health-related fitness benefits connected with PEC (Dudley et al., 2012).

This study aims to investigate whether 16 weeks of HIIT implemented on PEC, compared to 16-weeks of usual PEC, can improve physical fitness, body composition, PA and motivation for exercise in high-school adolescents. More precisely, we intend to study how these variables are associated, allowing us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people. Also, we aim to provide a rationale of design considerations for HIIT, such as appropriate length, intensity, and modality. Exploring the mechanisms or processes that mediate the effects of HIIT on physical fitness is crucial for developing effective interventions in PEC.

2.1. Physical Fitness

Children's and adolescents' cardiometabolic risk profiles are correlated with physical fitness, which is the ability to carry out daily tasks with vigor and energy, and it is mostly influenced by heredity and training (Ortega et al., 2008). The concept of physical fitness consists of several elements, which are typically divided into CRF and muscular fitness (Wilder et al., 2006). Resistance training and/or aerobic exercise are both helpful in lowering the prevalence of cardiovascular risk factors (Steinberger et al., 2016). Strong and persistent evidence links low CRF to higher morbidity and mortality from all causes, including cancer and cardiovascular disease (Kodama et al., 2009), and low CRF in childhood is a significant independent predictor of metabolic syndrome in early adulthood (Schmidt et al., 2016). A healthier cardiovascular profile at later age is linked to CRF improvement in childhood and adolescence (Ruiz et al., 2009), and an active childhood benefits a healthy lifestyle over the course of an individual's life (Telama et al., 2014).

The goal should be to improve CRF early in childhood because it is an objective and reproducible physiological marker that reflects the functional implications of PA habits, genetics, and illness state (Sui et al., 2007). Despite the World Health Organization's (WHO) recommendation that children engage in at least 60 minutes a day of MVPA (Bull et al., 2020), western children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Gentil et al., 2021; Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Moreover, adolescents tend to become more inactive as their age increases (Bluher et al., 2017). As a result, there are gradually more children and teenagers with low CRF (Martinez-Gomez et al., 2011). Therefore, it is crucial to develop efficient exercise methods to help young children to change their overall movement patterns and increase their level of PA (Schöffl et al., 2021).

Recent research shows that HIIT can enhance adolescents' fitness levels in terms of their health (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Eddolls et al., 2017), and each of these reviews discovered that HIIT in adolescents is a time-effective strategy to increase CRF when compared to methods using MVPA intensities or control groups. HIIT has shown to be more effective than Moderate-Intensity Continuous Training (MICT) at improving CRF in adolescents (Cao et al., 2019). An increase in mitochondrial content and induced higher increases in citrate synthase maximal activity (MacInnis et al., 2017), type II fiber activation, and adenosine monophosphate-activated protein kinase activity (Kristensen et al., 2015) can be some of the physiological mechanisms explaining why HIIT may improve CRF compared to MICT.

Nearly half of an individual's body weight is composed of skeletal muscles, which are critical for preserving health (You et al., 2021). Responses to HIIT include skeletal muscle adaptations, neurohumoral changes, vascular changes, and structural changes in the heart muscle (Kessler et al., 2012). Since muscle strength appears to have a high correlation with health benefits, the HIIT's muscle-strengthening component may be pivotal for young people (García-Hermoso et al., 2019) and prevent the metabolic health problems brought on by insufficient levels of physical activity from worsening (Gomes et al., 2017).

Childhood and adolescence are critical periods for the development of physical fitness. The improvement in physical fitness can lead to more people engaging in sports and exercise on their own, inasmuch that a result of HIIT could be seen as an end (to increase physical fitness) but also as a mean (to increase PA) (Gentil et al., 2021).

2.2. Body Composition

Common body composition indicators include Body Mass Index (BMI) and body fat percentage. Because it can improve body composition and sustain cardiometabolic health, exercise is crucial for managing pediatric obesity (Liu et al., 2020). In modern society, with the economic development and changes in dietary structure, high-calorie foods are more prevalent among adolescents, leading to a significant increase in the obesity rate of the youngest (Jebeile et al., 2021) and to the promotion of a positive energy balance. Due to its direct relationship with the long-term gain or loss of adipose tissue and changes in metabolic pathways, the difference between energy intake and expenditure has become of great interest, since it was recognized that overweightness and obesity are major risk factors for many other health conditions (Romieu et al., 2017).

Adolescent obesity is a severe health risk and is directly linked to chronic problems in adults (Twarog et al., 2021). Strong evidence suggests that childhood obesity is predicted by excess weight, and it can raise cardiometabolic risks in obese children, such as insulin resistance, dyslipidemia, hypertension, and poor CRF (Liu et al., 2020). Additionally, psychological and social wellbeing may be impacted, and obese young individuals are more likely to experience stigmatization (Rees et al., 2011), as well as lower quality of life and self-esteem (Griffiths et al., 2010).

In obese adolescents, MICT is an effective strategy to lower body fat and cardiometabolic risk (Liu et al., 2020). However, long-lasting sessions are essential for MICT to be successful (Alberga et al., 2013), and only a small amount of youngsters can reach the necessary effective duration (Fan & Cao, 2017). In children with obesity, body composition is improved similarly by HIIT and MICT. However, due to time commitment, HIIT might be a good substitute for MICT, providing similar levels of body composition improvement (Liu et al., 2020; You et al., 2021).

The key to the body's fat-reduction impact, from a dose-effect standpoint, is the exercise dose in weight control. The physiological nature of HIIT and MICT seems to be different. While high-intensity exercise may be linked to an increase in catecholamine and growth hormone secretion, which could improve the rates of adipose lipolysis, MICT may involve elevated rates of burning fat as a substrate, with a sustained high release of free fatty acids and subsequent oxidation (Jensen, 2003). Also, high excess post-exercise oxygen consumption caused by high-intensity exercise promotes a substrate shift that favors fat utilization throughout the recovery period (Islam et al., 2018).

2.3. Physical Activity

PA has proven to have potential advantages in the form of enhanced cognitive abilities in addition to its conventional health benefits (Mezcua-Hidalgo et al., 2019).

Short leisure time, reduced access to facilities and low motivation to engage in PA, are frequently reported barriers to poor adherence to exercise programs (Chen et al., 2021; Cvetkovic et al., 2018; Gentil et al., 2021; Lau et al., 2015; Martin-Smith et al., 2019). In modern society, it is unlikely that individuals will ever return to the high average PA levels of the past, and time-efficient interventions have a prominent role. Energy intake patterns and PA behaviors are influenced by a complex interaction of these factors. The focus of PA research has expanded to address the potential negative effects of sedentary behavior on energy balance (Popowczak et al., 2022; Romieu et al., 2017; You et al., 2021). Higher levels of PA have demonstrated to reduce the weight gain associated with increased energy density, and it appears that at low levels of PA, effective appetite suppression to maintain energy balance is compromised (Blundell et al., 2015). Environmental factors should be the primary objectives of epidemic intervention efforts, as they are modifiable, although genetic factors may play a role in affecting individuals' susceptibility to developing obesity (Romieu et al., 2017). From an evolutionary perspective, the adaptation that HIIT-related exercise delivers to the body is a fantastic countermeasure to the evolutionary mismatch caused by lifestyle (Batacan et al., 2017).

An active childhood benefits a healthy lifestyle over the course of an individual's life (Telama et al., 2014). WHO stated that the adolescent population should achieve at least an average of 60 min per day of MVPA and must limit sedentary time (Bull et al., 2020). By examining 16 intensity threshold data from 38,306 children and adolescents worldwide, Landgraff et al. (2021) concluded that the time spent on high-intensity PA, rather than its duration, is the primary driver of changes in cardiac metabolic risk variables.

The traditional method for improving PA is known as MICT (Liu et al., 2020); however, including HIIT in PEC influences the students' overall level of PA (Popowczak et al., 2022). Adolescents were more active when they did HIIT than on other days, according to Costigan et al. (2018).

2.4. Motivation

To achieve better health outcomes, there is a recognized need for physical a kind exercise that attracts the adolescent population (Faria et al., 2020). Students who are more highly motivated put in more effort into their academic work and physical exercises in PEC

(Bechter et al., 2018), and higher intention to engage in PA in the future can result from intrinsic PEC motivation (Ntoumanis, 2001). Regardless of a student's initial skill level at the start of a teaching cycle, there is a relationship between motivation and performance quality (Boiché et al., 2008). Interventions designed to increase MVPA in PEC indicate that programs could increase the proportion of time students spend in higher intensities and reduce sedentary behavior, insofar that motivational environments that emphasize effort and improvement and provide opportunities to demonstrate leadership and make decisions have a positive impact on PA (Lonsdale et al., 2013).

Recreational sport and exercise can be performed for the associated enjoyment or for the challenge of participating in an activity (Teixeira et al., 2012). According to the Self-Determination Theory (SDT), two types of motivation influence personal behavior: the intrinsic (doing a task for the inherent pleasure) and the extrinsic (doing an activity for instrumental reasons, to obtain separable outcomes, or to avoid disapproval). Extrinsically motivated behaviors are expressed in four regulations: external (influenced by external contingencies), introjected (performing to obtain social approval or avoid internal pressure), identified (recognition and acceptance of the behavior) and integrated (accepting and integrating the behavior in other aspects of the self) (Deci & Ryan, 2008). The vast majority of studies included an examination of the relationships between behavioral regulation and exercise behavior. Of these, most included some or all of the individual regulations specified within SDT, whereas others have collapsed autonomous and controlled forms of regulation into summary scales or adopted the Relative Autonomy Index (RAI) (Teixeira et al., 2012). RAI represents the self-determination continuum where lower scores indicate less autonomous motivation, whereas higher scores indicate more autonomous motivation (Verloigne et al., 2011). Nevertheless, studies have shown that exercise behavioral regulation was found to be predictive of vigorous exercise, where introjected regulation, identified regulation, and intrinsic motivation were associated positively with strenuous exercise behaviors (Edmunds et al., 2006). Still, intrinsic motivation appears to be a more consistent predictor of moderate and vigorous exercise than identified regulation, and autonomous motivation was predictive of long-term moderate-to-vigorous exercise (Silva et al., 2010). Physical self-perception could be considered for adherence to MVPA, although Rey et al. (2017) suggest that the adolescents' psychological perception and health might improve in response to morphological adaptations, without concomitant improvements in objectively measured physical characteristics or performances.

The growing evidence of the usefulness of SDT-based interventions for promoting the adoption and maintenance of exercise is a significant advance, but few studies included biological markers of successful exercise-related outcomes (Teixeira et al., 2012), such as volitional intensity. Volition consists of meta-motivational processes; when higher-level action control processes fail, volition may consist of increasing vigor. Research on the importance of volition in the area of exercise psychology is very limited; however, volitional skills have proven to be a sound predictor of performance in other areas of sport, such as elite sports (Elbe et al., 2005). Heart rate (HR) has become one of the most used outcomes to assess intensity, and several authors suggest that high-intensity exercise corresponds to a value equal to or higher than 90%HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). According to Bond et al. (2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. Nevertheless, to the best of our knowledge, no studies formally tested the mediating role of motivation in exercise intensity and physical fitness relationships in PEC.

While the effectiveness of HIIT for a variety of cardiometabolic health outcomes is unquestionable, it is debatable whether HIIT reduces an individual’s motivation to participate in long-term PA due to its physiologically exhausting nature (Eddolls et al., 2017). Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014; Lubans et al., 2022; Martínez-Díaz & Carrasco, 2021). An earlier study revealed that exercise adherence in overweight children was inversely correlated with the intensity of PA (Deforche et al., 2011). Notwithstanding the limited number of people willing to engage in moderate-to-vigorous physical e exercise (MVPE) and the high attrition of those who participate (Courneya, 2010), the evidence shows a high level of effectiveness of intense exercise to reduce mortality, even considering a long lifespan (Wen et al., 2011). No harmful associations in recent studies applying intense efforts are also encouraging (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Leahy et al., 2019). Furthermore, adolescents seem to be more enthusiastic about resistance training, whereas aerobic training is found to be boring (Lee et al., 2012). Other studies, besides aerobic and resistance training groups, included a variety of activities to enhance motivation and appeal to the interest of older adolescents, improving aspects of adolescents' cardiometabolic health (Weston et al., 2016), fitness and body composition, despite the lowest dose among groups (Logan et al., 2016).

While a scoping review has indicated that the benefits of HIIT are comparable to or superior to those of MICT in terms of satisfaction and preferences (Stork et al., 2017), previous meta-analyses have shown that HIIT presents typically lower dropout rates than standard exercise programs, making it a tolerable and acceptable intervention for untrained individuals (Reljic et al., 2019). Evidence suggests that HIIT participants exhibit high levels of motivation and pleasure and feel the program is more enjoyable than traditional training (Duncombe et al., 2022; Gentil et al., 2021). Shorter intervals appeared to be slightly more motivating for the students, who reported finding music to be both stimulating and useful for maintaining high levels of intensity. Furthermore, implementing difficult obstacle courses or circuit sessions that allowed for individual adaptation or exercise selection could boost motivation and notably benefit "unathletic" students who have trouble maintaining high levels of effort (Bossmann et al., 2022).

Although HIIT has already been recognized for improving cardiovascular and metabolic health in adolescents, its use to enhance cognitive and mental health also has a lot of research potential (Lubans et al., 2022; Valkenborghs et al., 2022; You et al., 2021). Further research is needed to create a HIIT model that promotes a higher degree of intrinsic motivation so that teachers can concentrate on the parts of a lesson that lead to better performance (Dudley et al., 2021).

2.5. HIIT

HIIT is a timesaving, globally applicable, and enjoyable strategy when compared to other training methods, such as resistance training and MICT (Gentil et al., 2021; You et al., 2021), and is characterized by relatively short periods of very intense exercise, interspersed with periods of pause or low-intensity exercise (Fisher et al., 2011; Gibala & Jones, 2013; Logan et al., 2016). The purpose of HIIT is to allow overloading physiological systems with exercises of higher intensity than those achieved during a gradual maximal test (Stuckey et al., 2012).

HIIT has the potential to reduce several negative health consequences in adolescents (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015). Preliminary studies conducted with adolescents have shown promising results on body composition and cardiometabolic health, and more effective and time-efficient intervention for improving blood pressure and aerobic capacity levels (Bluher et al., 2017; Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Duncombe et al., 2022; Eddolls et al., 2017; Garcia-Hermoso et al., 2016; Herget et al., 2016; Lubans et al., 2022). Therefore, HIIT is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Logan et al., 2014; Zhang et al., 2017), as it leverages the number of exercise participants, resulting in improvements in health outcomes, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017; Logan et al., 2016).

The shorter time commitment may be more significant than its effects and improve training adherence (Batacan et al., 2017). Children and adolescents have expressed a clear preference for time efficiency and pleasure, and the “stop-start” nature of HIIT seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Gentil et al., 2021; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). As a result, it might be more well received in this age group than MICT.

HIIT has virtually infinite variations and forms, and the specific physiological performance induced by HIIT depends on several variables, including intensity, length, number of completed intervals, and activity patterns during recovery (You et al., 2021). Regarding the time limitations teachers face when teaching PEC, HIIT is emerging as a potential option (Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Domaradzki et al., 2022). The long-term effects of HIIT participation on students’ health-related fitness and PA levels are still unknown (Dudley et al., 2021).

2.5.1. HIIT Protocols in PEC

Regarding HIIT protocols, the selection and choice of specific training parameters (length and number of intervals) seem arbitrary, and there is no state-of-the art for choosing training parameters (Bossmann et al., 2022). Clearer definitions of the nature of the exercise behaviors under analysis (type, intensity, volume, density), which may differ between studies, as well as their potential interest to the individual, may offer more information on this topic. Adolescents, especially older ones, are underrepresented in studies implemented in the school context (Leahy et al., 2019). Despite the widespread interest in the advantages that the HIIT methodology reveals, there is a lack of randomized controlled studies investigating the impact on adolescents (Leahy et al., 2019; Logan et al., 2014), mainly addressing adolescents' environments, such as schools (Harris et al., 2017; Logan et al., 2016).

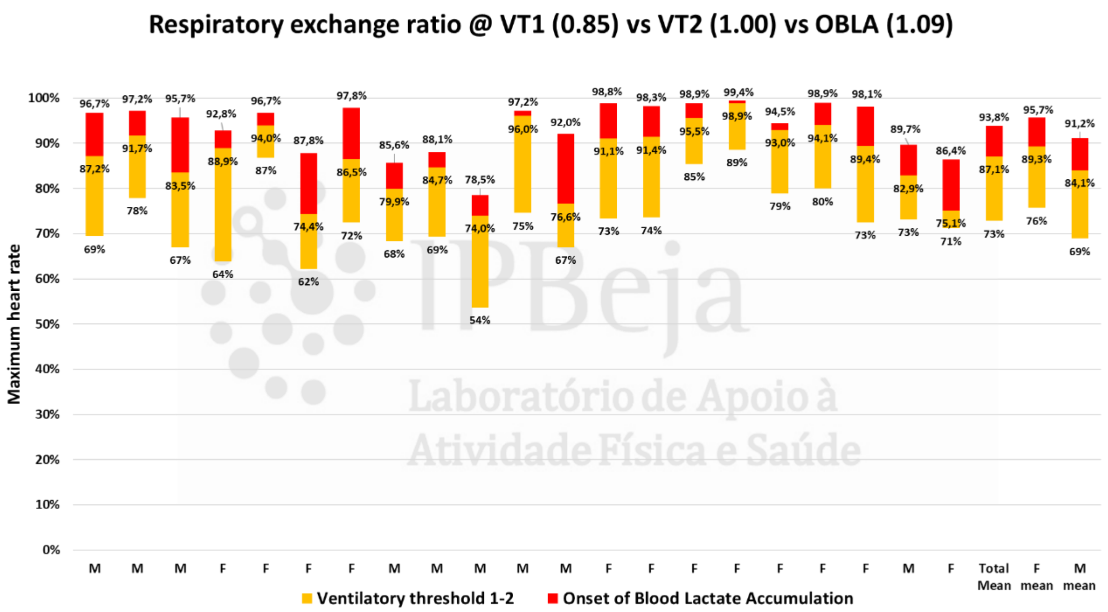
Recently, some studies present HIIT programs targeting school-aged children (Bogataj et al., 2021; Ketelhut et al., 2020; Sharp et al., 2020; Tottori et al., 2019), and in a scope of 10 years, we find dozens of works with students aged 10-19 years, but only a few were implemented in the school setting. Of them, just a few were implemented in PEC (Alonso-Fernández et al., 2019; Bogataj et al., 2021; Buchan et al., 2012; Chen et al., 2021; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Domaradzki et al., 2022; Dudley et al., 2021; Harris et al., 2021; Ketelhut et al., 2020; Martin-Smith et al., 2019; Martin et al., 2015; Popowczak et al., 2022), or replacing the entire session with the intervention (Dudley et al., 2012; Martin-Smith et al., 2019; Martin et al., 2015; Weston et al., 2016).

Almost all programs are limited to sprints, but some were designed to be implemented in couples (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Leahy et al., 2019) or individually (Alonso-Fernández et al., 2019) through calisthenic exercises and plyometrics. Optimal exercise duration and rest intervals remain ambiguous (Eddolls et al., 2017). In adults, previous findings suggest that a 2:1 work-to-rest ratio is optimal during HIIT for both men and women (Laurent et al., 2014). In adolescents, despite differences in protocols on intensity like all-out bouts or % of Maximal Aerobic Speed (MAS), modality (sprints vs calisthenics), and volume (6min-35min/session), most of them opted for 1:1 density (Eddolls et al., 2017).

Some studies that exceed 10 minutes per session (Cvetkovic et al., 2018; Leahy et al., 2019; Racil et al., 2013), for 12 weeks, did not go beyond the moderate effect on body composition and physical fitness, compared to protocols below 10 minutes and with the same Effect Size (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; Racil et al., 2016; Williams et al., 1991). Interestingly, other protocols that record Large Effect Size on CRF (Martin-Smith et al., 2019; Martin et al., 2015), PA (Martin-Smith et al., 2019), strength, power, and speed (Engel et al., 2019) needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, for only four (Engel et al., 2019; Martin-Smith et al., 2019) and seven weeks (Martin et al., 2015). It should be also emphasized that the same three studies that record Large Effect Sizes chose to use all-out bouts instead of a percentage of MAS, reinforcing the importance of including resistance training as a HIIT modality.

Although VO_2max is frequently used to determine the intensity of HIIT, this method ignores the subjects' anaerobic characteristics (**Fig. *2.1***), which are critical for HIIT (Vaccari et al., 2020). Since exercising at intensities above 80% of maximum HR may be important for this group, the higher intensity attained during HIIT appears to be a crucial factor for CRF in youth (Baquet et al., 2003). Adjusting exercise intensity using HR has been a valid option, mainly in prolonged and submaximal periods. HR has become one of the most used outcomes to assess intensity, and several authors suggest that high-intensity exercise corresponds to a value equal to or higher than $90\%HR_{max}$ (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007).

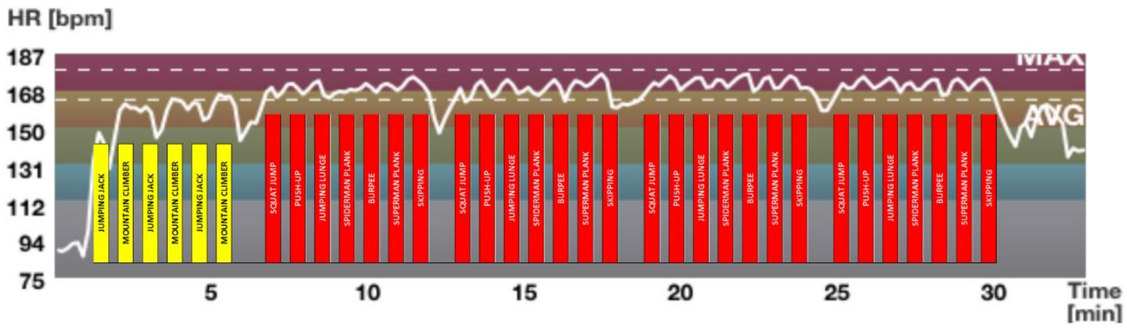
Fig. 2.1 *Respiratory exchange ratio during Bruce Protocol Maximal oxygen uptake (Bento & Loureiro, 2018)*



An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone* (**Fig. *2.2***), which usually means a minimum intensity of $90\%VO_{2max}$ (Buchheit & Laursen, 2013). It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds)

(Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response.

Fig. 2.2 *Red Zone: A cut-point of 90% of HR_{max} as a criterion for satisfactory compliance to high-intensity exercise (Bento & Loureiro, 2018)*



Few studies have objectively measured internal load by monitoring HR (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013) or rating perceived exertion (RPE) (Alonso-Fernández et al., 2019; Engel et al., 2019), but only some defined cut lines considering as high intensity >85%HR_{max} (Costigan et al., 2018; Leahy et al., 2019) or >90%HR_{max} (Bossmann et al., 2022; Cvetkovic et al., 2018).

Most studies opted to set intensity through external load, expressed in speed or distances. The more traditional HIIT methodology reflects a temporal efficiency in the improvement of several health markers and aerobic/anaerobic performance but lowered impact on strength, muscle strength, and power. New protocols that also include resistance exercises can induce a higher amount of beneficial adaptations in young people (Bento & Loureiro, 2018). Besides, RPE could also be measured in each exercise session to estimate effort, fatigue and training load, targeting >17 on the 6−20 Borg scale (Borg, 1970; Foster et al., 2001; Williams et al., 1991).

With this study, the authors aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), which include resistance exercises through calisthenic exercises and plyometrics, to implement PA interventions, which retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety. HIIT protocols implemented in schools reflect on improving physical fitness and reducing sedentary behaviors, compared to other types of less intense and higher volume activities. This efficiency, resulting from the reduced time required (on average, about 10 minutes), reflects the wide applicability that these protocols could have in PEC and the high adaptation to the facilities (including classrooms). Moreover, exercise protocols that result in physiological improvements and adaptations in terms of health in a short time are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals.

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2.7. Study 1. School-Based High-Intensity Interval Training Programs for Promoting Physical Activity and Fitness in Adolescents: A Systematic Review

Bento, A., Carrasco, L., & Raimundo, A. (2022). School-Based High-Intensity Interval Training Programs for Promoting Physical Activity and Fitness in Adolescents: A Systematic Review. *Journal of Teaching in Physical Education*, *41*(2), 288-300. https://doi.org/10.1123/jtpe.2020-0187

2.7.1. Abstract

Purpose: This review aimed to evaluate the utility of HIIT programs integrated into Physical Education classes (PEC).

Method: Searches of the electronic databases included from January 2008 to March 2020. Inclusion Criteria: applied to adolescents aged 10-19 years; applied in school settings; reported results on physical fitness, physical activity (PA), and motivation; at least for four weeks; and randomized controlled trials. Studies with adolescents with physical or intellectual limitations were excluded, as well as other interventions parallel to HIIT.

Results: 14 studies were included. All works present significant improvements in physical fitness and PA. Improvements in body composition recorded, at most, a moderate Effect Size. HIIT is presented as a powerful stimulus on cardiorespiratory fitness. Improvements in PA registered, a least, a moderate Effect Size.

Conclusion: HIIT in the school context has great potential in improving physical fitness and PA in adolescents. HIIT efficiency (about 10 minutes), reflects the wide applicability that these protocols can have in PEC, and the great adaptation to the facilities.

Registration Number: CRD42019138771

***Keywords*:** Fitness, Health, HIIT, Physical Education, Sedentary Behaviour

2.7.2. Introduction

Insufficient physical activity (PA), overweight and obesity, poor diet, low cardiorespiratory fitness (CRF), hypertension, chronic inflammation, and dyslipidemia are increasingly evident in the adolescent population (Logan et al., 2014). Exercise is one of the key strategies in reducing inflammatory processes and, consequently, reducing cardiovascular events (Kargarfard et al., 2016). Over 50% of obese children will become obese adults, with a significant increase in the risk of developing asymptomatic diseases, such as those previously described (Dias et al., 2016). In most Western countries, children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Data related to Health Behavior in School-Aged Children (HBSC) associate a sedentary lifestyle with headaches, sadness, irritability, and nervousness (Marques et al., 2015). Moreover, adolescents tend to become more inactive with increasing age (Bluher et al., 2017). Short leisure time, reduced access to facilities, and low motivation to engage in physical activities, are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). Interventions designed to increase moderate-to-vigorous PA in Physical Education classes (PEC) indicate that interventions can increase the proportion of time students spend in higher intensities during PEC and reduce sedentary behavior, since motivational climates that emphasize effort and improvement and provide opportunities to demonstrate leadership and make decisions have a positive impact on PA (Lonsdale et al., 2013). Physical self-perception could be considered for adherence to PA, although Rey et al. (2017) suggest that the adolescents' psychological perception and health might be improved in response to morphological adaptations, without concomitant improvements in objectively measured physical characteristics or performances. It seems to be a lack of research specifically reporting PEC contributions to increasing physical activity. Therefore, High-Intensity Interval Training (HIIT) is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Logan et al., 2014; Zhang et al., 2017), as it leverages the number of exercise participants, resulting in health outcomes improvements, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017).

HIIT is characterized by relatively short periods of very intense exercise, interspersed with periods of pause or low-intensity exercise (Fisher et al., 2011; Gibala & Jones, 2013; Logan et al., 2016). The purpose of HIIT is to allow overloading physiological systems with exercises of higher intensity than those achieved during a gradual maximal test (Stuckey et al., 2012). HIIT is a powerful stimulus in improving body composition and preventing cardiometabolic risk in adults (Sim et al., 2015). Preliminary studies conducted with adolescents have shown promising results on body composition and cardiometabolic health, and more effective and time-efficient intervention for improving blood pressure and aerobic capacity levels (Bluher et al., 2017; Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Eddolls et al., 2017; Garcia-Hermoso et al., 2016; Herget et al., 2016). Peripheral adaptations can explain the increase in CRF. According to Bond et al. (2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. An increase in mitochondrial content and induced higher increases in citrate synthase maximal activity (MacInnis et al., 2017), type II fiber activation, and adenosine monophosphate-activated protein kinase activity (Kristensen et al., 2015) can be some of the physiological mechanisms why HIIT may improve CRF.

Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014). However, children and adolescents have expressed a clear preference for time efficiency and pleasure, and the "stop-start" nature of HIIT seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). Optimal exercise duration and rest intervals remain ambiguous (Eddolls et al., 2017). Despite the widespread interest in the advantages that the HIIT methodology presents, there is a lack of randomized controlled studies investigating the impact on adolescents, mainly approaching adolescents' environment, such as schools (Harris et al., 2017; Logan et al., 2016; Logan et al., 2014). It is known that School and PEC are privileged spaces, promoters of positive changes for the rest of life (Mura et al., 2015).

In an attempt to broaden knowledge about evidence that relates to the variables mentioned above, this systematic review was based on the question: what are the effects of a HIIT program integrated into High-School PEC (students aged 10-19 years), on Physical Fitness, PA, and Motivation for Exercise? The aim of this review was 1) to evaluate the utility of a HIIT program integrated into High-School PEC, on Physical Fitness, PA, and Motivation for Exercise; and 2) to evaluate the effects of Protocols and Periodization on previous outcomes.

2.7.3. Methods

2.7.3.1. Search Strategy

This systematic review is put forward according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) (Liberati et al., 2009) and was preregistered in the International Prospective Register of Systematic Review (PROSPERO) with the number CRD42019138771. The author conducted searches on the electronic databases PubMed, MEDLINE, SPORTDiscus, CINAHL, MEDICLATINA, COCHRANE, and Web of Science from January 2008 to March 2020. The following search strategy was used: (("High-Intensity Interval Training" OR "High-Intensity Interval Exercise" OR HIIT OR "High-Intensity Intermittent Exercise" OR "High-Intensity Intermittent Training" OR "Sprint Interval Training" OR "Sprint Interval

Exercise” OR “sprint intermittent training” OR “sprint intermittent exercise” OR HIT) AND (Adolescents OR Adolescence OR Teens OR Teen OR Teenagers OR Teenager OR Youth OR Youths)) AND (motivation OR motivational OR behavior OR behavioral) OR (“Cardiorespiratory Fitness” OR Fitness OR Strength OR Endurance OR “Body composition” OR “Body mass” OR “Kinanthropometry” OR “Physical Conditioning” OR “Physical Fitness” OR “Physical Education” OR exertion OR “PHYSICAL endurance” OR “Physical Performance” OR “Athletic Ability”) OR (effect OR effects OR result OR results OR impact OR compared OR comparation)). This strategy was later limited to published peer-review studies, written in English, Portuguese, or Spanish. Initially, studies were analyzed by the title and abstract according to the inclusion criteria described in the next sub-section.

2.7.3.2. Inclusion Criteria and Study Selection

Studies were considered eligible if they: (i) had been applied to adolescents aged 10-19 years; (ii) the HIIT program has been applied in school settings;(iii) reported results on physical fitness, PA, and motivation for exercise; (iv) the intervention had been, at least, for four weeks; (v) randomized controlled trials (RCT) had been performed. Studies with adolescents with physical or intellectual limitations that could influence the intervention were excluded, as well as other interventions parallel to HIIT. Abstracts of conferences, theses, or articles published without peer-review were also not considered.

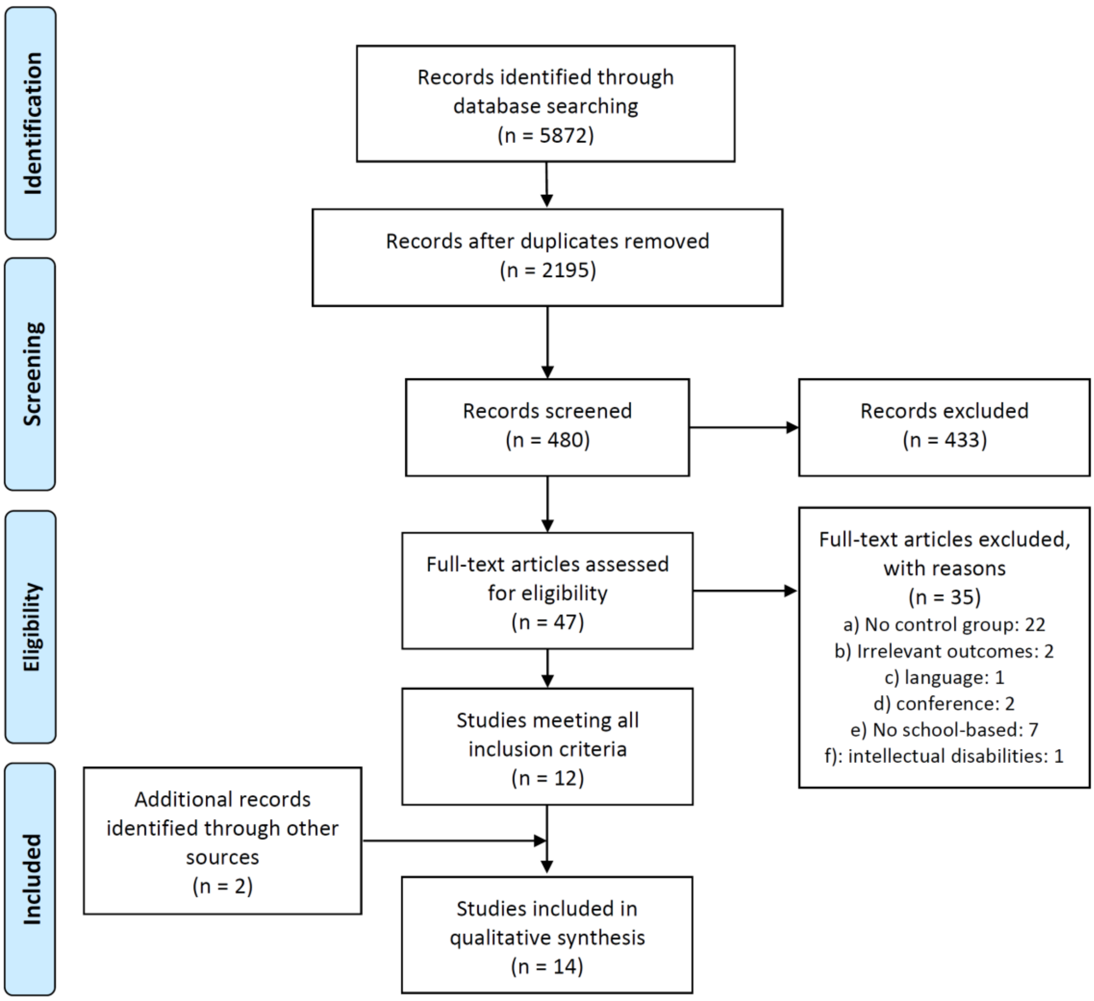
2.7.3.3. Data Extraction and Quality Assessment

The author performed data extraction and obtained the main characteristics of the studies, such as sample size, age and gender, duration, intervention variables (HIIT program), results relating to the physical fitness, PA, and motivation for exercise. The study included data from investigations providing mean values and measures of variability. In some cases, the mean and measures of variability were extrapolated from the figures.

Two independent researchers analyzed the selected studies for methodological quality through the Physiotherapy Evidence Database (PEDro) (Sherrington et al., 2000) and a seven-item checklist from the Cochrane Collaboration’s tool for assessing the risk of bias in randomized trials (Higgins et al., 2011).

The PEDro scale has a total of 11 items. Item 1 refers to the external validity of the study, while items 2 to 9 refers to internal validity. Items 10 and 11 indicate whether the statistical information provided by the authors allows an adequate interpretation of the results. All items on this list are dichotomized as "yes", "no" or "does not report". Each item answered as "yes" adds one point, while items answered as "no" or "does not report" add 0 points. This review did not take into consideration the first item of PEDro scale because it was related to the assessment of external validity. Therefore, only items 2 to 11 were selected for analysis of methodological quality. For this reason, the maximum score of an article will not exceed 10 points and can be a minimum of 0 points.

Fig. 2.3 *Flow diagram of outcomes of review illustrating the different phases of the search and selection of studies*



To assess the risk of bias, the Cochrane's 'Risk of bias's tool guidelines were used and performed by the two independent researchers. Judgments on the risk of bias included six domains: sequence generation; allocation concealment; blinding (of participants, personnel, and outcome assessors); incomplete outcome data; selective outcome reporting; and other risks of bias (such as the trial stopped early). The researchers categorized these judgments as low risk of bias, high risk of bias, or unclear risk of bias. Discrepancies were resolved through consensus, and inter-rater reliability was calculated by A.B. using percentage agreement.

2.7.4. Results

2.7.4.1. Search Result

Search in electronic databases resulted in 5872 studies (**Fig. *2.3***). After removing duplicates (n = 3677); electronic filters to include only RCT after 2008 applied to 10-19 years adolescents (n= 1715); abstracts (n = 480) and full articles screening (n = 47), a total of 12 studies were included in the review. Subsequently, two more articles were added from other sources (Engel et al., 2019; Lau et al., 2015). The descriptive characteristics of the protocols and the main results in terms of physical fitness, PA, and motivation for exercise are available in **Table *2.1***.

Briefly, samples ranged from 26 (Alonso-Fernández et al., 2019) and 68 (Leahy et al., 2019) students, and the length of the intervention ranged between four (Engel et al., 2019; Martin-Smith et al., 2019) and 14 weeks (Leahy et al., 2019). None of the studies reported any adverse events, either acute or chronic, resulting from the application of HIIT protocols.

Although all the studies have been implemented in the school setting, only six studies (Alonso-Fernández et al., 2019; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Martin-Smith et al., 2019; Martin et al., 2015) were implemented in PEC, two of which replaced the entire session with the intervention (Martin-Smith et al., 2019; Martin et al., 2015), and one was implemented in a classroom (Engel et al., 2019). Of those implemented in PEC, two reported one extra session at lunch (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018) and one proposed one extra session autonomously (Leahy et al., 2019). HIIT programs were implemented by researchers supported by PEC teachers, except for one, which the PEC teachers themselves implemented the protocols, after training with the researchers (Leahy et al., 2019). Regarding programs that were not limited to SPRINTS, three were designed to be implemented in couples (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Leahy et al., 2019), and one individually (Alonso-Fernández et al., 2019), through calisthenic exercises and plyometrics.

2.7.4.2. Risk of Bias

The methodological risk of bias scores is provided in **Table *2.2***. The lost points were mainly due to the blinding of participants and personnel, and blinding of the outcome assessment, as they are previously informed of the type of activity that will be undertaken.

According to the PEDro scale, the methodological quality of the analyzed studies ranged from 4 to 7, with an average of 6 (table 1). Four articles (29%) scored 7 points, seven articles (50%) scored 6 points, two articles (14%) scored 5 points, and one article (7%) scored 4 points.

The Cochrane Collaboration's tool for assessing the risk of bias does not recommend the use of scales that result from the individual score but considers the relative importance of the different domains. For example, to very subjective conclusions as pain, blind randomization is essential. Considering the objectivity of the presented outcomes, most studies report information with an unclear risk of bias, plausible to raise some doubts. Taken together, this indicates the relatively high probability of risk of bias in the present review.

2.7.4.3. Physical Fitness

All studies presented results regarding physical fitness, mainly CRF and body dimensions, except for the study by Costigan et al. (2018), which reported only levels of PA.

Table 2.1 *Summary of studies included in the present systematic review*

Reference, sample, duration, and frequency	Participants	HIIT PROGRAM		HIIT OUTCOMES (mean dif)	EFFECT SIZE (ES)
		Modality / Intensity	Work:Rest	Physical Fitness	
Buchan et al. (2012) 41 adolescents 7 weeks 3x/week	35♂, 6♀ 15-17 yrs HIIT 15♂, 2♀ CG 20♂, 4♀	SPRINTS all-out bouts	Week 1-2: 4x30s:30s Week 3-4: 5x30s:30s Week 5-6: 6x30s:30s Week 7: 6x30s:20s	+7,06laps CRF (p<0.005 CG) -0.02s agility (p<0.05 CG)	
Buchan et al. (2013) 89 adolescents 7 weeks 3x/week	64♂, 25♀ 16.7 ± 0.6 yrs HIIT 30♂, 12♀ CG 34♂, 13♀	SPRINTS all-out bouts	Week 1-2: 4x30s:30s Week 3-4: 5x30s:30s Week 5-6: 6x30s:30s Week 7: 6x30s:20s	-0.2kg BM -0.2 BMI -0.002cm WC +1.0cm CMJ (p<.05 baseline & CG) -0.09s 10mSprint (p<.05 baseline & CG) -0.05s Agility +4.6shuttles CRF (p<.001 baseline)	ES>0.5 clinical relevant change CMJ ES=0.49 SPRINT ES=0.78 CRF ES=0.78
Racil et al. (2013) 34 obese adolescents girls 12 weeks 3x/week	34♀ 15.9 ± 0.3 yrs HIIT 11♀ MIIT 11♀ CG12♀	SPRINTS Week 1-4: 100%MAS : 50% Week 5-8: 105 %MAS : 50% Week 9-12: 110%MAS : 50%	Week 1-4: 2x(6x30s:30s):4min Week 5-8: 2x(8x30s:30s):4min Week 9-12: 2x(8x30s:30s):4min	BM (p<0.05 baseline) BMIz (p<0.05 baseline & MIIT & CG) WC (p<0.05 baseline) %BF (p<0.05 baseline & MIIT & CG) ↑VO_2 (p<0.05 baseline & CG) ↑MAS (p<0.05 baseline & CG)	0.5>ES<0.8 moderate effect BMIz ES=0.75 WC ES=0.59 %BF ES=0.72 VO_2 ES=0.68
Lau et al. (2015) 48 overweight children 6 week 3x/week	36♂, 12♀ 10.4 ± 0.9 yrs HIIE 15 LIIE 21, CG 12	SPRINTS HIIE 120%MAS LIIE 100%MAS	HIIE 12x15s:15s LIIE 16x15s:15s	HIIE +2.3% BM (p<0.05 baseline) +1.1% BMI -12.2% SSF (p<0.05 baseline & LIIE & CG) -7.2% s FOP (p<0.05 baseline) -9.5% steps FOP (p<0.05 baseline & LIIE & CG) +21.1% CRF (p<0.05 baseline & CG) +0.8% MAS (p<0.05 CG) LIIE +1.5% BM (p<0.05 baseline) +0.4% BMI -0.4% SSF (p<0.05 HIIE) -2.9% s FOP +1.3% step FOP (p<0.05 HIIE) +10.4% CRF (p<0.05 CG) -0.1% MAS	0.5>ES<0.8 moderate effect BM ES=0.22/small BMI ES=0.24/small SSF ES=0.55/moderate s FOP ES=0.22/small steps FOP ES=0.65/moderate CRF ES=0.58/moderate MAS ES=0.47/small

AEP: Aerobic Exercise Program; CG: control group; BF: body fat; BM: Body mass; BMI: Body mass index; CG: control group; CI: confidence interval; CMJ: countermovement jump; CRF: cardio-respiratory fitness; FOP: functional obstacle performance; HC: hip circumference; HIIE: higher intensity intermittent exercise group; HIIT: high-intensity interval training; LBM: Lean body mass; LBMP: Lower body muscular power; LIIE: lower intensity intermittent exercise group; LJ: Lateral Jump; MAS: Maximal aerobic speed; MIIT: Moderate-Intensity Interval Training; MPA: Moderate Physical Activity; P+HIIT: Plyometric drills + HIIT; PU: push-ups; RAP: Resistance and Aerobic Program; SJ: Squat jump; SLJ: standing long jumps; SPA: Sedentary Physical Activity; SSF: sum of skinfolds; VPA: Vigorate Physical Activity; VO_2: oxygen consumption; WC: waist circumference

Table 4.1 *(continued)*

Reference, sample, duration, and frequency	Participants	HIIT PROGRAM		HIIT OUTCOMES (mean dif)	EFFECT SIZE (ES)
		Modality / Intensity	Work:Rest	Physical Fitness	
Martin et al. (2015) 43 adolescents 7 weeks 3x/week	31♂, 12♀ SIT 13♂, 7♀ 16.9 ± 0.3 yrs CG 18♂, 5♀ 16.8 ± 0.6 yrs	SPRINTS all-out bouts	Week 1-2: 4x30s:30s Week 3-4: 5x30s:30s Week 5-7: 6x30s:30s	¯BM ¯BMI CRF	ES>0.5 clinical relevant change PA ES=0.73 CRF ES=0.93
Costigan et al. (2015) 65 adolescents 8 weeks 3x/week	45♂, 20♀ 15.8 ± 0.6 yrs AEP 16 ♂, 5♀ RAP 15 ♂, 7♀ CG 14♂, 8♀	AEP – all-out Cardio exercises RAP – all-out Resistance + Cardio	Week 1-3: 8x30s:30s Week 4-6: 9x30s:30s Week 7-8: 10x30s:30s	AEP-CG +2.5laps CRF -0.27 $kg.m^{-2}$ BMI -0.10 BMI z-scores ($p<0.05$ CG) -1.5cm WC +1.4cm SLJ +0.5rep PU RAP-CG +5.4laps CRF -0.28 $kg.m^{-2}$ BMI -0.08 BMI z-scores -2.1cm WC ($p<0.05$ CG) +3.6cm SLJ +0.7rep PU	0.5>ES<0.8 moderate effect AEP BMI ES=0.53 BMIz ES=0.63 WC ES=0.5 RAP CRF ES=0.4 BMI ES=0.53 BMIz ES=0.5 WC ES=0.7
Racil et al. (2016a) 68 obese adolescents girls 12 weeks 3x/week	68♀ 16.6±1.3 yrs HIIT 23 P+HIIT 26 CG19	HIIT - SPRINTS Week 1-4: 100%MAS : 50% Week 5-8: 105 %MAS : 50% Week 9-12: 110%MAS : 50% P+HIIT Plyometric drills + HIIT	HIIT - SPRINTS Week 1-4: 2x(6x30s:30s):4min Week 5-8: 2x(8x30s:30s):4min Week 9-12: 2x(8x30s:30s):4min P all out bouts	HIIT -3.8% BM ($p<0.05$ baseline & CG) -15.9% BMIz ($p<0.05$ baseline & CG) -7.1%% BF ($p<0.05$ baseline & CG) +0.6% LBM -3.2% WC ($p<0.05$ baseline & CG) +7% VO_2 ($p<0.05$ baseline & CG) +10.9% MAS ($p<0.05$ baseline & CG) +10.4% SJ ($p<0.05$ baseline & CG) +11.8% CMJ ($p<0.05$ baseline & CG) P+HIIT -2.0% BM ($p<0.05$ baseline & CG) -9.6% BMIz ($p<0.05$ baseline & CG) -7.2%% BF ($p<0.05$ baseline & CG) +3.0% LBM ($p<0.05$ baseline & HIIT & CG) -4.0% WC ($p<0.05$ baseline & CG) +9.5% VO_2 ($p<0.05$ baseline & CG) +11.7% MAS ($p<0.05$ CG) +22.2% SJ ($p<0.05$ baseline & HIIT & CG) +20.0% CMJ ($p<0.05$ baseline & CG)	

AEP: Aerobic Exercise Program; CG: control group; BF: body fat; BM: Body mass; BMI: Body mass index; CG: control group; CI: confidence interval; CMJ: countermovement jump; CRF: cardio-respiratory fitness; FOP: functional obstacle performance; HC: hip circumference; HIIE: higher intensity intermittent exercise group; HIIT: high-intensity interval training; LBM: Lean body mass; LBMP: Lower body muscular power; LIIE: lower intensity intermittent exercise group; LJ: Lateral Jump; MAS: Maximal aerobic speed; MIIT: Moderate-Intensity Interval Training; MPA: Moderate Physical Activity; P+HIIT: Plyometric drills + HIIT; PU: push-ups; RAP: Resistance and Aerobic Program; SJ: Squat jump; SLJ: standing long jumps; SPA: Sedentary Physical Activity; SSF: sum of skinfolds; VPA: Vigorate Physical Activity; VO_2: oxygen consumption; WC: waist circumference

Table 4.1 *(continued)*

Reference, sample, duration, and frequency	Participants	HIIT PROGRAM		HIIT OUTCOMES (mean dif)	EFFECT SIZE (ES)
		Modality / Intensity	Work:Rest	Physical Fitness	
Racil et al. (2016b) 47 obese adolescents girls 12 weeks 3x/week	47♀ 14.2±1.2 yrs HIIT 11 MIIT 11 CG12	SPRINTS 100%MAS : 50%	Week 1-4: 8x15s:15s Week 5-8: 12x15s:15s Week 9-12: 16x15s:15s	-3.7% BM ($p<0.05$ baseline & MIIT & CG) -9.22% BMIz ($p<0.05$ baseline & CG) -9.6% BF ($p<0.05$ baseline & MIIT & CG) -3.23% WC ($p<0.05$ baseline & MIIT & CG) +2.22% VO_2 ($p<0.05$ baseline & CG)	0.5>ES<0.8 moderate effect BM ES=0.45 BMIz ES=0.57 BF ES=0.64 WC ES=0.42 VO_2 ES=0.52
Cvetkovic et al (2018) 35 overweight and obese children 12 weeks 3x/week	35♂ 11-13 yrs HIIT 11 Football 10 CG 14	SPRINTS 100%MAS	Week 0-4: 3x(5x10s:10s):3min Week 5-8: 3x(8x15s:15s):3min Week 9-12: 3x(10x20s:20s):3min	+0.1% BM, -1.0% BMI -5.2% %BF -4.9% BFM +2.5% LBM +2.5% %LBM +2.7% MM +2.8% %MM +6% CMJ -5.4% Agility ($p<0.05$ baseline) +81.3% CRF ($p<0.05$ baseline)	0.6>ES<1.2 moderate effect Agility ES=0.91 CRF ES=1.03
Costigan et al. (2018) 65 adolescents 8 weeks 3x/week	45♂, 20♀ 15.8 ± 0.6 yrs AEP 21 RAP 22 CG PE 22	AEP – all-out Cardio exercises RAP – all-out Resistance + Cardio	Week 1-3: 8x30s:30s Week 4-6: 9x30s:30s Week 7-8: 10x30s:30s		0.5>ES<0.8 moderate effect MPA ES=0.04 VPA ES=0.55
Leahy et al. (2019) 68 adolescents 14 weeks 3x/week	37♂, 31♀ 16.2 ± 0.4 yrs HIIT 38 CG 30	RAP – all out Resistance + Cardio	8-16 x 30s:30s	+8.9laps CRF ($p<0.05$ baseline & CG) +1.7reps PU +10.1cm LBMP ($p<0.05$ CG) +0.4kg.m^{-2} BMI ($p<0.05$ CG)	0.5>ES<0.8 moderate effect CRF ES=0.69 PU ES=0.29 LBMP ES= 0.46 BMI ES=0.67 Intrinsic ES=0.09 Identified ES=0.06 Autonomy support ES=0.09 Relatedness support ES=0.27 Competence support ES=0.2

AEP: Aerobic Exercise Program; CG: control group; BF: body fat; BM: Body mass; BMI: Body mass index; CG: control group; CI: confidence interval; CMJ: countermovement jump; CRF: cardio-respiratory fitness; FOP: functional obstacle performance; HC: hip circumference; HIIE: higher intensity intermittent exercise group; HIIT: high-intensity interval training; LBM: Lean body mass; LBMP: Lower body muscular power; LIIE: lower intensity intermittent exercise group; LJ: Lateral Jump; MAS: Maximal aerobic speed; MIIT: Moderate-Intensity Interval Training; MPA: Moderate Physical Activity; P+HIIT: Plyometric drills + HIIT; PU: push-ups; RAP: Resistance and Aerobic Program; SJ: Squat jump; SLJ: standing long jumps; SPA: Sedentary Physical Activity; SSF: sum of skinfolds; VPA: Vigorate Physical Activity; VO_2: oxygen consumption; WC: waist circumference

Table 4.1 *(continued)*

Reference, sample, duration, and frequency	Participants	HIIT PROGRAM		HIIT OUTCOMES (mean dif)	EFFECT SIZE (ES)
		Modality / Intensity	Work:Rest	Physical Fitness	
Martin et al. (2019) 56 adolescents 4 weeks 3x/week	34 ♂, 22 ♀ 16.5 ± 0.5 yrs HIIT 13 ♂, 9 ♀ CG 19 ♂, 11 ♀	SPRINTS all-out bouts	Week 1-2: 5x30s:30s Week 3-4: 6x30s:30s	+5.03ml/kg/min VO_2 (p>0.05 baseline) -1.2cm WC -0.73cm HC	VO_2 ES=0.92 WC ES=0.14 HC ES=0.11 SPA ES=1.8 MPA ES=1.5 VPA ES=1.2
Alonso-Fernández et al (2019) 26 adolescents 7 weeks 2x/week	13 ♂, 13 ♀ 15-16 yrs HIIT 13 CG 13	CALISTHENICS all-out bouts	Week 1: 8x20s:10s Week 2-3: 10x20s:10s Week 4-5: (8x20s:10s):1min+2x 20s:10s Week 6-7: 2x(8x20s:10s):1min	+0.91% BM -0.88% BMI -7.81% %BF (p<0.001 baseline) -6.97% BF (p<0.001 baseline) +6.25% LBM (p<0.001 baseline) +10.21% VO_2 (p<0.001 baseline)	%BF ES=0.58 BF ES=0.02 LBM ES=0.15 VO_2 ES=0.33
Engel et al. (2019) 35 children 4 weeks 4x/week	24 ♂, 11 ♀ 11.6 ± 0.2 yrs HIIT 11 ♂, 6 ♀ CG 11 ♂, 7 ♀	CALISTHENICS all-out bouts	6min 20s:10s 30s:15s 45s:15s 50s:10s	+9.9% PU +3.1% SIT Ups (p<0.005 baseline & CG) +3.4% SLJ (p<0.005 baseline) +4.6% LJ (p<0.005 CG) -15.8% 20m Sprint (p<0.005 baseline & CG) +2.1% 6min run	Eta-square >0.14 large; <0.14 medium; >0.06 small BM ES=0.004 BMI ES=0.028 PU ES=0.017 SIT Ups ES=0.485 SLJ ES=0.015 LJ ES=0.382 20m Sprint ES=0.691 6min run ES=0.008

AEP: Aerobic Exercise Program; CG: control group; BF: body fat; BM: Body mass; BMI: Body mass index; CG: control group; CI: confidence interval; CMJ: countermovement jump; CRF: cardio-respiratory fitness; FOP: functional obstacle performance; HC: hip circumference; HIIE: higher intensity intermittent exercise group; HIIT: high-intensity interval training; LBM: Lean body mass; LBMP: Lower body muscular power; LIIE: lower intensity intermittent exercise group; LJ: Lateral Jump; MAS: Maximal aerobic speed; MIIT: Moderate-Intensity Interval Training; MPA: Moderate Physical Activity; P+HIIT: Plyometric drills + HIIT; PU: push-ups; RAP: Resistance and Aerobic Program; SJ: Squat jump; SLJ: standing long jumps; SPA: Sedentary Physical Activity; SSF: sum of skinfolds; VPA: Vigorate Physical Activity; VO_2: oxygen consumption; WC: waist circumference

2.7.4.3.1. Body composition

Regarding dimensions and body composition, only one study did not report data (Costigan et al., 2018). Statistically significant reductions were observed in six studies (Alonso-Fernández et al., 2019; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016); the remaining seven did not achieve significant changes. In Racil et al.'s works, body mass (BM) decreased significantly between 2%-4% relative to the baseline (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), to Control Group (CG) (G. Racil et al., 2016; Ghazi Racil et al., 2016) and even to a moderate-intensity intervention group (G. Racil et al., 2016). The same workgroup had significant reductions in BMI between 9% - 16% relative to the baseline (Racil et al., 2013; Ghazi Racil et al., 2016), to CG (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016) and a moderate-intensity intervention group (Racil et al., 2013). Costigan et al. (2015) observed a significant reduction in BMI z-score compared to CG. Waist circumference (WC) was assessed in five studies (Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Martin-Smith et al., 2019; Racil et al., 2013; Ghazi Racil et al., 2016), where three show significant reductions compared to the baseline (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), three to CG (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; G. Racil et al., 2016; Ghazi Racil et al., 2016) and one to a moderate-intensity intervention group (G. Racil et al., 2016), between 3%-4%. Body composition was assessed in six studies: body fat (Alonso-Fernández et al., 2019; Cvetkovic et al., 2018; Lau et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), lean body mass (LBM) (Alonso-Fernández et al., 2019; Cvetkovic et al., 2018; Ghazi Racil et al., 2016) and the sum of skinfolds (Lau et al., 2015). Body Fat (BF) decreased significantly between 5%-9% compared to the baseline (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), to CG (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016) and a moderate-intensity intervention group (Racil et al., 2013; G. Racil et al., 2016). The sum of skinfolds, in an intervention at 120%MAS, recorded a reduction of 12% with significance relative to the baseline and another high-intensity group at 100%MAS (Lau et al., 2015). Two studies reported significant increases in LBM, between 3%-7%, compared to the baseline (Alonso-Fernández et al., 2019; Ghazi Racil et al., 2016) and CG (Ghazi Racil et al., 2016). From these, the protocol that added plyometrics to HIIT also obtained significant increases compared to the group that only did HIIT (Ghazi Racil et al., 2016).

Table 2.2 *Risk of bias assessment*

Study	PEDro[1]	Cochrane Collaboration's tool for assessing risk of bias[2]								Level of Evidence[3]
	Total	1	2	3	4	5	6	7	Total	
Buchan et al. (2012)	4	-	-	-	-	?	+	?	1	B
Buchan et al. (2013)	6	+	+	-	-	?	+	?	3	B
Racil et al. (2013)	6	-	-	-	-	?	+	?	1	B
Lau et al. (2015)	6	-	-	-	-	?	+	?	1	B
Martin et al. (2015)	5	+	+	-	-	?	+	?	3	B
Costigan et al. (2015)	7	+	+	?	+	?	+	?	4	B
Racil et al. (2016a)	6	-	-	-	-	?	+	?	1	B
Racil et al. (2016b)	6	-	-	-	-	?	+	?	1	B
Cvetkovic et al. (2018)	5	-	-	-	-	?	+	?	1	B
Costigan et al. (2018)	7	+	+	?	+	?	+	?	4	B
Leahy et al. (2019)	7	+	+	?	+	?	+	?	4	B
Martin et al. (2019)	7	+	+	-	-	?	+	?	3	B
Alonso-Fernández et al (2019)	6	-	-	-	-	?	+	?	1	B
Engel et al. (2019)	6	-	-	-	-	?	+	?	1	B

[1]PEDro – Physiotherapy Evidence Database (Sherrington et al., 2000)

[2]Cochrane Collaboration's tool for assessing risk of bias Criteria (Higgins et al., 2011): (1) Random sequence generation; (2) Allocation concealment; (3) Blinding of participants and personnel; (4) Blinding of outcome assessment; (5) Incomplete outcome data; (6) Selective reporting; (7) Other bias. Coding: 'clearly described' (+), 'absent' (-), or 'unclear or inadequately described' (?).

[3] Level of Evidence (Rosenbrand et al., 2008)

2.7.4.3.2. Physical fitness

As for physical fitness, there were outcomes regarding CRF (Alonso-Fernández et al., 2019; Buchan et al., 2013; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Cvetkovic et al., 2018; Engel et al., 2019; Lau et al., 2015; Leahy et al., 2019; Martin-Smith et al., 2019; Martin et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), agility (Buchan et al., 2013; Buchan et al., 2012; Cvetkovic et al., 2018; Lau et al., 2015), power (Buchan et al., 2013; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Cvetkovic et al., 2018; Engel et al., 2019; Leahy et al., 2019; Ghazi Racil et al., 2016), running speed (Buchan et al., 2013; Engel et al., 2019), upper strength (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Engel et al., 2019; Leahy et al., 2019) and trunk strength (Engel et al., 2019). CRF increased significantly between 2%-81% compared to the baseline (Alonso-Fernández et al., 2019; Buchan et al., 2013; Cvetkovic et al., 2018; Lau et al., 2015; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016) and CG (Buchan et al., 2012; Lau et al., 2015; Leahy et al., 2019; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016). Agility improved significantly with time reductions between 5%-7% over the baseline (Cvetkovic et al., 2018; Lau et al., 2015) and CG (Buchan et al., 2012). Speed increased significantly compared to the baseline (Buchan et al., 2013; Engel et al., 2019) and CG (Engel et al., 2019). Power, assessed through jump tests, achieved significant improvements between 3%-22% compared to the baseline (Buchan et al., 2013; Engel et al., 2019; Ghazi Racil et al., 2016) and CG (Buchan et al., 2013; Engel et al., 2019; Leahy et al., 2019; Ghazi Racil et al., 2016). From these, the protocol that added plyometrics to HIIT also obtained significant increases compared to the group that only did HIIT (Ghazi Racil et al., 2016). Only mid-section strength achieved significant increases of 3% compared to the baseline and CG (Engel et al., 2019).

2.7.4.3.3. Physical Activity

Only three studies assessed the impact of HIIT on daily PA, all with significant improvements over the baseline in increasing total PA (Martin et al., 2015), in increasing moderate physical activity (MPA) and vigorous physical activity (VPA) (Costigan et al., 2018; Martin-Smith et al., 2019), and reduction of sedentary activity (Martin-Smith et al., 2019). Martin et al. (2015) assessed PA subjectively through questionnaires, whereas in the other two studies it was objectively measured using accelerometers.

2.7.4.4. Motivation

Only two studies reported the impact of HIIT on adolescent motivation, with no significant changes (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Leahy et al., 2019). The specific motivational variables included were intrinsic, identified, autonomy support, relatedness support and competence support (Leahy et al., 2019). Costigan et al. (2015) used an 8-item questionnaire examining benefits, fun, importance, enjoyment, effort, pleasure, restlessness and satisfaction related to participation in physical activity.

2.7.4.5. Protocols and Periodization of HIIT Interventions

Running/Sprint (Buchan et al., 2013; Buchan et al., 2012; Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019; Martin et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016) was the most used exercise modality (9/14, 64%), and resistance training as HIIT modality accounts for 36% (calisthenics and plyometrics). Training intensity was ensured by percentages of maximum aerobic speed (MAS) (6/14, 43%), 100%MAS (Cvetkovic et al., 2018; Engel et al., 2019; Lau et al., 2015; G. Racil et al., 2016) to 120%MAS (Engel et al., 2019; Lau et al., 2015), or all-out bouts. Heart rate (HR) monitoring was used in only seven studies (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013), but only three defined cut lines considering high intensity as >85%$HR_{máx}$ (Costigan et al., 2018; Leahy et al., 2019) or >90% $HR_{máx}$ (Cvetkovic et al., 2018). Only two studies (Alonso-Fernández et al., 2019; Engel et al., 2019) applied the rating of perceived exertion (RPE).

As for the weekly frequency, the majority performed three workouts per week, except for two studies, which performed two (Alonso-Fernández et al., 2019) and four workouts (Engel et al., 2019) per week. The length of HIIT protocols ranged between five (Buchan et al., 2013; Buchan et al., 2012) and 35 minutes (Ghazi Racil et al., 2016). The time of each interval ranged between 10 (Cvetkovic et al., 2018) and 50 seconds (Engel et al., 2019), and recovery between 10 (Alonso-Fernández et al., 2019; Cvetkovic et al., 2018) and 30 seconds (Buchan et al., 2013; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Martin et al., 2015; Racil et al., 2013; Ghazi Racil et al., 2016). The vast of studies majority adopted a 1:1 ON/OFF ratio (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Cvetkovic et al., 2018; Lau et al., 2015; Leahy et al., 2019; Martin-Smith et al., 2019; Martin et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), with only five showing higher densities: 3:2 (Buchan et al., 2013; Buchan et al., 2012), 2:1 (Alonso-Fernández et al., 2019; Engel et al., 2019); 3:1 and 5:1 (Engel et al., 2019).

2.7.5. Discussion

This review aimed to evaluate the utility of a HIIT program integrated into High-School PEC, on Physical Fitness, PA, and Motivation for Exercise. Only one study had a sample above 80 participants (Buchan et al., 2013). Four studies calculated power and sample size but only three included a sufficient number of 17 participants per group to adequately address the research question (Buchan et al., 2013; Martin-Smith et al., 2019; Martin et al., 2015). Engel et al. (2019) did not include a sufficient number of 20 participants. The small sample sizes do not warrant analysis for the potential influence of sex or age on the results, may not be generalizable, and may lack external validity. None of the studies reported any adverse events, either acute or chronic. All works reveal significant improvements, as well as moderate effect sizes, in at least two of the dimensions evaluated: physical fitness and PA. Only Costigan et al. (2015; 2018) measured student's and teacher's program receptivity, recording an average of 4.2 on the Likert scale. Although it was not measured, the researcher's perception was that students liked the intervention more than the classic alternative (Racil et al., 2013) due to spending less time, being more competitive, fun, and effective in improving physical fitness (Martin-Smith et al., 2019). Even in the case where the teachers themselves implemented for the HIIT program, reported that interest, performance, and behavior tend to improve in PEC (Leahy et al., 2019).

2.7.5.1. Physical Fitness

As insufficient PA, overweight and obesity, poor diet, low CRF, hypertension, chronic inflammation, and dyslipidemia are evident in increasingly more adolescents (Logan et al., 2014). Exercise is one of the key strategies in reducing inflammatory processes and, consequently, cardiovascular events (Kargarfard et al., 2016). Over 50% of obese children will become obese adults, with a significant increase in the risk of developing asymptomatic diseases such as those previously described (Dias et al., 2016).

Improvements in body composition recorded, at most, a moderate Effect Size (Alonso-Fernández et al., 2019; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; Leahy et al., 2019; Racil et al., 2013; G. Racil et al., 2016). In adolescents who are overweight (Lau et al., 2015) or obese (Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), significant improvements were expected, although Cvetkovic et al. (2018) only achieved this significance in the group that implemented football. Despite the intense and intermittent nature of small-sided games applied to the football group, the intervention volume was more than double (45min football vs 20min HIIT). There was also a significant increase in LBM in two interventions, one of which with obese adolescents (Alonso-Fernández et al., 2019; Ghazi Racil et al., 2016). It should be noted that there is no need for external loads to implement these protocols. The reduced volume, the use of all-out bouts and plyometrics are also simple approaches. Some studies that did not report improvements in body composition (Buchan et al., 2013; Lau et al., 2015) revealed that the CG significantly worsened, which gives HIIT a possible protective effect on body composition in these populations.

Indeed, HIIT is presented as a powerful stimulus in improving physical fitness, mainly on CRF in most protocols, and in power and speed when modality is plyometrics. Like body composition, a possible protective effect of HIIT was observed when the improvements in physical fitness were not significant, as the CG significantly worsened the performance (Buchan et al., 2013; Buchan et al., 2012; Martin-Smith et al., 2019; Martin et al., 2015). Improvement of physical fitness is very important in adolescents, especially in those who are overweight and obese, as they improve the quality of daily physical activities, prevent falls, improve self-esteem, etc. (Rodriguez-Ayllon et al., 2018).

In most western countries, children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Only three studies evaluated the impact of HIIT on daily PA, recording a moderate (Costigan et al., 2018; Martin et al., 2015) and large Effect Sizes (Martin-Smith et al., 2019). Likewise, HIIT appears to have a protective effect as CG worsens sedentary behaviors (Martin-Smith et al., 2019; Martin et al., 2015). These are promising results, as increases in VPA can result in improved CRF and body composition (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015).

2.7.5.2. Motivation

The motivational dimension did not show significant improvements; however, only two studies evaluated it (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Leahy et al., 2019). Considering that intense efforts have been deemed inappropriate for the general/sedentary population due to feelings of incompetence (Hardcastle et al., 2014), no negative associations in these studies are encouraging. Other studies included a variety of activities to enhance motivation and appeal to the interest of older adolescents, improving aspects of adolescents' cardiometabolic health (Weston et al., 2016), and fitness and body composition despite the lowest dose among groups (Logan et al., 2016). Furthermore, adolescents seems to be more enthusiastic with resistance training, whereas aerobic training is found to be boring (Lee et al., 2012).

2.7.5.3. Protocols and Periodization of HIIT Interventions

Short leisure time, reduced access to facilities, and low motivation to practice, are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). Therefore, HIIT is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Zhang et al., 2017), which leverages the number of exercise participants, resulting in improvements in health outcomes, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017; Logan et al., 2016; Logan et al., 2014). The more traditional HIIT methodology translates a temporal efficiency in the improvement of several health markers and aerobic/anaerobic performance but lowered impact strength, muscle strength, and power. New protocols that also include resistance exercises induce a greater amount of beneficial adaptations in adults (Buckley et al., 2015; Falatic et al., 2015; McRae et al., 2012; Murawska-Cialowicz et al., 2020; Paoli et al., 2012; Schaun & Alberton, 2020; Schaun et al., 2018; Williams & Kraemer, 2015) or even older people (Ballesta-Garcia et al., 2019; Garcia-Pinillos et al., 2019; Jiménez-García et al., 2019). In adolescents, Lee et al. (2012) found that there were differences in how much they enjoyed the exercise intervention, as participants in the aerobic group found the exercise to be boring, whereas those in the resistance group were much more enthusiastic and seemingly enjoyed the exercise intervention. Nevertheless, only the resistance group significantly decreased body mass and increased lean body mass, which emphasizes the importance of including resistance training in PEC as a HIIT modality.

In this review, as in Eddolls et al.'s (2017), most studies opted for 1:1 density (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Cvetkovic et al., 2018; Lau et al., 2015; Leahy et al., 2019; Martin-Smith et al., 2019; Martin et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016), despite protocols discrepancy on intensity (all-out bouts vs %MAS), modality (sprints vs calisthenics), and volume (6min-35min/session). When we observe the Effect Size, the only studies that exceed 10 minutes per session (Cvetkovic et al., 2018; Leahy et al., 2019; Racil et al., 2013), for 12 weeks, did not go beyond the moderate effect on body composition and physical fitness, compared to protocols below 10min and with the same Effect Size (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; G. Racil et al., 2016). Interestingly, the only protocols to record Large Effect Size on CRF (ES=0.93 (Martin et al., 2015); ES=0.92 (Martin-Smith et al., 2019)), PA (ES>1.2 (Martin-Smith et al., 2019)), strength, power, and speed (η^2>0.14, (Engel et al., 2019)), needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, for only four (Engel et al., 2019; Martin-Smith et al., 2019) and seven weeks (Martin et al., 2015).

It should be also emphasized that the same three studies that record Large Effect Sizes chose to use all-out bouts instead of a percentage of MAS, reinforcing the importance of including resistance training as a HIIT modality. Heart rate (HR) monitoring was used in only seven studies (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013), but only three defined cut lines considering as high intensity >85%HR_{max} (Costigan et al., 2018; Leahy et al., 2019) or >90%HR_{max} (Cvetkovic et al., 2018). HR has become one of the most used outcomes to assess the intensity, and several authors suggest that each interval corresponds to a value equal to or higher than 90%HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of 90%VO_{2max} (Buchheit & Laursen, 2013). It is expected that HR reach maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response.

2.7.5.4. Strengths and Limitations

The strengths of this study include the criteria for assessing study risk of bias through PEDro (Sherrington et al., 2000) and the Cochrane Collaboration’s tool (Higgins et al., 2011), and the inclusion of surrogate programs of PEC means we have almost doubled the number of studies that could be included in the overall analysis.

The main limitation of the study is the high risk of bias. Therefore, there is a high risk that the results will overestimate the benefits and underestimate the lack of effect. According to the Dutch CBO guidelines (Rosenbrand et al., 2008), this review has a level 3 of evidence, since all studies are classified as B, that is, these studies are not double randomized clinical trials of good quality and sufficient power. The small sample sizes do not warrant analysis for the potential influence of sex or age on the results, may not be generalizable, and may lack external validity.

Despite the possibility of studies being missed out on the search strategy, only 14 studies were included in this review, most of which were produced on younger children. Regarding the defined interval (2008-2020), it is our understanding that, on the one hand, the 11-year timeframe would be a sufficiently long period to include a considerable number of articles. On the other hand, we believe that older articles (prior to 2008) would have already been included in previous systematic reviews. We also believe that, as scientific knowledge is advancing at great speed, the most recent years may translate the most up-to-date procedures on the application of HIIT in the target context (students in the context of PEC). Adolescents, especially older ones, are underrepresented in studies implemented in the school context (Leahy et al., 2019), so the results of the present study may not represent the entire universe of secondary school students, which calls for the recommendation of further studies related to this age group. Only three studies incorporate the assessment of participants' sexual maturation (Buchan et al., 2013; Martin-Smith et al., 2019; Martin et al., 2015), so it is unclear whether the results of health measures may be confounded.

Few studies have objectively measured internal load by monitoring HR (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013) or RPE (Alonso-Fernández et al., 2019; Engel et al., 2019). HR has become one of the most used outcomes to assess intensity. Adjusting exercise intensity using HR has been a valid option, mainly in prolonged and submaximal periods. Most studies opted to set intensity through external load expressed in speed or distances. The more traditional HIIT methodology translates a temporal efficiency in the improvement of several health markers and aerobic/anaerobic performance but lowered impact strength, muscle strength, and power. New protocols that also include resistance exercises, can induce a higher amount of beneficial adaptations in young people (Bento & Loureiro, 2018).

In a school context, more than seven weeks can be problematic due to activities and teaching breaks provided for in planning and the school calendar (Martin-Smith et al., 2019). However, one of the gaps in HIIT research is the small number of volunteers and the short duration of interventions so that significant impacts on public health can be inferred (Biddle & Batterham, 2015).

2.7.6. Conclusions

HIIT shows a high potential impact on fitness and PA in adolescents. The application of HIIT in schools is feasible: shorter duration is more appealing to deconditioned youth; logistical constraints and material resources are minimal, and HIIT is possible even in a classroom; the variety of stimuli (strength, speed, dance, fight, sports, games, individual, couples, etc.) allows enjoyable protocols. Moreover, exercise protocols that result in physiological improvements and adaptations in terms of health in a short time are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals. This review suggests that the introduction of HIIT in the school context has high potential on improving physical fitness and PA, and a moderate effect on improving body composition in adolescents. Ultimately, it can serve as prophylaxis by acting as a sanitary cord in an expected reduction of functional capacity in youth, weight gain, and risk factors associated with physical inactivity, as teenagers tend to become more inactive as their age increases. Considering the results put forth, it seems evident the efficiency that HIIT protocols implemented in schools translate in the improvement of physical fitness and reduction of sedentary behaviors, compared to other types of less intense and higher volume activities. This efficiency, resulting from the reduced time required (on average, about 10 minutes), reflects the wide applicability that these protocols can have in PEC, and the great adaptation to the facilities (including classrooms).

2.7.7. References

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CHAPTER 3

3. Studies Methodology

3.1. Studies overview

This chapter will provide a brief description of the methodology involving the five articles of this thesis, however individual studies will provide further thorough information on the methods (**Chapter 2.7, 3.10, 4** to **6**). This project was approved by the Ethics Committee of the University of Évora (doc. 19017, APPENDIX 1) and conducted according to the Declaration of Helsinki on Human Research.

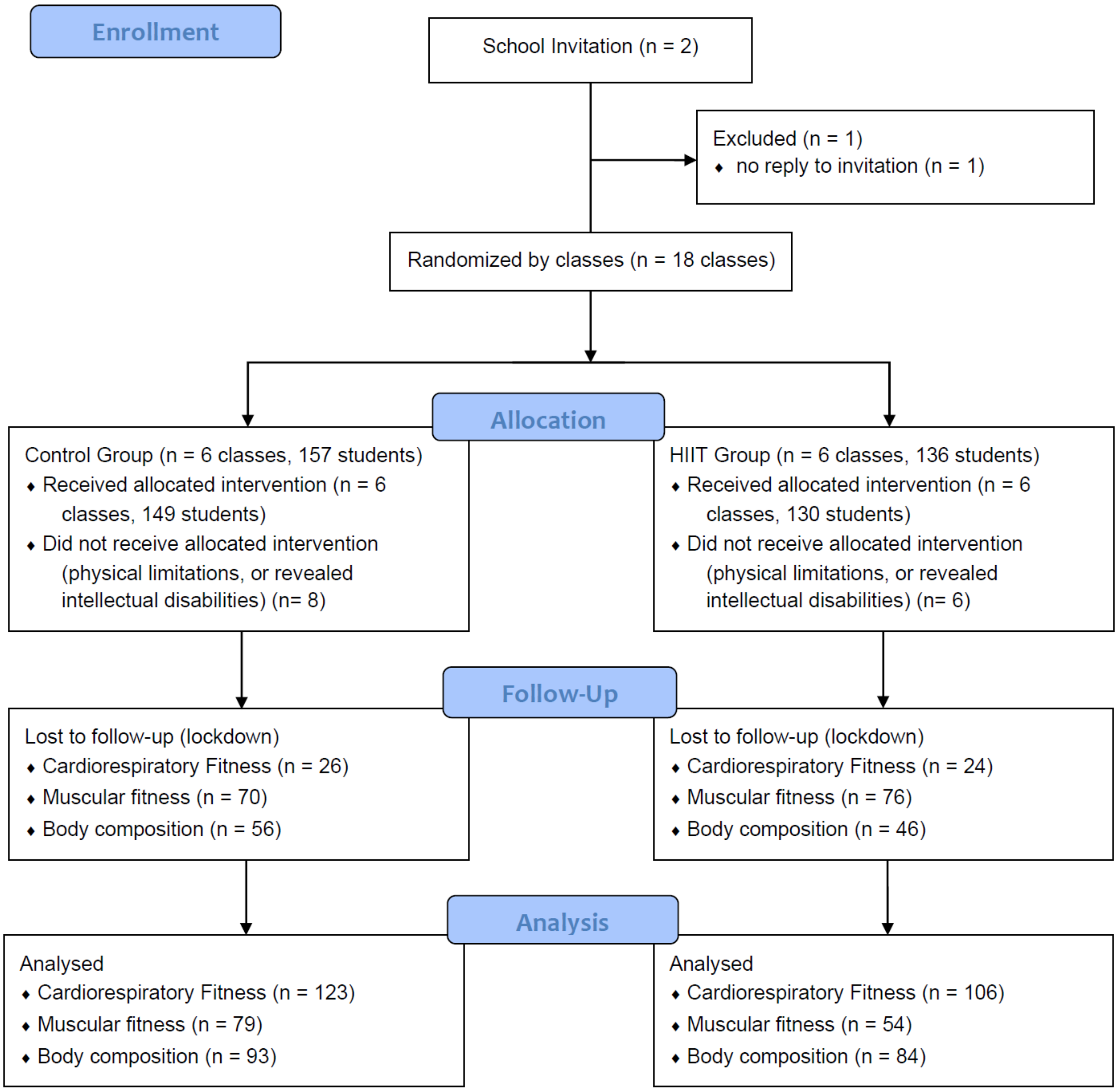
In study 1, the systematic review was registered at PROSPERO with the number CRD42019138771 (APPENDIX 2) and described in **Chapter 2.7** according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA). The core studies of this thesis were registered on ClinicalTrials.gov (ID: NCT04022642, (APPENDIX 3) and are a study protocol for a randomized controlled trial (Study 2), two cross-sectional observational, descriptive and correlational studies (Study 3 and 5) and a randomized controlled trial (Study 4).

On 13 March 2020, the Portuguese Government adopted strict containment measures to avoid the new coronavirus (SARS-CoV-2) spread, and the student population was placed in home confinement, with permission only to leave home for limited and documented purposes (e.g., for health reasons or buying food), and several activities were temporarily prevented, including schools. These global preventive strategies posed unprecedented challenges and obstacles for our research, experiencing lower follow-up rates in the ongoing trial. As a negative consequence of home confinement, we experienced a high number of dropouts in several outcomes.

3.2. Study design and sampling

This study was a two-arm randomized controlled trial design with adolescents from the 10^{th} to 12^{th} grades (15-17 years old). Twelve from a total of 18 classes with an average of 25 students each, recruited from a public school (**Fig. *3.1***), were randomized to either 16 weeks of HIIT (HIIT-G, n = 106 students) implemented on PEC warm-up or a control group (CG, n = 123 students) of usual PEC warm-up. After an invitation, the researchers met with the school principal to provide information on the whole project. After accepting to participate, adolescents and their parents were informed of a detailed description of the scientific background, objectives, and safety (APPENDIX 4).

Fig. 3.1 *Study design*



The school principal, as a person independent of the study, concealed participant allocation by shaking a bag with all 18 classes before baseline testing. Classes were randomized so that two classes from each grade were allocated to the intervention condition and the other two were used as control group. Using this approach, each class had an equal chance of being allocated to the intervention condition while maintaining an appropriate balance of grades across the two conditions. Students were ineligible if they did not provide parental consent to participate, had physical limitations or revealed intellectual disabilities.

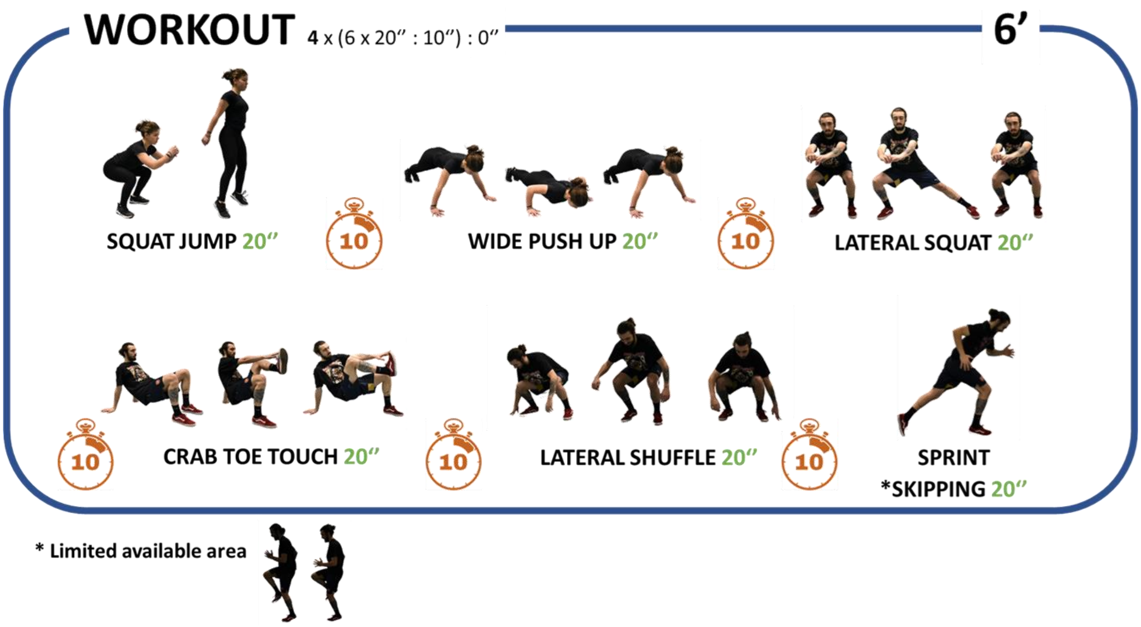
Power calculations were based on the primary outcome of CRF, assessed using the 20-m Progressive Aerobic Cardiovascular Endurance Run (PACER) (Henriques-Neto et al.

(2020). To detect a clinically meaningful baseline-adjusted between-group difference of seven laps (Leahy et al., 2019) with 80% power at a 5% significance level, 58 students per treatment group were required (i.e., four classes of 15 students), for a potential drop-out rate of 15% at our primary study end point (i.e., 16 weeks).

3.3. Experimental design

Throughout the 16-week intervention period, the HIIT-G took part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum. The HIIT-G replaced the warm-ups established in the PEC curriculum with the proposed HIIT training sessions. After the HIIT sessions, students completed the planned PEC.

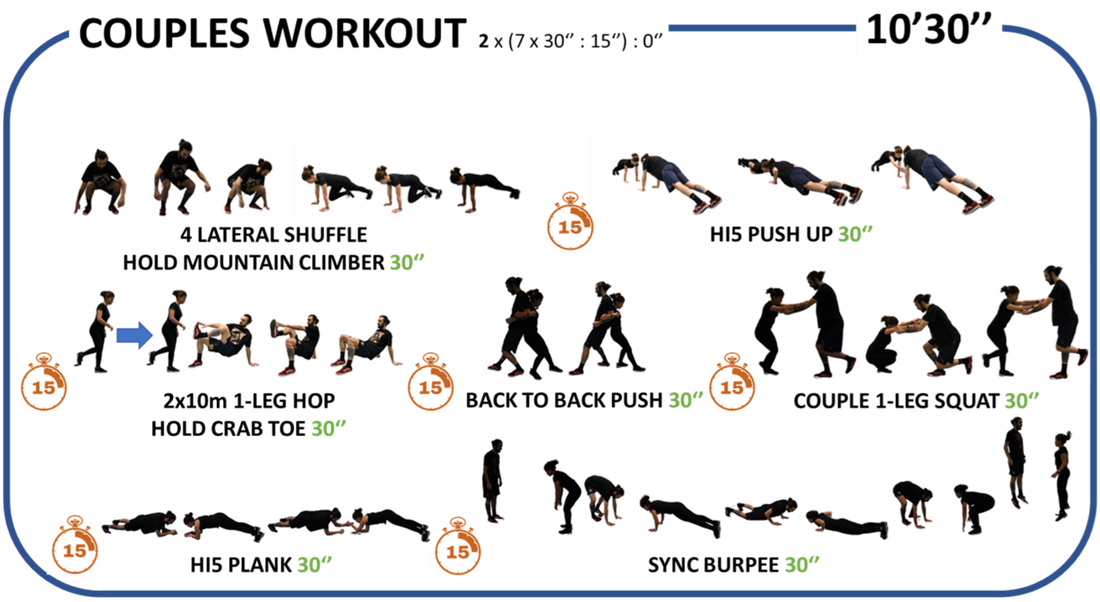
Fig. 3.2 *Graphical description of an example session*



The HIIT sessions were applied in the first 10-15 minutes of each PEC and ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work-to-rest ratio, involving a combination of aerobic and body weight muscle-strengthening exercises, and designed to be fun and engaging, as well as vigorous in nature (**Fig.** ***3.2***). Most protocols in the literature opted for 1:1 density and SPRINT as modality (Eddolls et al., 2017). Some, recording large effect sizes on CRF (Martin-Smith et al., 2019; Martin et al., 2015), PA (Martin-Smith et al., 2019), strength, power, and speed (Engel et al., 2019), needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, and chose to use all-out bouts instead of a percentage of MAS. In adults, previous findings suggest that a 2:1 work-to-rest ratio is optimal during HIIT for both men and women (Laurent et al., 2014). We aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), implement PA interventions that retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety.

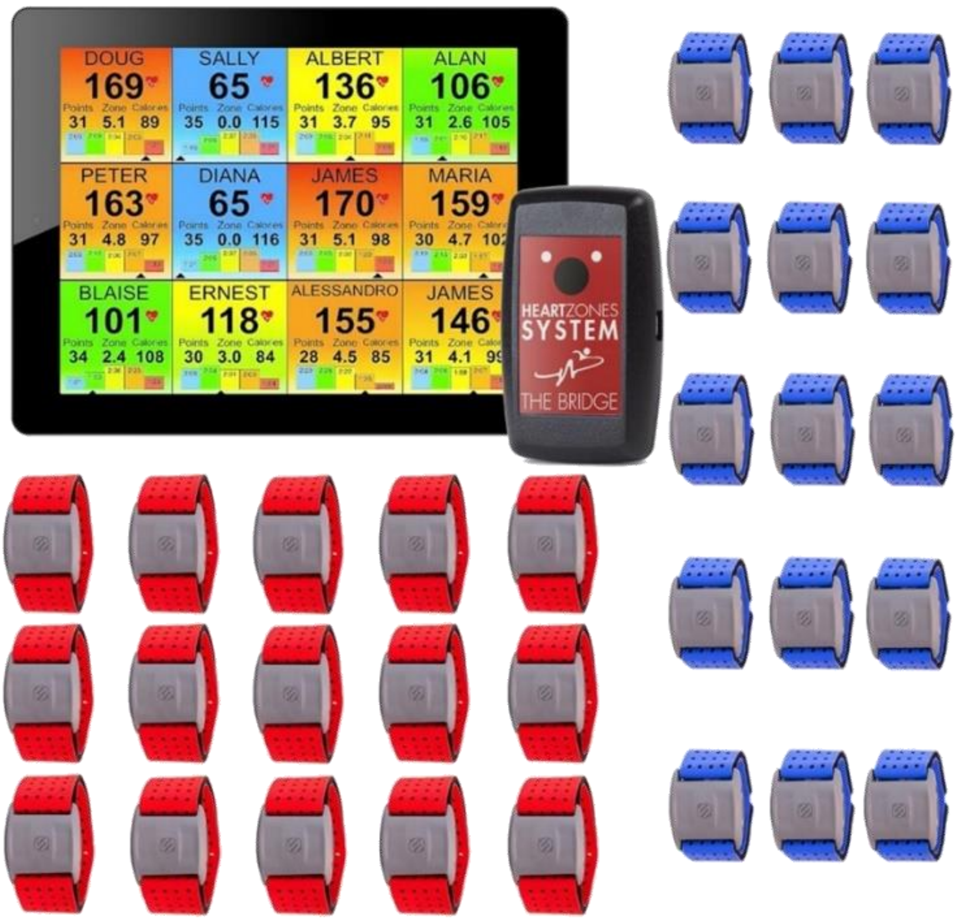
To promote exercise adherence, sessions were designed progressively from four minutes in week zero to 10 minutes in week three using the Tabata et al. (1996) protocol (20s intense work, followed by 10s rest). From week four to week seven, the same volume but using 30s-intense work, followed by 15s rest. From weeks nine to 15, sessions were completed in pairs (**Fig.** ***3.3***). Participants gave additional elements of choice, such as music, exercises, and workouts (APPENDIX 8).

Fig. 3.3 *Graphical description of an example session (couples)*



A cut-point of 90% of HR_{max} was a criterion for satisfactory compliance to high-intensity exercise. HR has become one of the most used outcomes to assess the intensity, and several authors suggest that each interval corresponds to a value equal to or greater than 90%HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of 90%VO_{2max} (Buchheit & Laursen, 2013). It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response. During the supervised intervention, the researchers recorded HR using the Heart Zones Move™ software application (**Fig. *3.4***) which uses a forearm wearable plethysmography heart rate sensor (Scosche Industries, CA, USA) to ensure compliance with the exercise stimulus at the predetermined target HR zone (APPENDIX 10). Besides, rating perceived exertion (RPE) was also measured in each exercise session to estimate effort, fatigue, and training load (APPENDIX 9), targeting >17 on the 6−20 Borg scale (Borg, 1970; Williams et al., 1991).

Fig. 3.4 *Heart Zones Move™ software application*



Throughout the 16-week intervention period, the CG took part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum.

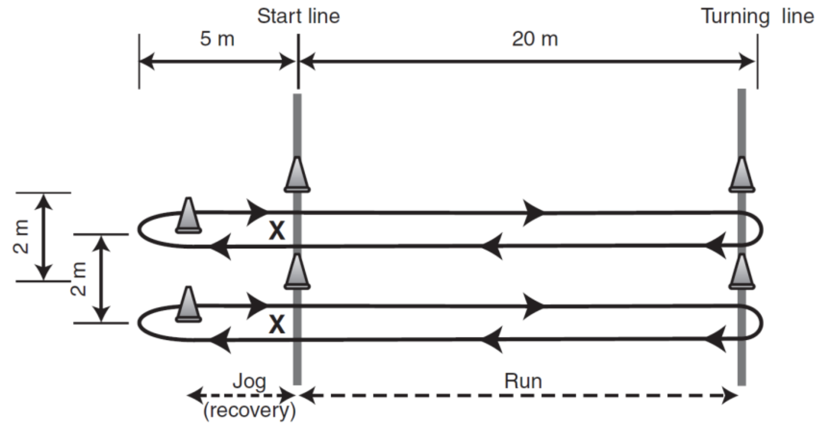
3.4. Physical fitness assessment

Physical fitness was assessed by the Principal Investigator at the schools participating in the study. CRF was assessed using the Yo-Yo Intermittent Endurance Test level one and PACER, and upper and lower-body strength were assessed using push-up and horizontal jump tests, respectively. Anthropometric assessments were conducted sensitively with the presence of a same-sex research staff when possible. The Principal Investigator provided a brief verbal description and demonstration of each fitness test before evaluation. The authors evaluated measures and data collection, not blinded for group allocation.

3.4.1. Cardiorespiratory fitness

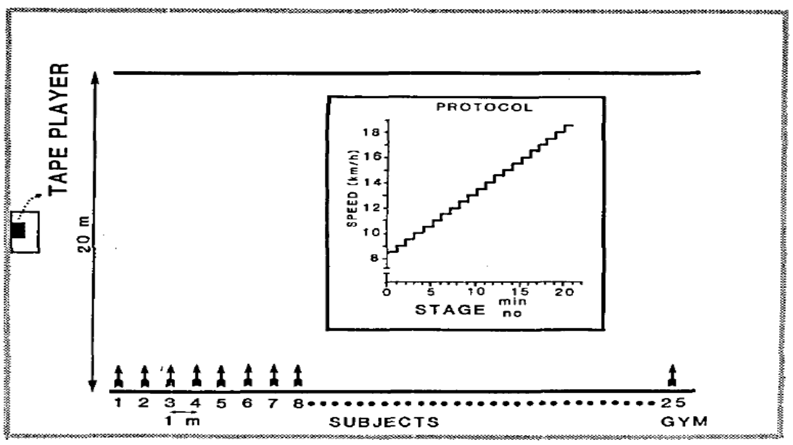
CRF was assessed using the Yo-Yo Intermittent Endurance Test level one (**Fig. *3.5***) and PACER (**Fig. *3.6***). Yo-Yo Intermittent Endurance Test level one has been previously confirmed as valid and reliable to assess aerobic fitness and intermittent high-intensity endurance in 9-to 16-year-old children (Póvoas et al., 2016). This test consists of incremental shuttle running starting from the speed of 8 $km{\cdot}h^{-1}$ until exhaustion. The maximum running speed is 14.5 $km{\cdot}h^{-1}$. Each shuttle run consists of 2 × 20 m interspersed by 10 seconds of active recovery (slow jog or walk) for a short 2.5 m shuttle. There are multiple shuttle runs within each speed stage. A pre-recorded audio track dictates running speed. By the time each audio is played, participants must have crossed the 20 m line. If the participant cannot sustain the appropriate speed for the second time during the shuttle running bout, the test is over. Using the following equation, the total number of laps were utilized to estimate maximal aerobic capacity (VO_2 max): IRT1 distance (m) x 0.0084 + 36.4 ($ml.kg^{-1}.min^{-1}$) (Tanner & Gore, 2014). HR was monitored by telemetric HR during testing. The peak HR recorded during the test was assumed to be representative of maximal HR (Krustrup et al., 2003).

Fig. 3.5 *Setup for Yo-Yo intermittent recovery test (Tanner & Gore, 2014)*



PACER (Henriques-Neto et al., 2020) consists of incremental shuttle running, starting from the speed of 8.5 km·h^{-1} and increasing progressively 0.5 km·h^{-1} every minute until exhaustion. Each shuttle run consists of 2 × 20 m. Within each speed stage, there are several shuttle runs. Running speed is prescribed by a pre-recorded audio track. Participants must reach the 20 m line by the time each audio is heard. The test is finished if the participant is unable to maintain the required speed for the second time during the shuttle running bout. The total number of laps will be used to estimate maximal aerobic capacity (i.e., VO_2 max), using the following equation: 41.76799 + (0.49261 x PACER) – (0.00290 x PACER^2) – (0.61613 x BMI) + (0.34787 x gender x age), [R = 0.75, R^2 = 0.56, SEE = 6.17 ml.kg^{-1}.min^{-1}], where PACER is the number of laps completed; for gender, 1 = boy and 0 = girl; and age is in years (Mahar et al., 2011). HR was monitored by telemetric HR during testing. The peak HR recorded during the test was assumed to be representative of maximal HR (Krustrup et al., 2003).

Fig. 3.6 *Setup for PACER (Leger et al., 1988)*



3.4.2. Strength

The push-up test (Henriques-Neto et al., 2020) started with the participant's hands and feet touching the floor, and the body in a plank position, with feet apart and the hands positioned below the shoulder line (**Fig. *3.7***). The participants should lower the body until forming a 90° angle between the arm and the forearm and then return to the starting position. This action was repeated with a previously defined cadence of 20 push-ups per minute. Cooper Institute thresholds were used to identify "low fitness" levels (Plowman, 2019).

Fig. 3.7 *Push-up test (FITescola®;(Henriques-Neto et al., 2020))*

The horizontal jump test (Henriques-Neto et al., 2020) started in the standing position, with the feet slightly apart from each other and below the shoulder line, immediately behind a line drawn on the floor (**Fig. *3.8***). Then, the participant jumped as far as possible, landing with the feet together. The distance between the starting line, and the heel of the back foot was recorded. The best result of the two trials was considered.

Fig. 3.8 *Horizontal jump test (FITescola®;(Henriques-Neto et al., 2020))*

3.4.3. Body composition

Participants' body composition was measured to the nearest 0.1 kg in light sportswear on a bioelectrical impedance scale (Tanita MC -780), and height was measured to the nearest 1 mm using a portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer) (**Fig. *3.9***). Body composition measurements (body fat, lean body mass and basal metabolic rate) were performed by bioelectrical body impedance analysis (BIA). Measurements were performed without accessories that have metal (earrings, belts, coins), and female adolescents were asked if they were on their menstrual period. When they were in their menstrual period, they repeated the assessment the following week. To ensure normal hydration status for BIA testing, participants were asked to adhere to the following pretest requirements: no vigorous exercise within 12 hours of the test and no caffeine or alcohol consumption within 12 hours of the test (Jackson et al., 1988).

Fig. 3.9 *Bioelectrical impedance scale (Tanita MC -780) and portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer*

3.5. Physical Activity assessment

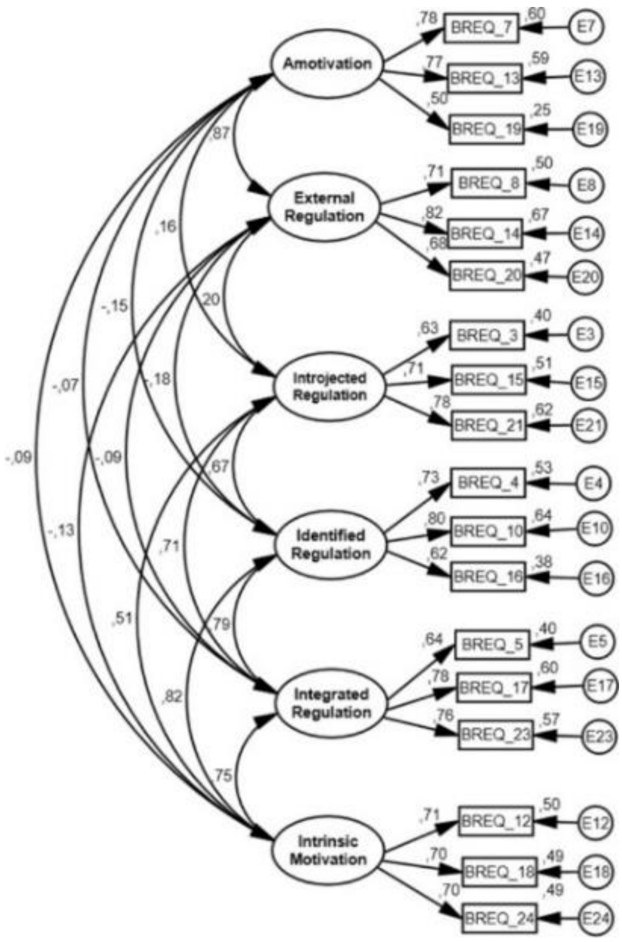
As recommended in a recent systematic review (Migueles et al., 2017), triaxial accelerometers were used to determine PA levels and sedentary time for seven consecutive days. Participants were instructed to wear an ActiGraph wGT3X-BT (**Fig. *3.10***) accelerometer on their waist for 24 hours/day (which would be removed only during shower time or swimming activities), fixed to an elasticized belt and placed on the right side of the participant's hip. At least three weekdays and one weekend day were considered a minimum recording time for valid records. PA was calculated (i.e., mean minutes per day) using existing thresholds for categorizing PA into sedentary behavior, light, moderate and vigorous intensity.

Fig. 3.10 *ActiGraph wGT3X-BT accelerometer*

3.6. Motivation assessment

Motivation was assessed with the Behavioral Regulation in Exercise Questionnaire 3 (BREQ-3) (Cid et al., 2018). BREQ-3 (APPENDIX 6) is a valid and reliable measurement instrument to measure behavior regulation underlying the self-determination theory in the exercise domain and consists of 18 items with a five-point Likert scale (**Fig.** ***3.11***), which varies between 1 ("not true for me") and 5 ("very true for me").

Fig. 3.11 *Standardized individual parameters all (BREQ-3 – six factors and 18 items) for the validation sample final model (Cid et al., 2018)*



The scores from each BREQ subscale (amotivation, external, introjected, identified and intrinsic motivation) were weighted and subsequently aggregated to form a solitary numerical index, the RAI, representing the self-determination continuum where lower scores indicate less autonomous motivation, whereas higher scores indicate more autonomous motivation: (amotivation multiplied by -3) + (external regulation multiplied by -2) + (introjected regulation multiplied by -1) + (identified regulation multiplied by 2) + (intrinsic regulation multiplied by 3) (Verloigne et al., 2011).

3.7. Dietary Registration

Daily dietary intake was estimated with a validated self-reported food frequency questionnaire (Lopes et al., 2007), which lists food types and meals typical of a Portuguese diet. A semiquantitative food frequency questionnaire from the previous month was used to assess daily dietary intake, which included 82 food or beverage categories and a frequency section with nine possible responses ranging from never to six or more times per day (APPENDIX 7).

3.8. Statistical analysis

In the systematic review Two independent researchers analyzed the selected studies for methodological quality through the Physiotherapy Evidence Database (PEDro) (Sherrington et al., 2000) and a seven-item checklist from the Cochrane Collaboration's tool for assessing the risk of bias in randomized trials (Higgins et al., 2011). Full details in chapter 4.

All statistical analyses were performed with the Statistical Package for the Social Sciences v.24 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to characterize the subjects and exercise test results. All data of baseline and post intervention were confirmed to be normally distributed by the Kolmogorov-Smirnov test were tested prior to further statistical analysis. In studies 3 and 5 a Bivariate analysis, using parametric Pearson correlation coefficient or the nonparametric Spearman correlation coefficient (r_s), was used to indicate the strength of the association between variables. Interpretation of correlation coefficients was as follows: $r \leq 0.49$ weak relationship; $0.50 \leq r \leq 0.74$ moderate relationship; and $r \geq 0.75$ strong relationship

(Portney & Watkins, 2000). All p-values were two-tailed and values below 0.05 were considered to indicate statistical significance. To examine whether motivation mediated the relationship of physical fitness with exercise intensity, separate models were created for each outcome with physical fitness as a predictor, and motivation as a mediator. Full details in chapter 3 and 5.

In study 4, the normality of data distribution was tested using the Kolmogorov-Smirnov test. When normality was observed, data were checked for significant differences between baseline and post-intervention applying student's t-test for paired samples and for significant differences between the two groups applying student's t-test for unpaired samples. Where the analysis suggested non-normality, simple effects were examined using the non-parametric Wilcoxon's signed ranks test for differences between baseline and post-intervention and the Mann-Whitney U test for significant differences between the two groups and genders.

Due to the negative consequences of home confinement, we experienced a significant number of dropouts in several outcomes, so the primary analysis of the data set was not carried out according to the 'intention to treat' principle. These simple effects were examined either using separate independent repeated measurement analysis, such as t-tests or – where the analysis of the residuals suggested non-normality – using the non-parametric Wilcoxon's signed ranks test. To estimate effect sizes, Hedge's g was calculated for normally distributed measurements (one of the means from the two distributions is subtracted from the other, and the result is divided by the pooled sample standard deviation) and interpreted as follows: d = 0.2, d = 0.5, and d = 0.8, considered as small, medium, and large effect sizes, respectively (Fritz et al., 2012). For non-normal distributions, the z value was used to calculate the effect size, such as the r proposed by Cohen (1988, cit in Fritz et al., 2012); Cohen's guidelines for r are that a large effect is .5, a medium effect is .3, and a small effect is .1. Significance was set at $p < 0.05$.

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3.10. Study 2. High-intensity interval training in high-school physical education classes: Study protocol for a randomized controlled trial

Bento, A., Carrasco, L., & Raimundo, A. (2021). High-intensity interval training in high-school physical education classes: Study protocol for a randomized controlled trial. *Contemporary Clinical Trials Communications*, *24*, 100867. https://doi.org/https://doi.org/10.1016/j.conctc.2021.100867

3.10.1. Abstract

BACKGROUND: School and Physical Education classes (PEC) are privileged spaces, promoters of positive changes for the rest of life. High-Intensity Interval Training (HIIT) is presented as a time-efficient alternative to aerobic training, as it leverages the number of exercise participants, resulting in improvements in health outcomes. Despite the widespread interest in the advantages that the HIIT methodology reveals, there is a lack of randomized controlled studies investigating the impact on adolescents, mainly adressing adolescents' environment, such as schools. This study aims to evaluate the utility of a HIIT program integrated into high-school PEC, as a strategy that allows students to improve their Physical Fitness, Physical Activity (PA) level, and Motivation for Exercise.

METHODS: This study is a two-arm randomized controlled trial design with adolescents from the 10th to 12th grades (15-17 years). The trial will aim to recruit 300 students from 1 secondary school. The HIIT sessions will be applied in the first 10-15 minutes of each PEC, twice a week, for 16 weeks, ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work to rest ratio. A cut-point of >=90% of maximal heart rate will be a criterion for satisfactory compliance to high-intensity exercise. A rated perceived exertion scale will be measured in each exercise session to estimate effort, fatigue, and training load. The control group will continue the usual programmed PEC. Study outcomes will be measured at baseline and after the HIIT program. Cardiorespiratory fitness is the primary outcome. Secondary outcomes include: muscular fitness, PA and motivation for exercise.

DISCUSSION: HIIT protocols presents wide applicability in PEC and great adaptation to the facilities. The authors aim to provide novel HIIT protocols for schools.

KEYWORDS: Fitness, Health, HIIT, Physical Education, Sedentary Behaviour

TRIAL REGISTRATION: ClinicalTrials.gov NCT04022642 registered on 17 July 2019

3.10.2. Introduction

Insufficient physical activity (PA), overweight and obesity, poor diet, low cardiorespiratory fitness (CRF), hypertension, chronic inflammation, and dyslipidemia are increasingly evident in the adolescent population (Logan et al., 2014). Over 50% of obese children will become obese adults, with a significant increase in the risk of developing asymptomatic diseases including cardiovascular diseases, cancer and type 2 diabetes mellitus (Dias et al., 2016). In most Western countries, children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Data related to Health Behavior in School-Aged Children (HBSC) associate a sedentary lifestyle with headaches, sadness, irritability, and nervousness (Marques et al., 2015). Moreover, adolescents tend to become more inactive as their age increase (Bluher et al., 2017). Short leisure time, reduced access to facilities, and low motivation to engage in physical activities, are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). Interventions designed to increase moderate-to-vigorous PA in Physical Education classes (PEC) indicate that interventions can increase the proportion of time students spend in higher intensities during PEC and reduce sedentary behavior, since motivational climates that emphasize effort and improvement and provide opportunities to demonstrate leadership and make decisions have a positive impact on PA (Lonsdale et al., 2013). Physical self-perception could be considered for adherence to PA, although Rey et al. (2017) suggest that the adolescents' psychological perception and health might be improved in response to morphological adaptations, without concomitant improvements in objectively measured physical characteristics or performances.

Therefore, High-Intensity Interval Training (HIIT) is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Logan et al., 2014; Zhang et al., 2017), as it leverages the number of exercise participants, resulting in improvements in health outcomes, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017; Logan et al., 2016). HIIT is characterized by relatively short periods of very intense exercise, interspersed with periods of pause or low-intensity exercise (Fisher et al., 2011; Gibala & Jones, 2013), the purpose of HIIT is that physiological systems may perform exercises of higher intensity than those achieved during a gradual maximal test (Stuckey et al., 2012). HIIT is a powerful stimulus in improving body composition and preventing cardiometabolic risk in adults (Sim et al., 2015). Preliminary studies conducted with adolescents have shown promising results on body composition and cardiometabolic health, and more effective and time-efficient intervention for improving blood pressure and aerobic capacity levels (Bluher et al., 2017;

Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Eddolls et al., 2017; Garcia-Hermoso et al., 2016; Herget et al., 2016). According to Bond et al. (2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014). However, children and adolescents have expressed a clear preference for time efficiency and pleasure, and the "stop-start" nature of HIIT seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). No negative associations in recent studies applying intense efforts are also encouraging (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Leahy et al., 2019).

Adolescents, especially older ones, are underrepresented in studies implemented in the school context (Leahy et al., 2019). Despite the widespread interest in the advantages that the HIIT methodology reveals, there is a lack of randomized controlled studies investigating the impact on adolescents (Leahy et al., 2019; Logan et al., 2014), mainly adressing adolescents' environment, such as schools (Harris et al., 2017; Logan et al., 2016). It is known that School and PEC are privileged spaces, promoters of positive changes for the rest of life (Mura et al., 2015). Recently, some studies presents HIIT programs targeting school-aged children (Bogataj et al., 2021; Ketelhut et al., 2020; Sharp et al., 2020; Tottori et al., 2019), and in a scoope of 10 years we find dozens of works with students aged 10-19 years, but only a few were implemented in the school setting. Notwithstanding some studies have been implemented in the school setting, only a few (Alonso-Fernández et al., 2019; Bogataj et al., 2021; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Ketelhut et al., 2020; Martin-Smith et al., 2019; Martin et al., 2015) were implemented in PEC, some of which replaced the entire session with the intervention (Martin-Smith et al., 2019; Martin et al., 2015), or were applied in a classroom (Engel et al., 2019). This study aims to investigate whether 16-weeks of HIIT implemented on PEC warm-up, compared to 16-weeks of usual PEC warm-up, can improve Physical Fitness, PA, and Motivation for Exercise in high-school adolescents.

The present manuscript details a protocol for a randomized controlled trial examining the effect of HIIT in PEC. CRF is the primary outcome and secondary outcomes includes:

muscular fitness, PA and motivation for exercise. Also we aim to provide a rationale of design considerations for HIIT, such as appropriate length, intensity, and modality.

3.10.3. Methods

3.10.3.1. Study design

This project is registered on ClinicalTrials.gov (ID: NCT04022642) and has been approved by the Ethics Committee of the University of Évora (doc. 19017). In all aspects, this trial will be conducted according to the Declaration of Helsinki on Human Research. Two public schools in the city of Beja (Portugal) will be invited to participate. Written consent will be obtained before participation from the school principal and parents. Any protocol modifications will be communicated and registered on ClinicalTrials.gov.

3.10.3.2. Study population

This study is a two-arm randomized controlled trial design with adolescents from the 10th to 12th grades (15-17 years old). This age group has been selected because it is underrepresented in studies implemented in the school context (Leahy et al., 2019).

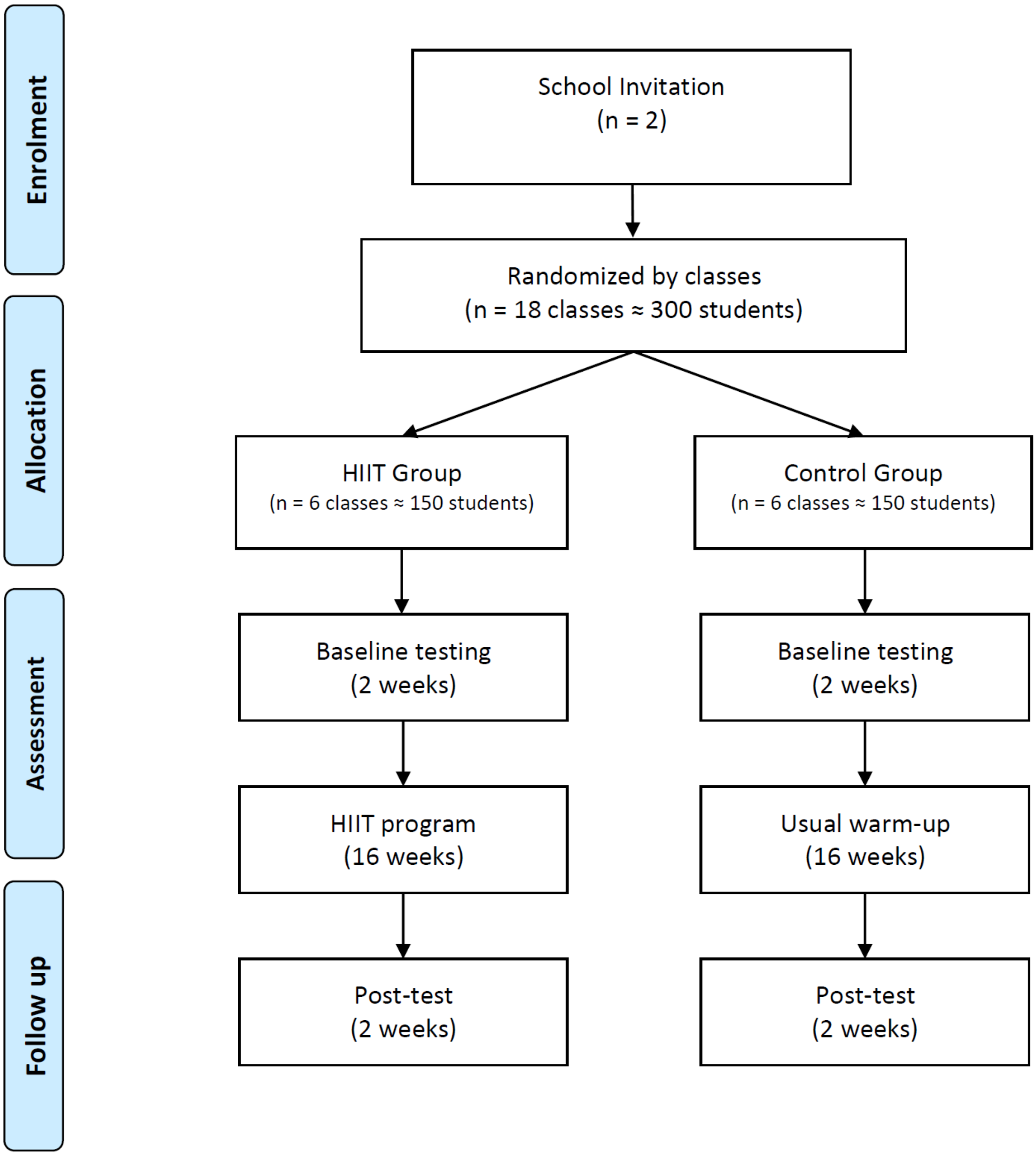
3.10.3.3. Recruitment

Twelve from a total of 18 classes with an average of 25 students each, recruited from a public school in the city of Beja, Portugal (**Fig. *2.1***) will be randomized to either a 16-weeks of HIIT (HIIT-G, n ≈ 150 students) implemented on PEC warm-up or a control group (CON-G, n ≈ 150 students) of usual PEC warm-up. After an invitation, the researchers will meet with the school principal to provide information on the whole project. After accepting to participate, adolescents and their parents will be informed of a full description of the scientific background, objectives, and safety.

3.10.3.4. Randomization

School principal, as a person independent of the study, will conceal participant allocation by shaking a bag with all 18 classes, before baseline testing. Classes will be randomized such that two classes from each grade will be allocated to the intervention condition and the other two to the control condition. Using this approach, each class will have an equal chance of being allocated to the intervention condition, while maintaining an appropriate balance of grades across the two conditions.

Fig. 3.12 *Study design*



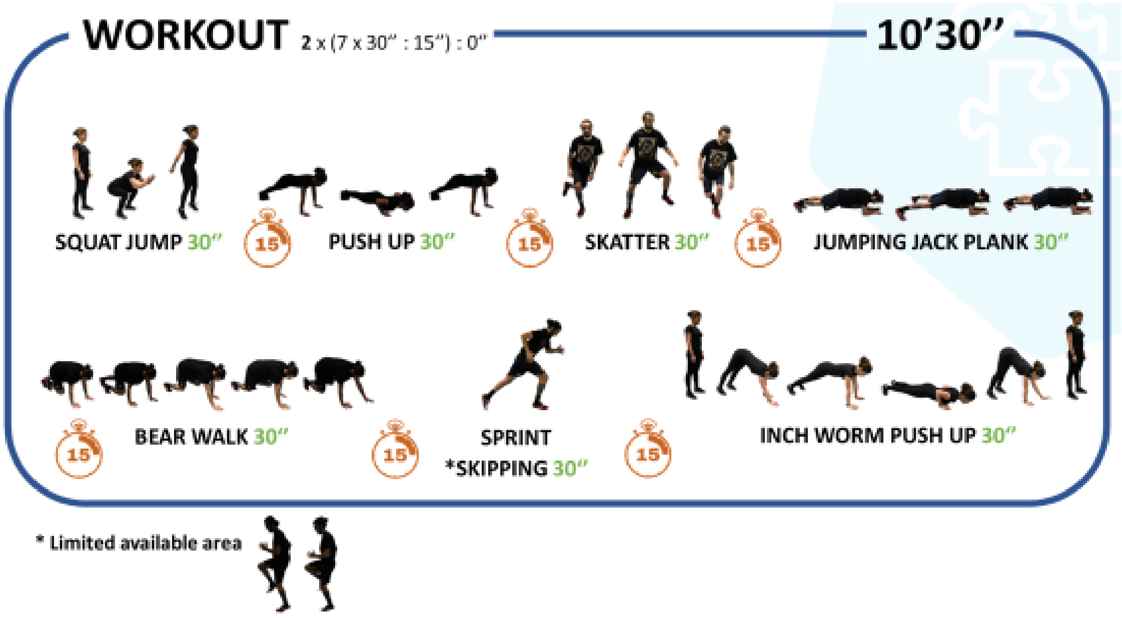
3.10.3.5. Inclusion/exclusion criteria

As stated above, girls and boys from the 10th to 12th grades (15-17 years old) taking part in the regular PEC will be included in the study. For ethical reasons, adolescents who have any physical, psychiatric, and/or psychological disability will also be included in the intervention if both children and parents approve their participation. Once the evaluation process is concluded, these children could be excluded from the main analysis. Students will be ineligible if they do not provide parental consent to participate, have physical limitations, or reveal intellectual disabilities.

3.10.3.6. Sample size

Power calculations were based on the primary outcome of CRF, assessed using the Yo-Yo Intermittent Endurance Test level one (Póvoas et al., 2016). To detect a clinically meaningful baseline-adjusted between-group difference of six laps (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Weston et al., 2016) with 80% power at a 5% significance level will require 158 students per treatment group (ie, 12 classes of 13 students from each school), for a potential drop-out rate of 15% at our primary study end point (i.e., 16 weeks).

Fig. 3.13 *Graphical description of an example session*

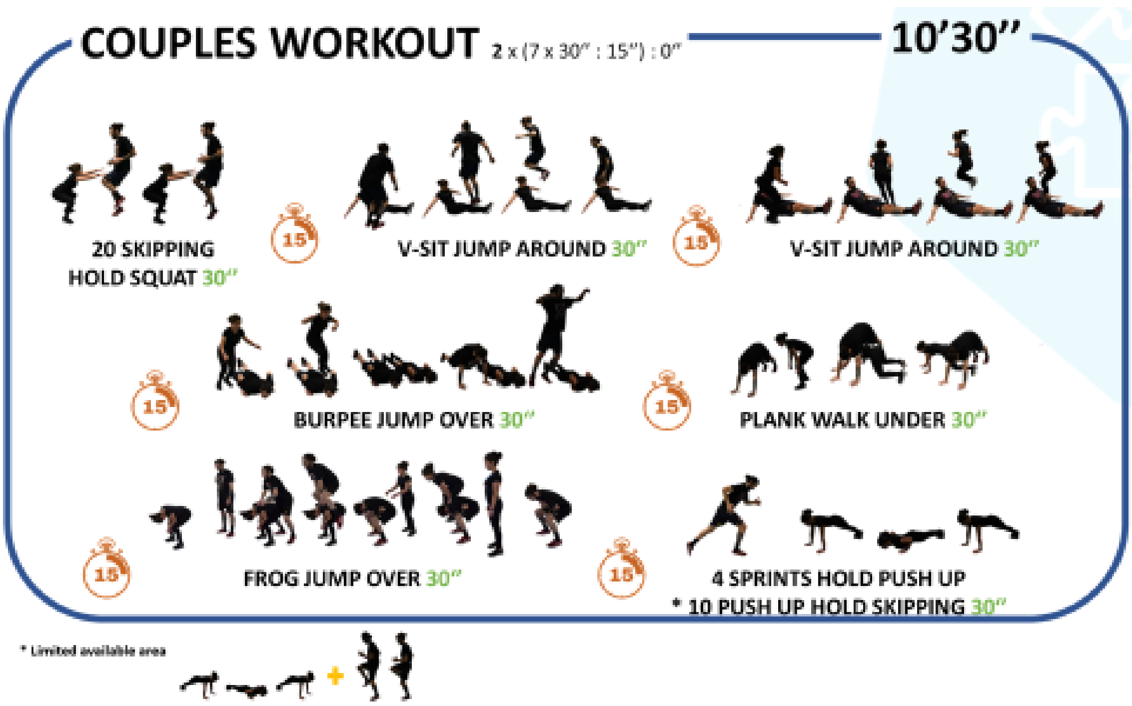


3.10.3.7. Intervention group

Throughout the 16-weeks intervention period the HIIT-G will take part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum. The HIIT-G replaces the warm-ups established in the PEC curriculum with the proposed HIIT training sessions. After the HIIT sessions, students will complete the planned PEC.

The HIIT sessions will be applied in the first 10-15 minutes of each PEC, including a brief warm-up, ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work to rest ratio, involving a combination of aerobic and body weight muscle-strengthening exercises, and designed to be fun and engaging as well as vigorous in nature (**Fig. *3.13***). Most protocols in the literature opted for 1:1 density and SPRINT as modality (Eddolls et al., 2017). Some, recording large effect sizes on CRF (Martin-Smith et al., 2019; Martin et al., 2015), PA (Martin-Smith et al., 2019), strength, power, and speed (Engel et al., 2019), needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, and chose to use all-out bouts instead of a percentage of Maximal Aerobic Speed (MAS). In adults, previous findings suggest that a 2:1 work-to-rest ratio is optimal during HIIT for both men and women (Laurent et al., 2014). We aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), to implement PA interventions that retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety.

Fig. 3.14 *Graphical description of an example session (couples)*



To promote exercise adherence, sessions were designed progressively from four minutes in week zero to 10 minutes in week three using the Tabata protocol (20s intense work, followed by 10s rest). From week four to week seven, the same volume but using 30s intense work, followed by 15s rest. From weeks eight to 16, sessions will be completed in pairs (**Fig. *3.14***). Participants will be able to give additional elements of choice, such as music, exercises, and workouts.

A cut-point of >=90% of maximal HR will be a criterion for satisfactory compliance to high-intensity exercise. HR has become one of the most used outcomes to assess the intensity, and several authors suggest that each interval corresponds to a value equal to or greater than 90%HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of 90%VO_{2max} (Buchheit & Laursen, 2013). It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response. During the supervised intervention, the researchers will record HR using a technology based on forearm plethysmography (Scosche Industries, CA, USA) to ensure compliance with the exercise stimulus at the predetermined target HR zone. Besides, rating perceived exertion (RPE) will also be measured in each exercise session to estimate effort, fatigue, and training load, targeting >17 on the 6−20 Borg scale (Borg, 1970; Williams et al., 1991).

3.10.3.8. Control group

Throughout the 16-weeks intervention period the CON-G will take part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum.

3.10.3.9. Outcome measures (primary and secondary)

All primary and secondary outcomes will be measured at baseline two weeks prior the intervention, and after 16-weeks of the HIIT program (**Fig. *3.15***). CRF is the primary outcome. Secondary outcomes includes: muscular fitness, PA and motivation for exercise. All assessments will be conducted by the Principal Investigator at the schools participating in the study. Anthropometric assessments will be conducted sensitively by the presence of a same-sex research staff when possible. The Principal Investigator will provide a brief verbal description and demonstration of each fitness test before commencement. Measures and data collection will be evaluated by the authors, not blinded for group allocation.

Fig. 3.15 *Schedule of assessment and HIIT intervention. (') Total work in minutes, ('':'') ratio ON:OFF in seconds*

WEEK	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TASKS	BASELINE TESTING		**4' = 8 x 20":10"**	**6' = 12 x 20":10"**	**8' = 16 x 20":10"**	**10' = 20 x 20":10"**		**10' = 14 x 30":15"**							**10' COUPLES = 14 x 30":15"**					POST-TEST	

3.10.3.9.1. Physical Fitness assessment

CRF will be assessed using the Yo-Yo Intermittent Endurance Test level one. This test has been previously confirmed as valid and reliable to assess aerobic fitness and intermittent high-intensity endurance in 9-to 16-year-old children (Póvoas et al., 2016). This test consists of incremental shuttle running starting from the speed of 8 $km{\cdot}h^{-1}$ until exhaustion. The maximum running speed is 14.5 $km{\cdot}h^{-1}$. Each shuttle run consists of 2 × 20 m interspersed by 10 seconds of active recovery (slow jog or walk) for a short 2.5 m shuttle. Within each speed stage, there are several shuttle runs. Running speed is prescribed by a pre-recorded audio track. Participants must reach the 20 m line by the time each audio is heard. The test is terminated if the participant is unable to maintain the required speed for the second time during the shuttle running bout. The total number of laps will be used to estimate maximal aerobic capacity (i.e., VO_2 max), using the following equation: IRT1 distance (m) x 0.0084 + 36.4 ($ml.kg^{-1}.min^{-1}$) (Tanner & Gore, 2014). Heart Rate (HR) will be monitored by telemetric HR during testing. The peak HR recorded during the test will be assumed to be representative of maximal HR (Krustrup et al., 2003).

FITescola® is a battery used to assess physical fitness in the Portuguese school setting (Henriques-Neto et al., 2020). Upper body muscle force will be assessed through the push-up test. The test starts with the participant's hands and feet touching the floor, and the body in a plank position, with feet apart and the hands positioned below the shoulder line. The participants should lower the body until forming a 90° angle between the arm and the forearm and then return to the starting position. This action will be repeated with a previously defined cadence of 20 push-ups per minute.

Participants' body composition and body mass will be measured to the nearest 0.1 kg in light sportswear on an electrical weight scale (Tanita MC -780), and height will be measured to the nearest 1 mm using a portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer). Both weight and height will be measured twice to reduce the risk of measurement error. A third measurement will occur should there be a difference of >0.1 kg for weight and >0.3 cm for height between the first and second measurements. Considering that the portable stadiometer has a precision of 3 mm and the scale of 0.1 kg, making a third measurement when the difference between the first and the second exceeds these precision levels can be justified by the objective of reducing to the maximum the technical error of measurement (TEM) and, consequently, the reliability of the results to attain. TEM should not be higher than 1.5% (intra-observer) or 2.0% (inter-observer) (Talita Adão et al., 2005). BMI will be calculated using the standard formula (weight [kg]/height [m^2]).

3.10.3.9.2. Physical Activity, Motivation, and Dietary Registration

Before the exercise intervention, both HIIT-G and CON-G participants will be instructed to maintain their dietary or lifestyle behaviors during the intervention period, so that, in this way, possible changes in eating habits may not contaminate the results. Daily dietary intake will be estimated with a validated self-reported food frequency questionnaire (Lopes et al., 2007), which list food types and meals typical of a Portuguese diet. Will be assessed using a semiquantitative food frequency questionnaire of the previous month, covering 82 food items or beverage categories, and a frequency section with nine possible responses ranging from never to six or more times per day.

As has been recommended in a recent systematic review (Migueles et al., 2017), triaxial accelerometers will be used to determine PA levels, sedentary time, and sleeping time during 24 hours (seven days). Participants will be instructed to wear an ActiGraph wGT3X-BT accelerometer on their waist for 24 hours/day (will be only removed during shower time or swimming activities), fixed to an elasticized belt and placed on the right side of the participant's hip, for seven consecutive days. Adolescents will be encouraged to wear accelerometers on their dominant wrist (Sadeh et al., 1994) during the night to assess the time and quality of sleep. At least three weekdays and one weekend day will be considered as a minimum recording time for valid registers. Physical activity will be calculated separately on weekdays and weekend days (i.e., mean minutes per day), using existing thresholds for categorizing physical activity into a light, moderate and vigorous intensity.

Moreover, a self-reported questionnaire – the International Physical Activity Questionnaire (i-PAQ) – will assess the participants' physical activity behavior during the prior seven days, including the number of days spent engaged in sporting activity, physical activity during the school day, and physical activity out-with the school day. This questionnaire has been validated in different countries (Craig et al., 2003), and has shown acceptable psychometric properties to assess PA levels with good reliability.

Motivation will be assessed with the Behavioral Regulation in Exercise Questionnaire 3 (BREQ-3) (Cid et al., 2018). BREQ-3 is a valid and reliable measurement instrument to measure behavior regulation underlying the self-determination theory in the exercise domain and consists of 18 items with a five-point Likert scale, which varies between 1 ("Strongly Disagree") and 5 ("Strongly Agree").

3.10.3.10. Statistical analyses

The final data will be analyzed using IBM SPSS 26.0 (SPSS, Inc., Chicago, IL, USA). An exploratory analysis will be performed to determine the frequency, range, variability, and distribution type for each variable, to use the most appropriate statistical test when comparisons will be necessary. According to the subjects' recruitment, cluster analyses (a-priori segmentation approach) will be also considered.

If necessary, analyses will be adjusted for baseline differences. In order to avoid outcomes baseline imbalance, analysis of covariance should be used to adjust for baseline in the data analysis stage. Moreover, a post-hoc cluster analysis could be performed using interrelated variables from which subjects could be clustered into groups whose average within-group similarity is high while between-group similarity is low. The primary analysis of the data set will be carried out according to the 'intention to treat' principle. Analyses will include standard descriptive statistics, t tests, correlation, regression and two-way repeated measures ANOVA or the comparable non-parametric test as necessary to examine differences between and within groups. Missing data will be handled by multiple imputation approach (Rubin, 1987).

With the aim to minimize threats to internal validity, thereby strengthening external validity and improving the generalizability of results, an independent statistician will be in charge of the data analysis.

3.10.4. Discussion

On adolescents, despite differences in protocols on intensity like all-out bouts or % of MAS, modality (sprints vs calisthenics), and volume (6min-35min/session), most of them opted for 1:1 density (Eddolls et al., 2017). Almost all programs are limited to sprints, but some were designed to be implemented in couples (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Leahy et al., 2019), or individually (Alonso-Fernández et al., 2019) through calisthenic exercises and plyometrics. Some studies that exceed 10 minutes per session (Cvetkovic et al., 2018; Leahy et al., 2019; Racil et al., 2013), for 12 weeks, did not go beyond the moderate effect on body composition and physical fitness, compared to protocols below 10 minutes and with the same Effect Size (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; G. Racil et al., 2016). Interestingly, other protocols record Large Effect Size on CRF (Martin-Smith et al., 2019; Martin et al., 2015), PA (Martin-Smith et al., 2019), strength, power, and speed (Engel et al., 2019), needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, for only four (Engel et al., 2019; Martin-Smith et al., 2019) and seven weeks (Martin et al., 2015). It should be also emphasized that the same three studies that record Large Effect Sizes chose to use all-out bouts instead of a percentage of MAS, reinforcing the importance of including resistance training as a HIIT modality.

Few studies have objectively measured internal load by monitoring HR (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013) or RPE (Alonso-Fernández et al., 2019; Engel et al., 2019). Most studies opted to set intensity through external load, expressed in speed or distances. The more traditional HIIT methodology reflects a temporal efficiency in the improvement of several health markers and aerobic/anaerobic performance but lowered impact strength, muscle strength, and power. New protocols that also include resistance exercises, can induce a higher amount of beneficial adaptations in young people (Bento & Loureiro, 2018).

Optimal exercise duration and rest intervals remain ambiguous (Eddolls et al., 2017). Some studies that did not report improvements in body composition (Buchan et al., 2013; Lau et al., 2015) revealed that the CON-G significantly worsened, which gives HIIT a possible protective effect on body composition in these populations. Like body composition, a possible protective effect of HIIT was observed when the improvements in physical fitness were not significant, as the CON-G significantly worsened the performance (Buchan et al., 2013; Buchan et al., 2012; Martin-Smith et al., 2019; Martin et al., 2015). Ultimately, it can serve as protective factor against loss of functional capacity in youth, weight gain, and risk factors associated with physical inactivity, as teenagers tend to become more inactive as their age increases.

Despite some limitations, as the absence of a detailed evaluation to determine intervention fidelity to confirm treatment/protocol adherence, this project aims to evaluate the utility of a HIIT program integrated into high-school PEC, on Physical Fitness, PA, and Motivation for Exercise. Although some studies have been implemented in the school setting, only a few (Alonso-Fernández et al., 2019; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Martin-Smith et al., 2019; Martin et al., 2015) were implemented in PEC. With this study, the authors aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), to implement PA interventions, which retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety. The efficiency seems evident that HIIT protocols implemented in schools reflects in the improvement of physical fitness and reduction of sedentary behaviors, compared to other types of less intense and higher volume activities. This efficiency, resulting from the reduced time required (on average, about 10 minutes), reflects the wide applicability that these protocols could have in PEC and the great adaptation to the facilities (including classrooms). The introduction of HIIT in the school context has a high potential for improving physical fitness (Alonso-Fernández et al., 2019; Buchan et al., 2013; Buchan et al., 2012; Cvetkovic et al., 2018; Engel et al., 2019; Lau et al., 2015; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016) and PA (Costigan et al., 2018; Martin-Smith et al., 2019; Martin et al., 2015), and a moderate effect on improving body composition in adolescents (Alonso-Fernández et al., 2019; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Lau et al., 2015; Racil et al., 2013; G. Racil et al., 2016; Ghazi Racil et al., 2016). Moreover, exercise protocols that result in physiological improvements and adaptations in terms of health in a short time are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals.

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CHAPTER 4

4. Study 3. The Mediating Effect of Physical Fitness and Dietary Intake on the Relationship of Physical Activity with Body Composition in High School Students

Bento, A., Carrasco, L., & Raimundo, A. (2022). The Mediating Effect of Physical Fitness and Dietary Intake on the Relationship of Physical Activity with Body Composition in High School Students. *International Journal Of Environmental Research And Public Health*, *19*(12), 7301. https://www.mdpi.com/1660-4601/19/12/7301

4.1. Abstract

We aimed to investigate the relationship between physical activity (PA) and health-related physical fitness (PF) in adolescents and analyze if the associations of PA with body composition (BC) in adolescents are mediated by physical fitness or energy intake (EI). The participants were 236 adolescents (140 girls 16.1 ± 0.92 years). Cardiorespiratory fitness (CRF) was assessed using the Yo-YoITL1, and the push-up test was used to evaluate strength. BCs were measured on an electrical weight scale. Triaxial accelerometers were used to determine PA levels and moderate-to-vigorous PA (MVPA) levels. EI was estimated with a validated questionnaire. Mediation effects were estimated using bootstrapped 95% confidence intervals and were deemed significant if zero was not included in the intervals. The mediation analysis revealed an indirect effect of MVPA only through PF on BC, specifically through CRF on body fat (B = −0.0146, 95% BootCI (−0.0219; −0.0076)) and on lean body mass (B = 0.0096, 95% BootCI (0.0049; 0.0152)), as well as through upper body strength on body fat (B = −0.012, 95% BootCI (−0.0171; −0.0072)) and on lean body mass (B = 0.0059, 95% BootCI (0.003; 0.0095)). These results suggest that PA of at least a moderate intensity is relevant to BC and health-related PF in adolescents, regardless of the EI.

Keywords: exercise; health; fitness; youth

4.2. Introduction

Low cardiorespiratory fitness (CRF), measured by maximal oxygen consumption (VO_2max), is a powerful predictor of all-cause mortality and morbidity in young people (Carnethon et al., 2003). Despite the numerous benefits of regular physical activity (PA), Western children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Moreover, adolescents tend to become more inactive as their age increases (Bluher et al., 2017). Short leisure time, reduced access to facilities, as well as low motivation to engage in physical activities, are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). In any case, higher amounts of sedentary behavior are associated with increased adiposity, as well as poorer cardiometabolic health and fitness in children and adolescents (Bull et al., 2020).

In modern society, with the economic development and changes in dietary structure, high-calorie foods are more prevalent among adolescents, leading to a significant increase in the obesity rate of the youngest (Jebeile et al., 2021) and to the promotion of a positive energy balance. Because of its direct relationship to the long-term gain or loss of adipose tissue and changes in metabolic pathways, the difference between energy intake and expenditure has become of great interest since it was recognized that overweightness and obesity are major risk factors for many other health conditions (Romieu et al., 2017). While objective metrics for assessing energy expenditure or PA exist (Craig et al., 2003; Migueles et al., 2017), there are none for assessing energy intake. Measures of energy intake, although not being useful for assessing energy balance, as well as PA continue to play other important roles in epidemiologic studies and in monitoring population trends. Diet combined with PA leads to higher weight loss and is more effective at keeping lean body mass, resulting in a more desirable influence on overall body composition than diet alone (Miller et al., 2013).

Energy intake patterns and PA behaviors are influenced by a complex interaction of these factors. The focus of PA research has expanded to address the potential negative effects of sedentary behavior on energy balance (Romieu et al., 2017). Higher levels of PA have been demonstrated to reduce the weight gain associated with increased energy density, and it appears that at low levels of PA, an effective appetite suppression to maintain energy balance is compromised (Blundell et al., 2015). Environmental factors should be the primary objectives of epidemic intervention efforts, as they are modifiable, although genetic factors may play a role in affecting individuals' susceptibility to developing obesity (Romieu et al., 2017).

The World Health Organization (WHO) stated that this population should achieve at least an average of 60 min per day of moderate-to-vigorous PA (MVPA) and must limit sedentary time, and, as good practice, recommend that doing some physical activity is better than doing none (Bull et al., 2020). Every move counts, says WHO. Notwithstanding, the limited number of people willing to engage in MVPA and the high attrition of those who participate (Courneya, 2010), the evidence shows a high effectiveness of MVPA to reduce mortality, even considering a long lifespan (Wen et al., 2011). In modern society, it is unlikely that individuals will ever return to the high average PA levels of the past, and time-efficient interventions have a prominent role. Intervention and implementation research is needed to learn about social and physiological changes, in particular among the youngest in school-based settings, therefore allowing us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people.

According to Bond et al. (2015), the time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. There is a lack of studies evidencing the association between PA and physical fitness development in children and adolescents (Poitras et al., 2016). Additionally, there is an important lack of data on diet, PA, and adiposity in most parts of the world (Romieu et al., 2017). To the authors' knowledge, no previous study has examined the mediating role of physical fitness or energy intake in PA and body composition relationships in Physical Education classes (PEC). Based on the need and importance to increase the knowledge about the relationship between PA and health-related body composition, we aimed to analyze the level of PA, energy intake, and fitness in a sample of the Portuguese adolescent population. As a result, the primary goal of this research was to examine the indirect (physical fitness or energy intake-mediated) effects of PA on adolescents from the 10th to 12th grades on body composition (body fat and lean body mass). More precisely, investigating as to how these variables are associated allowed us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people. Identifying the pathways or systems that mediate the effects of PA on physical fitness is essential for the development of successful PEC interventions.

4.3. Methods

4.3.1. Study Design

Data were retrieved from the baseline assessment of a randomized controlled trial investigating the effects of High-Intensity Interval Training (HIIT) in High School PEC. The Ethics Committee of the University of Évora (doc. 19017) approved this study, which was registered on ClinicalTrials.gov (ID: NCT04022642). This trial was conducted in accordance with the Declaration of Helsinki on Human Research.

4.3.2. Participants

Two public schools in the Portuguese city of Beja were invited to participate. Before participating, the school administrator and parents signed a consent form. The researchers met with the school principal after receiving an invitation and provided information on the whole project. After accepting to participate, 236 adolescents from the 10th to 12th grades (96 boys and 140 girls, mean age 16.1 years, SD = 0.92) and their parents were informed of a full description of the scientific background, objectives, and safety. Students were ineligible if they did not provide parental consent to participate, had physical limitations, or revealed intellectual disabilities.

4.3.3. Measurements

The Principal Investigator assessed PA and physical fitness (CRF, upper-body strength, and body composition) at the schools participating in the study. When possible, participants' body composition and body mass assessments were performed in the presence of a same-sex research team. Before the evaluation, the Principal Investigator gave a brief verbal description and an explanation of each fitness test.

4.3.3.1. Physical Activity

Triaxial accelerometers were used to measure PA levels and sedentary time for seven days, as recommended in a recent systematic review (Migueles et al., 2017). The ActiGraph wGT3X-BT accelerometer, which was connected to an elasticized belt and positioned on the right side of the participant's hip, was to be worn on their waist for 24 h per day (and only removed during shower time or swimming activities). For valid records, at least three weekdays and one weekend day were required to be reported. PA was calculated (i.e., mean minutes per day) using existing thresholds for categorizing physical activity into sedentary behavior, as well as light, moderate, and vigorous intensity.

4.3.3.2. Physical Fitness

The Yo-Yo Intermittent Endurance Test level one was used to test CRF. This test has previously been demonstrated to be valid and accurate for assessing aerobic fitness and intermittent high-intensity endurance in children aged 9 to 16 (Póvoas et al., 2016). It also consists of incremental shuttle running starting from the speed of 8 $km \cdot h^{-1}$ until exhaustion. The maximum running speed is 14.5 $km \cdot h^{-1}$. Each shuttle run consists of 2 × 20 m interspersed by 10 s of active recovery (slow jog or walk) for a short 2.5 m shuttle. There are multiple shuttle runs within each speed stage. A pre-recorded audio track dictates the running speed. By the time each audio is played, participants must have crossed the 20 m line. The test is over if the participant cannot maintain the appropriate speed for the second time during the shuttle running bout. Using the following equation, the total number of laps were utilized to estimate maximal aerobic capacity (VO_2max): IRT1 distance (m) × 0.0084 + 36.4 (ml $kg^{-1}\cdot min^{-1}$) (Tanner & Gore, 2014). During testing, telemetric heart rate (HR) was used to monitor HR. The maximum HR was considered to be represented by the peak HR observed during the test (Krustrup et al., 2003). FITNESSGRAM thresholds were used to identify "low fitness" levels (Welk et al., 2011).

Upper body strength was assessed using the push-up test (FITescola®; (Henriques-Neto et al., 2020)). The test started with the participant's hands and feet touching the floor, and their body in a plank position, with their feet apart and their hands positioned below the shoulder line. With the body straight (without arching up or slumping down) and only the hands and toes touching the floor the participants should lower the body until forming a 90° angle between the arm and the forearm and then return to the starting position. This action was repeated with a previously defined cadence of 20 push-ups per minute. Cooper Institute thresholds were used to identify "low fitness" levels (Plowman, 2019).

4.3.3.3. Body Composition

Participants' body composition and body mass were measured to the nearest 0.1 kg in light sportswear on a bioelectrical impedance scale (Tanita MC −780, Tokyo, Japan), and height was measured to the nearest 1 mm using a portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer). Body composition measurements (body fat, lean body mass and basal metabolic rate) were performed through a bioelectrical body impedance analysis (BIA). Female adolescents did not have a menstrual period during examinations, and measurements were taken without metal items (earrings, belts, coins). To ensure the proper hydration for BIA testing, participants were asked to follow the following pre-test conditions: there should be no vigorous exercise or caffeine or alcohol consumption within 12 h of the test (Jackson et al., 1988). Body fat (BF) percentage thresholds were identified in relation to metabolic syndrome status (Laurson et al., 2011). Both weight and height were measured twice to reduce the risk of measurement error. BMIs were calculated using the standard formula (weight (kg)/height (m^2)). Age-specific and sex-specific BMI z-scores were calculated and used to classify participants into weight categories (Cole & Lobstein, 2012).

4.3.3.4. Dietary Registration

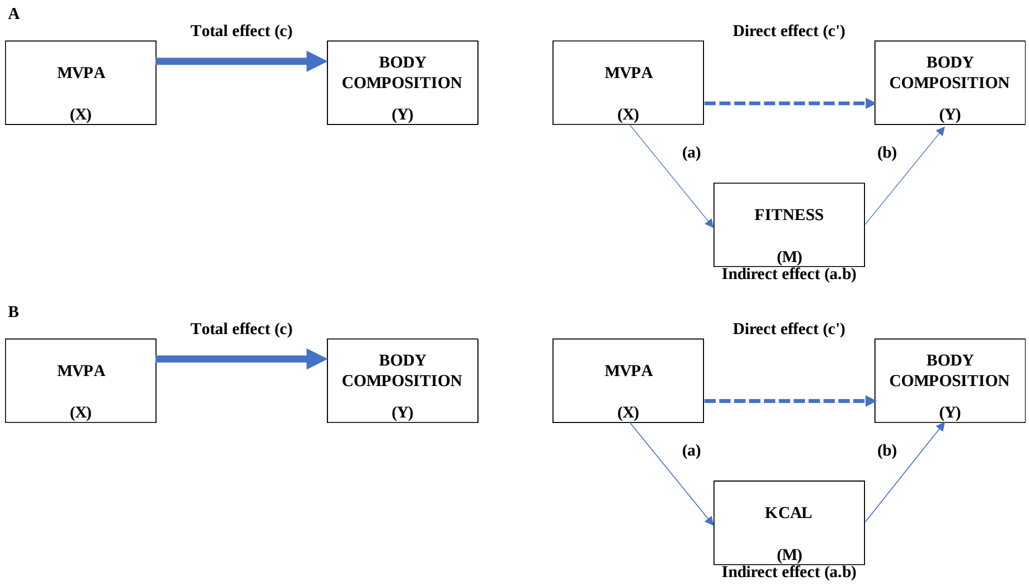
Daily dietary intake was estimated with a validated self-reported food frequency questionnaire (Lopes et al., 2007), which lists food types and meals that are typical of a Portuguese diet. A semiquantitative food frequency questionnaire from the previous month was used to assess daily dietary intake, which included 82 food or beverage categories and a frequency section with nine possible responses ranging from never to six or more times per day.

4.3.4. Statistical Analysis

Descriptive statistics were used to characterize the subjects and exercise test results. All variables were assessed for normality using the Kolmogorov–Smirnov test. A bivariate analysis was performed, using the parametric Pearson correlation coefficient or the nonparametric Spearman correlation coefficient (r_s), in order to indicate the strength of the association between variables. Interpretation of correlation coefficients was as follows: $r \leq 0.49$ weak relationship; $0.50 \leq r \leq 0.74$ moderate relationship; $r \geq 0.75$ strong relationship (Portney & Watkins, 2000). To examine whether physical fitness or energy intake mediated the relationship of MVPA with body composition, MVPA was used as a predictor in distinct models for each outcome, and physical fitness or energy intake were used as a mediator.

Fig. *4.1* illustrate the overall mediation models used in the analysis, a nonparametric sampling procedure, bootstrapping, has been advocated to obtain percentile-based confidence limits (Hayes, 2009; Preacher & Hayes, 2004; Sobel, 1982). This procedure provides the total and specific indirect effects (through the proposed mediator: fitness or energy intake) of the predictor (MVPA) on the outcomes (body composition). SPSS macro developed by Preacher and Hayes (2004) (PROCESS version 4.0) was used to test mediation. The indirect impact was calculated using 10,000 bootstrap samples for the bootstrap confidence intervals (CI), corrected for bias. An indirect effect is considered to be statistically significant if the CI established (95% CI, 95% BootCIs) does not include 0. If the CI contains the value 0, the null hypothesis demonstrates that the indirect effect equals 0, i.e., there is no association between the variables considered. Finally, unstandardized (B) and completely standardized effects (β) were used to describe the indirect effects. All *p*-values were two-tailed, and values below 0.05 were considered to indicate statistical significance. All statistical analyses were performed with the Statistical Package for the Social Sciences v.24 (SPSS Inc., Chicago, IL, USA).

Fig. 4.1 *Conceptual models of mediation analysis: indirect effect through fitness (**A**) or kcal (**B**).*



Note: path a = effect of X on M; path b = effect of M on Y; path c' = direct effect of X on Y controlling for M; path a.b = indirect effect of X on Y through M; path c = total effect of X on Y (direct and indirect). MVPA, moderate to vigorous physical activity.

4.4. Results

Data for 236 students (59.3% female) aged 16.1 ± 0.92 years that presented valid accelerometry data were available for analysis (**Table *4.1***). Overall, the bivariate analyses demonstrate consistent small to medium significant relationships between the variables. Regarding body composition, despite 82% of the students presenting with a normal weight, 33% are at high risk according to their body fat. Data from physical fitness assessment show that most students were at a low CRF level (71%), and only 23% showed a low muscular fitness level. Triaxial accelerometers data revealed that participants spent an average of 842.4 min per day on sedentary behaviors, 139.6 min per day on light PA, 23.0 min per day on moderate PA, and 13.6 min per day on vigorous PA. Boys had more time on vigorous PA than girls ($p < 0.001$). Only 8% of the students performed the recommended minutes of MVPA (at least 60 min per day).

Regarding body composition and physical fitness, the associations among the study variables showed less correlations for PA below MVPA. Regarding the risk thresholds presented in **Table *4.1***, bivariate correlation results showed, for body fat, a negative correlation with energy intake ($\rho = -0.146$, $p < 0.05$), CRF ($\rho = -0.790$, $p < 0.01$), upper body muscle force (ρ = −0.687, $p < 0.01$), vigorous PA (ρ = −0.400, $p < 0.01$), and MVPA (ρ = −0.341, $p < 0.01$). Thus, regarding physical fitness, CRF and strength, respectively, they showed positive correlations with energy intake (ρ = 0.269, $p < 0.01$; ρ = 0.256, $p < 0.01$), basal metabolic rate (ρ = 0.383, $p < 0.01$; ρ = 0.314, $p < 0.01$), vigorous PA (ρ = 0.482, $p < 0.01$; ρ = 0.400, $p < 0.01$), and MVPA (ρ = 0.347, $p < 0.01$; ρ = 0.310, $p < 0.01$), and a negative correlation between CRF and sedentary behavior (ρ = −0.139, $p < 0.05$). Light or moderate PA did not reveal any correlation with energy intake, physical fitness, or body composition. Sedentary behavior showed a negative correlation with energy intake (ρ = −0.136, $p < 0.05$), lean body mass (ρ = −0.177, $p < 0.01$), and basal metabolic rate (ρ = −0.144, $p < 0.05$). Correlations among the study variables are presented in **Table *4.2***.

Table 4.1 *Descriptive statistics of study variables (mean ± SD).*

	Total
ANTHROPOMETRIC (n)	236 (f = 140)
Body Fat (%)	25.0 (7.8)
High metabolic syndrome risk	33%
Lean Body Mass (kg)	45.3 (8.7)
BMI (kg m^{-2})	22.0 (3.7)
Thinness (<−2 SD)	2%
Normal-weight	82%
Overweight (>+1 SD)	10%
Obesity (>+2 SD)	6%
Basal Metabolic Rate (Kcal)	1531.6 (249.3)
Dietary Registration (n)	236 (f = 140)
Daily Kcal	2129.3 (1170.1)
Cardiorespiratory Fitness (n)	235 (f = 139)
Yo-Yo IE L-1 (laps)	23.7 (18.2)
“low fitness” level	71%
Muscular Fitness (n)	223 (f = 134)
Push-ups (reps)	15.3 (9.7)
“low fitness” level	23%
PHYSICAL ACTIVITY (n)	236 (f = 140)
Sedentary (min day^{-1})	842.4 (161.5)
Light (min day^{-1})	139.6 (44.0)
Moderate (min day^{-1})	23.0 (9.5)
Vigorous (min day^{-1})	13.6 (11.1)
Recommended MVPA	8%

BMI: Body mass index; MVPA: moderate to vigorous physical activity.

Fig. *4.2*.A1–A4 show the results of the mediation analysis for each outcome according to Conceptual Model A (**Fig. *4.1***). The total effect (*path c*) was significant on all models mediated through physical fitness or energy intake. Mediation through physical fitness does not include zero for any outcomes in the 95% BootCIs, revealing a significant indirect effect of MVPA, through physical fitness, on both the components of body composition, specifically for CRF on body fat (B = −0.0146, 95% BootCI (−0.0219; −0.0076)) and on lean body mass (B = 0.0096, 95% BootCI (0.0049; 0.0152)). This was also seen specifically for upper body strength on body fat (B = −0.012, 95% BootCI (−0.0171; −0.0072)) and on lean body mass (B = 0.0059, 95% BootCI (0.003; 0.0095)). Models A2 and A4 had a positive indirect effect since both *path a* and *path b* were positive, implying that high MVPA values improve physical fitness, which improves lean body mass. Because *path a* was positive and *path b* was negative in models A1 and A3, the indirect effect was negative. As a result, the indirect impact revealed that high MVPA levels promote physical fitness, which leads to a reduction in body fat. The completely standardized indirect effect indicated the largest indirect effect of MVPA through CRF on body fat (β = −0.2345, 95% BootCI (−0.3472; −0.1245)), followed by the indirect effect of upper body strength (β = −0.1854, 95% BootCI (−0.2561; −0.1126)), the indirect effect of CRF on lean body mass (β = 0.1449, 95% BootCI (0.0748; 0.2284)), and the indirect effect of upper body strength (β = 0.0873, 95% BootCI (0.0455; 0.1377)). Except for the influence of upper body strength on lean body mass, MVPA had no direct effects (*path c′*) on any outcomes.

Table 4.2 *Correlations among study variables.*

	1	2	3	4	5	6	7	8	9	10	11
1. Body Fat	x										
2. Lean Body Mass	−0.273 †	x									
3. BMI	0.556 †	0.548 †	x								
4. Basal metabolic rate	−0.258 †	0.977 †	0.548 †	x							
5. Daily Kcal	−0.146 *	0.642 †	0.445 †	0.615 †	x						
6. Yo-Yo IE L−1	−0.790 †	0.381 †	−0.274 †	0.383 †	0.269 †	x					
7. Upper body strength	−0.687 †	0.317 †	−0.238 †	0.314 †	0.256 †	0.727 †	x				
8. Sedentary	0.092	−0.177 †	−0.044	−0.144 *	−0.136 *	−0.139 *	−0.114	x			
9. Light	−0.020	0.039	0.062	0.060	0.433 †	−0.029	0.003	0.272†	x		
10. Moderate	−0.101	0.073	0.046	0.059	0.521 †	0.072	0.078	0.154 *	0.567 †	x	
11. Vigorous	−0.400 †	0.352 †	0.009	0.339 †	0.670 †	0.482 †	0.400 †	0.012	0.290 †	0.428 †	x
12. Daily MVPA	−0.287 †	0.267 †	0.046	0.242 †	0.739 †	0.347 †	0.310 †	−0.113	0.380 †	0.740 †	0.833 †

BMI: Body mass index; MVPA: moderate to vigorous physical activity; * Correlation is significant at the 0.05 level (2-tailed); † Correlation is significant at the 0.01 level (2-tailed).

According to conceptual model B (**Fig. *4.1***), **Fig. *4.2*** (B1, B2) show the findings of the mediation analysis for each outcome. The 95% BootCIs for any outcomes mediated through energy intake contained zero, indicating that MVPA has a non-significant indirect effect on both components of body composition, specifically body fat (B =

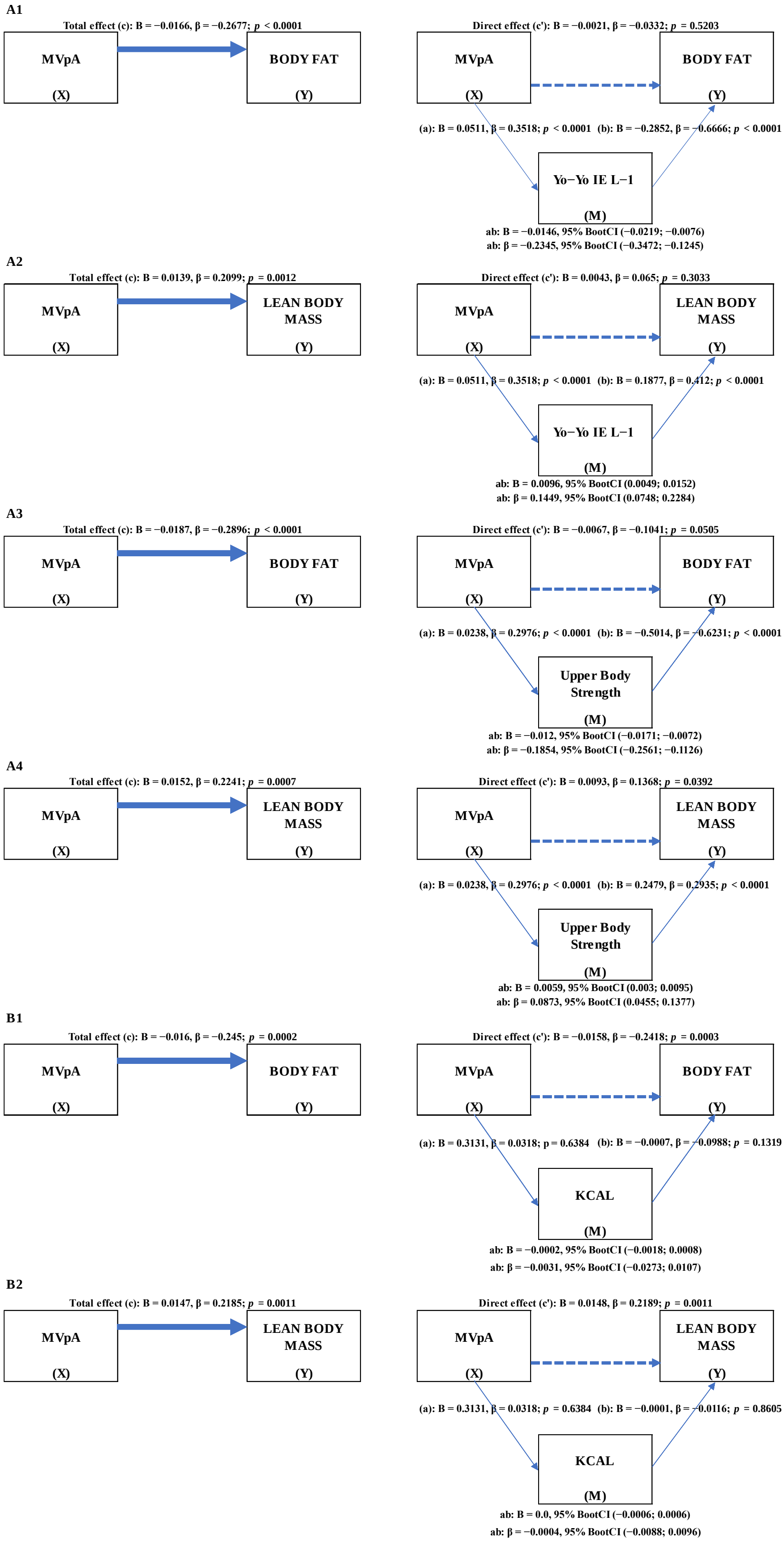
−0.0002, 95% BootCI (−0.0018; 0.0008)) and lean body mass (B = 0, 95% BootCI (−0.0006; 0.0006)).

4.5. Discussion

These results provide support that youth and adolescents should do regular vigorous-intensity activity to improve CRF and muscular fitness. Despite high-calorie foods promoting a positive energy balance and leading to a significant decline in the body composition of the youngest (Jebeile et al., 2021), we found a non-significant indirect effect of MVPA for energy intake on both components of body composition. Moreover, we found a negative association between adiposity and energy intake and a moderate positive correlation between lean body mass and energy intake ($\rho = -0.146$, $p < 0.05$; $\rho = 0.642$, $p < 0.01$, respectively). There is an important lack of data on diet, PA, and adiposity in most parts of the world; for these reasons, there is no systematic information on the determinants of the divergent trends in body composition in children and adolescents, be it on food environments and behaviors or on policies that affect them (Bentham et al., 2017). Additionally, we found a negative association between sedentary behavior and energy intake and a moderate positive correlation between MVPA and energy intake, respectively ($\rho = -0.136$, $p < 0.05$; $\rho = 0.739$, $p < 0.01$).

The major findings of our study imply that MVPA has a positive indirect effect on body composition through physical fitness. These findings highlight the need of regular MVPA for maintaining or improving physical fitness, which has a positive impact on body composition. In children and adolescents, higher rates of sedentary behavior are associated with increased adiposity, as well as poorer cardiometabolic health and fitness (Bull et al., 2020). In our study, the time spent doing light or moderate PA did not reveal any correlation with body composition. Even when the adolescents reported a higher time spent in sedentary behavior, their body fat did not show a positive correlation. PA is reported to be associated with adiposity, and higher levels of activity may be associated with healthy weight status; moreover, recent evidence reaffirms that increased PA improves CRF and muscular fitness (Poitras et al., 2016). In our study, we only found a positive association between adiposity and PA when adolescents reported a higher time spent in vigorous PA or combined vigorous plus moderate intensity, and in both dimensions of physical fitness: CRF and muscular fitness.

Fig. 4.2. *Mediation model A showing the effects (total, direct, and indirect) of MVPA on body composition variables. Mediation model B showing the effects (total, direct, and indirect) of MVPA on body composition variables. Abbreviations: MVPA, moderate-to-vigorous physical activity; IE L−1, Intermittent Endurance Test level one.*



Low CRF is a powerful predictor of all-cause mortality and morbidity in young people (Carnethon et al., 2003). A recent meta-analysis reported that school-based PA programs were associated with improvements in diastolic blood pressure and fasting insulin when compared with non-PA interventions (Pozuelo-Carrascosa et al., 2018). We found a strong negative correlation between CRF and body fat. Also, a positive association between CRF and PA was observed when adolescents reported a higher time spent in vigorous PA or combined vigorous plus moderate intensity. However, the time spent in light or moderate PA was not correlated with CRF. According to Bond et al. (2015), the time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. There is a lack of studies evidencing the association between PA and physical fitness development in children and adolescents (Poitras et al., 2016). We found a strong negative correlation between muscular fitness and body fat. Additionally, a positive association between muscular fitness and PA was observed when adolescents reported a higher time spent in vigorous PA or combined vigorous plus moderate intensity PA. Children and adolescents have expressed a clear preference for time efficiency and pleasure of MVPA, and its nature seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). Furthermore, adolescents seem to be more enthusiastic about resistance training, whereas aerobic training is found to be boring (Lee et al., 2012). The lack of negative associations found in recent studies applying intense interventions are encouraging (Costigan et al., 2015; Leahy et al., 2019); other studies, aside from aerobic and resistance training groups, included a variety of activities to enhance the motivation and appeal of exercise to the interest of older adolescents, thereby improving aspects of adolescents' cardiometabolic health (Weston et al., 2016), fitness, and body composition, despite using the lowest dose of exercise among the groups (Logan et al., 2016).

Notwithstanding the impact that PA has on physical fitness and that both variables have on body composition, these variables (i.e., PA and physical fitness) were examined separately. Several studies have shown that physically active adolescents have a better body composition when compared to inactive adolescents (Bull et al., 2020; Poitras et al., 2016); the mechanisms by which PA may cause improvements in body composition are still unknown. According to our findings, the favorable effect of PA on body composition could be mediated by improvements in physical fitness. In line with our hypothesis, we observed a significant and positive indirect influence of MVPA on body composition through physical fitness. The largest indirect effect of MVPA through physical fitness was observed through CRF on body fat, followed by an indirect effect through upper body strength, an indirect effect through CRF on lean body mass, and an indirect effect through upper body strength. Overall, these findings suggest that accumulating MVPA on a daily basis promotes physical fitness, which improves body composition in adolescents.

The mediation mechanism assumes that the independent variable influences the mediator, and the mediator affects the dependent variable. So, the independent variable's total effect is divided into indirect effects through a mediator. In our work, we used this statistical method to test if physical fitness and energy intake were mediators of the relationship of MVPA with body composition. In this study, our mediation analyses indicated that adolescents with a higher daily accumulation MVPA showed better physical fitness and therefore an improved body composition. This research adds to the existing literature by examining the indirect effect of PA on body composition in adolescents via physical fitness. It is critical to define and measure the mechanisms through which PA may be linked to body composition in order to improve recommendations and interventions. This is because Investigating mediators can aid in identifying critical aspects that require more attention in order to enhance outcomes.

Despite the novelty and interest of our findings, some limitations must be addressed. First, the use of a cross-sectional design is limiting, which prevents the determination of the temporality of the effect of MVPA, physical fitness, and energy intake on body composition; additionally, the inference of causality from our hypothesized path models is limited by the use of cross-sectional data. Second, our sample was limited to adolescents from the 10th to 12th grades from a public school in the city of Beja (Portugal), concluding that our findings cannot be applied to other populations. However, our selected bootstrapping method has strong statistical power and is considered a useful tool for avoiding Type I errors (Hayes, 2009). Third, using accelerometry to assess PA does not provide inferences about the form of physical activity undertaken. Furthermore, accelerometers do not detect all activities that may benefit physical fitness and body composition. The higher the intensity of PA, however, the more likely fitness and body composition adjustments are. To discover the specificities of PA required for the maintenance or improvement of physical fitness and body composition in adolescents, more intervention studies employing real-life scenarios are needed. Finally, other mediator variables may contribute to the links between PA and body composition. Measures of energy intake and expenditure are not precise enough, and the quality of the diet may exert its effect on energy balance through complex hormonal and neurological pathways that influence satiety, and, possibly, through other mechanisms (Romieu et al., 2017).

4.6. Conclusions

The present study examined the relationship between PA, physical fitness, energy intake, and health-related body composition in adolescents. The aim of this study was to assess if MVPA had an indirect effect on body composition through physical fitness or calorie intake. Total sedentary time was not associated with health outcomes (physical fitness and body composition); nonetheless, the time in MVPA has been positively associated with fitness and body composition. Regular MVPA is indirectly associated with improvements in body composition in adolescents when using physical fitness as a mediator, but not energy intake. To our knowledge, this is the first study to use a mediation model to investigate the indirect influence of MVPA on body composition in older adolescents (through physical fitness or energy intake). Our findings suggest that MVPA is beneficial to adolescents' health by promoting physical fitness maintenance or improvement; however, more research is needed to corroborate these findings. Moreover, exercise protocols that result in short-term physiological health improvements are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals. The results of this study emphasize the importance of new strategies in PEC with acute vigorous-intensity activities, as well as those that strengthen muscle, which retain their health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety. The idea that public health gains will be greater if we help the least active become more active is being challenged. In a modern society, it is unlikely that individuals will ever return to the high average PA levels of the past. This study highlights that time-efficient interventions have a preeminent role.

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CHAPTER 5

5. Study 4. High-Intensity Interval Training (HIIT) Program in Physical Education Classes for Promoting Fitness in Adolescents: A Randomized Controlled Trial

Bento, A., Carrasco, L., & Raimundo, A. (2022). High-Intensity Interval Training (HIIT) Program in Physical Education Classes for Promoting Fitness in Adolescents: A Randomized Controlled Trial **(under review)**

5.1. Abstract

Purpose: This study aims to investigate whether 16 weeks of High-Intensity Interval Training (HIIT) implemented on Physical Education classes (PEC), can improve physical fitness in high-school adolescents.

Methods: This study was a two-arm randomized controlled trial design with adolescents (15-17 years old). Twelve classes were randomized to either a 16 weeks of HIIT (HIIT-G, n = 106 students) implemented on PEC warm-up or a control group (CG, n = 123 students) of usual PEC warm-up. The HIIT sessions ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work-to-rest ratio.

Results: Post-intervention measures revealed a significant difference between groups in CRF and girls from HIIT-G increased their cardiorespiratory fitness (CRF) with significant difference between female groups and a medium to large effect size.

Conclusion: The main findings from this study indicate that brief whole-body HIIT of an extremely low volume, over 16 weeks, can improve CRF in adolescent girls.

Keywords: Health, cardiorespiratory fitness, muscular fitness, body composition.

5.2. Introduction

Low cardiorespiratory fitness (CRF), measured by maximal oxygen consumption (VO_2max), is a powerful predictor of all-cause mortality and morbidity in young people (Carnethon et al., 2003). Insufficient physical exercise (PE) but also other factors, such as overweight and obesity, and poor diet, are increasingly evident in the adolescent population, and could be decisive both for low CRF and the increasing incidence of different pathologies (Logan et al., 2014). Over 50% of obese children will become obese adults, with a significant increase in the risk of developing asymptomatic diseases, including cardiovascular diseases, cancer, and type 2 diabetes mellitus (Dias et al., 2016). Despite the numerous benefits of regular PE, western children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). Data related to Health Behavior in School-Aged Children (HBSC) associate a sedentary lifestyle with headaches, sadness, irritability, and nervousness (Marques et al., 2015). Moreover, adolescents tend to become more inactive as their age increases (Bluher et al., 2017).

Short leisure time, reduced access to facilities and low motivation to engage in physical activities, are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). In modern society, it is unlikely that individuals will ever return to the high average PE levels of the past. In any case, higher amounts of sedentary behavior are associated with increased adiposity, poorer cardiometabolic health and fitness in children and adolescents, and the World Health Organization (WHO) stated that this population should achieve at least an average of 60 minutes per day of moderate-to-vigorous PE (MVPE) and must limit sedentary time (Bull et al., 2020). Notwithstanding the limited number of people willing to engage in MVPE and the high attrition of those who participate (Courneya, 2010), the evidence shows high effectiveness of MVPE in reducing mortality, even considering a long lifespan (Wen et al., 2011).

Therefore, High-Intensity Interval Training (HIIT) is presented as a time-efficient alternative to aerobic training (Kilian et al., 2016; Kong et al., 2016; Logan et al., 2014; Zhang et al., 2017), as it leverages the number of exercise participants, resulting in improvements in health outcomes, mainly from adolescents (Garcia-Hermoso et al., 2016; Harris et al., 2017; Lazzer et al., 2017; Logan et al., 2016). HIIT is characterized by relatively short periods of very intense exercise, interspersed with periods of pause or low-intensity exercise (Fisher et al., 2011; Gibala & Jones, 2013). The purpose of HIIT is that physiological systems may perform exercises of higher intensity than those achieved during a gradual maximal test (Stuckey et al., 2012). HIIT is a powerful stimulus in improving body composition and preventing cardiometabolic risk in adults (Sim et al., 2015). Preliminary studies conducted with adolescents have shown promising results on body composition and cardiometabolic health and more effective and time-efficient interventions for improving blood pressure and aerobic capacity levels (Bluher et al., 2017; Costigan, Eather, Plotnikoff, Taaffe, & Lubans, 2015; Eddolls et al., 2017; Garcia-Hermoso et al., 2016; Herget et al., 2016). According to Bond et al. (2015), time spent in high-intensity activities is the most relevant factor in promoting vascular health and autonomic cardiac modulation. Children and adolescents have expressed a clear preference for time efficiency and pleasure, and the “stop-start” nature of HIIT seems to reflect the activities traditionally observed in childhood (Dias et al., 2016; Herget et al., 2016; Kilian et al., 2016; Logan et al., 2014). No harmful associations in recent studies applying intense efforts are also encouraging (Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Leahy et al., 2019). Furthermore, adolescents seem to be more enthusiastic about resistance training, whereas aerobic training is found to be boring (Lee et al., 2012). Other studies, besides aerobic and resistance training groups, included a variety of activities to enhance motivation and appeal to the interest of older adolescents, improving aspects of adolescents' cardiometabolic health (Weston et al., 2016), fitness and body composition, despite the lowest dose among groups (Logan et al., 2016). Interventions designed to increase MVPE in Physical Education classes (PEC) indicate that programs could increase the proportion of time students spend in higher intensities and reduce sedentary behavior, since motivational climates that emphasize effort and improvement and provide opportunities to demonstrate leadership and make decisions have a positive impact on PA (Lonsdale et al., 2013).

Adolescents, especially older ones, are underrepresented in studies implemented in the school context (Leahy et al., 2019). Despite the widespread interest in the advantages that the HIIT methodology reveals, there is a lack of randomized controlled studies investigating the impact on adolescents (Leahy et al., 2019; Logan et al., 2014), mainly addressing adolescents' environments, such as schools (Harris et al., 2017; Logan et al., 2016). It is known that the school and PEC are privileged spaces and promoters of positive changes for the rest of life (Mura et al., 2015), in which time-efficient approach interventions have a prominent role. Recently, some studies present HIIT programs targeting school-aged children (Bogataj et al., 2021; Ketelhut et al., 2020; Sharp et al., 2020; Tottori et al., 2019), and in a scope of 10 years, we find dozens of works with students aged 10-19 years, but only a few were implemented in the school setting. Of them, just a few (Alonso-Fernández et al., 2019; Bogataj et al., 2021; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Ketelhut et al., 2020; Martin-Smith et al., 2019; Martin et al., 2015) were implemented in PEC, replacing the entire session with the intervention (Martin-Smith et al., 2019; Martin et al., 2015). This study aims to investigate whether 16 weeks of HIIT implemented on PEC, compared to 16-weeks of usual PEC, can improve body composition and physical fitness in high-school adolescents. More precisely, we intend to study how these variables are associated, allowing us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people. Exploring the mechanisms or processes that mediate the effects of HIIT on physical fitness is crucial for developing effective interventions in PEC.

5.3. Methods

5.3.1. Study Design

This project was registered on ClinicalTrials.gov (ID: NCT04022642) and approved by the Ethics Committee of the University of Évora (doc. 19017). In all aspects, this trial was conducted according to the Declaration of Helsinki on Human Research. Apart public schools in the city of Beja (Portugal) were invited to participate, but only one consented to participate. Written consent was obtained before participation from the school principal and parents.

5.3.2. Participants

This study was a two-arm randomized controlled trial design with adolescents from the 10th to 12th grades (15-17 years old). Twelve from a total of 18 classes with an average of 25 students each, recruited from a public school (**Fig. *5.1***), were randomized to either 16 weeks of HIIT (HIIT-G, n = 106 students) implemented on PEC warm-up or a control group (CG, n = 123 students) of usual PEC warm-up. After an invitation, the researchers met with the school principal to provide information on the whole project. After accepting to participate, adolescents and their parents were informed of a detailed description of the scientific background, objectives, and safety.

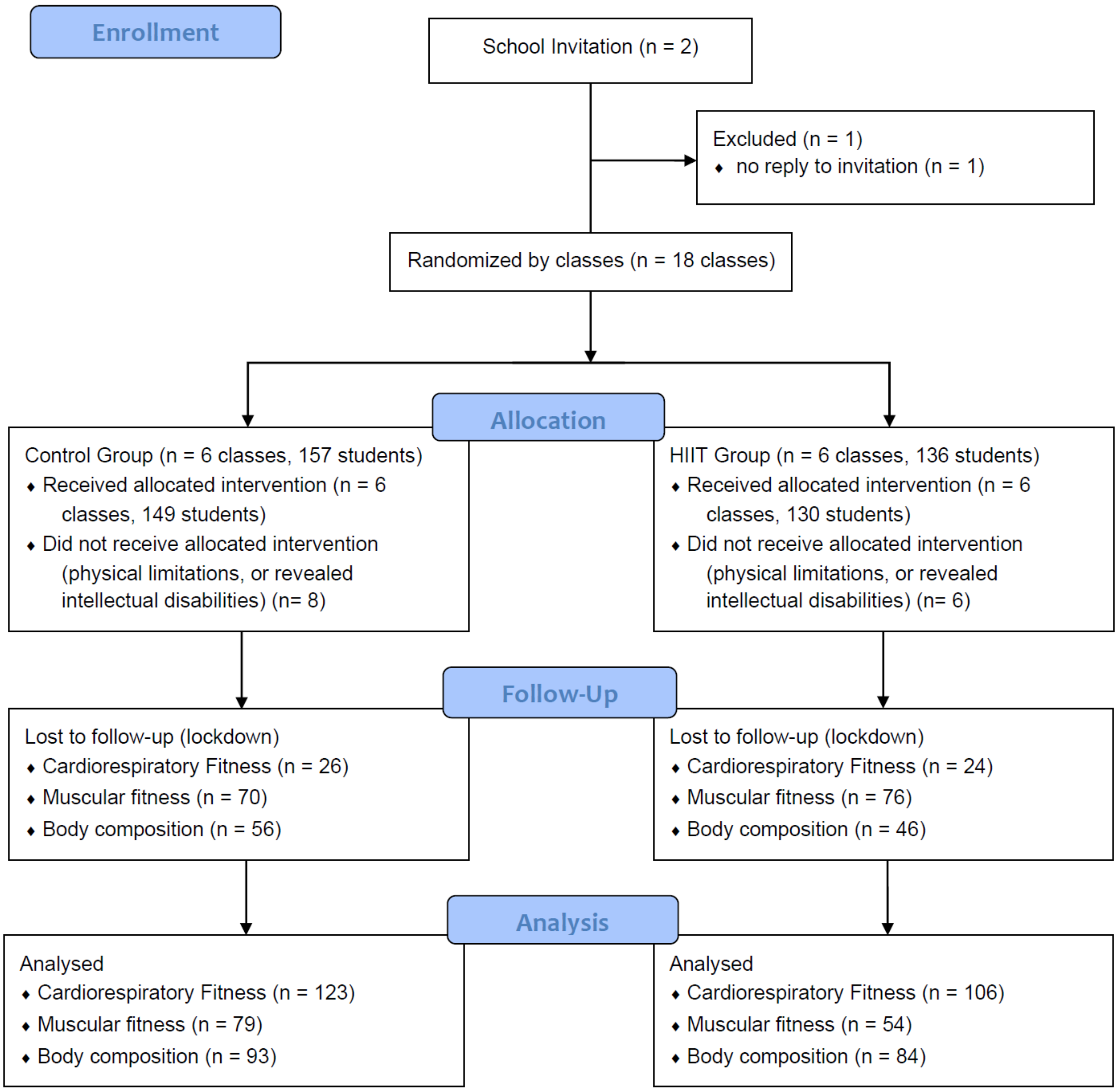
5.3.3. Randomization

The school principal, as a person independent of the study, concealed participant allocation by shaking a bag with all 18 classes before baseline testing. Classes were randomized so that two classes from each grade were allocated to the intervention condition and the other two were used as control group. Using this approach, each class had an equal chance of being allocated to the intervention condition while maintaining an appropriate balance of grades across the two conditions. Students were ineligible if they did not provide parental consent to participate, had physical limitations or revealed intellectual disabilities.

5.3.4. Sample size

Power calculations were based on the primary outcome of CRF, assessed using the 20-m Progressive Aerobic Cardiovascular Endurance Run (PACER) (Henriques-Neto et al. (2020). To detect a clinically meaningful baseline-adjusted between-group difference of seven laps (Leahy et al., 2019) with 80% power at a 5% significance level, 58 students per treatment group were required (i.e., four classes of 15 students), for a potential drop-out rate of 15% at our primary study end point (i.e., 16 weeks).

Fig. 5.1 *Study design*

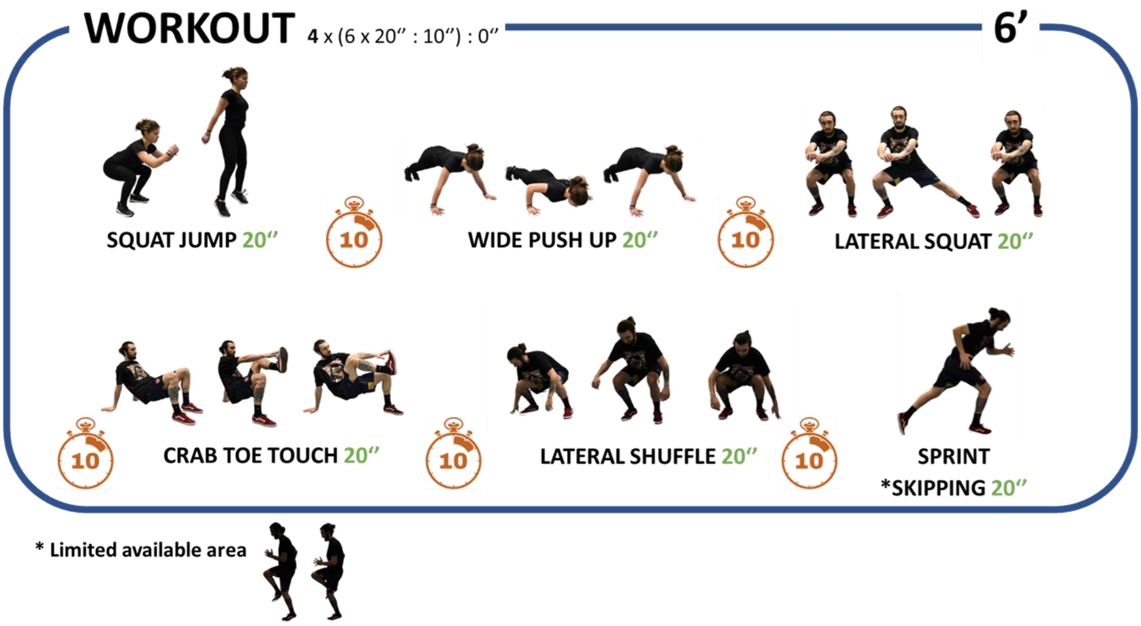


On 13 March 2020, the Portuguese Government adopted strict containment measures to avoid the new coronavirus (SARS-CoV-2) spread, and the student population was placed in home confinement, with permission only to leave home for limited and documented purposes (e.g., for health reasons or buying food), and several activities were temporarily prevented, including schools. These global preventive strategies posed unprecedented challenges and obstacles for our research, experiencing lower follow-up rates in the ongoing trial. As a negative consequence of home confinement, we experienced a high number of dropouts in several outcomes (**Fig. *5.1***).

5.3.5. Intervention Program

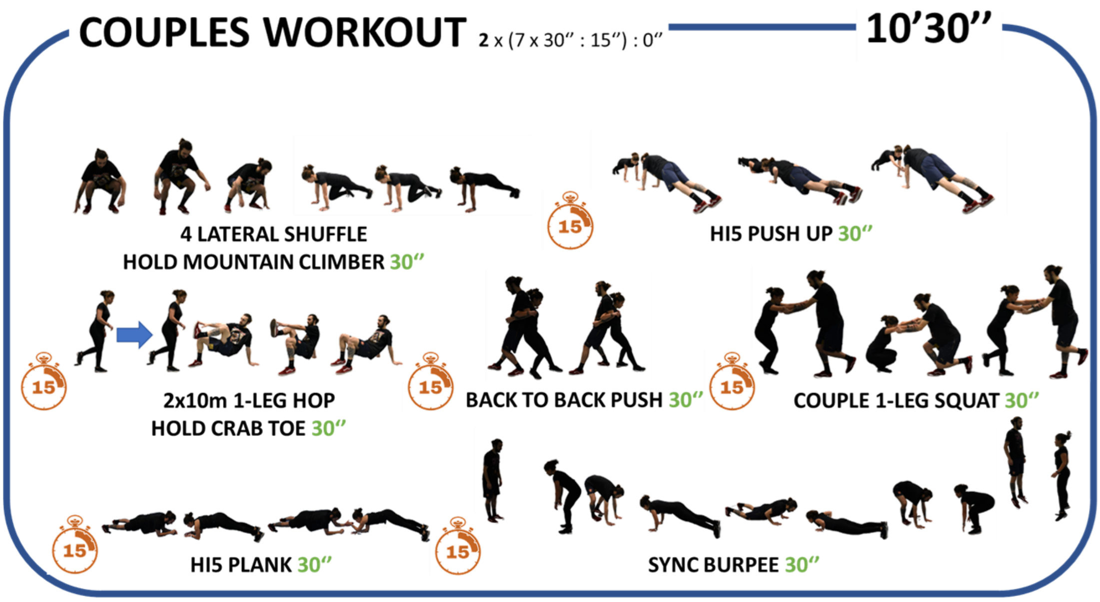
Throughout the 16-week intervention period, the HIIT-G took part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum. The HIIT-G replaced the warm-ups established in the PEC curriculum with the proposed HIIT training sessions. After the HIIT sessions, students completed the planned PEC.

Fig. 5.2 *Graphical description of an example session*



The HIIT sessions were applied in the first 10-15 minutes of each PEC and ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work-to-rest ratio, involving a combination of aerobic and body weight muscle-strengthening exercises, and designed to be fun and engaging, as well as vigorous in nature (**Fig.** *5.2*). Most protocols in the literature opted for 1:1 density and SPRINT as modality (Eddolls et al., 2017). Some, recording large effect sizes on CRF (Martin-Smith et al., 2019; Martin et al., 2015), PA (Martin-Smith et al., 2019), strength, power, and speed (Engel et al., 2019), needed only six minutes three (Martin-Smith et al., 2019; Martin et al., 2015) and four times (Engel et al., 2019) a week, and chose to use all-out bouts instead of a percentage of Maximal Aerobic Speed (MAS). In adults, previous findings suggest that a 2:1 work-to-rest ratio is optimal during HIIT for both men and women (Laurent et al., 2014). We aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), implement PA interventions that retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety.

Fig. 5.3 *Graphical description of an example session (couples)*



To promote exercise adherence, sessions were designed progressively from four minutes in week zero to 10 minutes in week three using the Tabata et al. (1996) protocol (20s intense work, followed by 10s rest). From week four to week seven, the same volume but using 30s-intense work, followed by 15s rest. From weeks nine to 15, sessions were completed in pairs (**Fig. *5.3***). Participants gave additional elements of choice, such as music, exercises, and workouts.

A cut-point of 90% of HR_{max} was a criterion for satisfactory compliance to high-intensity exercise. HR has become one of the most used outcomes to assess the intensity, and several authors suggest that each interval corresponds to a value equal to or greater than $90\%HR_{max}$ (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of $90\%VO_{2max}$ (Buchheit & Laursen, 2013). It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response. During the supervised intervention, the researchers recorded HR using the Heart Zones Move™ software application which uses a forearm wearable plethysmography heart rate sensor (Scosche Industries, CA, USA) to ensure compliance with the exercise stimulus at the predetermined target HR zone. Besides, rating perceived exertion (RPE) was also measured in each exercise session to estimate effort, fatigue, and training load, targeting >17 on the 6−20 Borg scale (Borg, 1970; Williams et al., 1991).

Throughout the 16-week intervention period, the CG took part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum.

5.3.6. Measures

All primary and secondary outcomes were measured at baseline two weeks prior the intervention and after 16 weeks after the HIIT program (**Fig.** ***5.4***). CRF was the primary outcome, and secondary outcomes includes muscular fitness and body composition. All assessments were conducted by the Principal Investigator. Anthropometric assessments were conducted sensitively with the presence of a same-sex research staff when possible. The Principal Investigator provided a brief verbal description and demonstration of each fitness test before evaluation. The authors evaluated measures and data collection, not blinded for group allocation.

Fig. 5.4 *Schedule of assessment and HIIT intervention. (') Total work in minutes, ('':'') ratio ON:OFF in seconds*

WEEK	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
TASKS	BASELINE TESTING		**4' = 8 x 20'':10''**	**6' = 12 x 20'':10''**	**8' = 16 x 20'':10''**	**10' = 20 x 20'':10''**	**CANCELED DUE TO SCHOOL ACTIVITIES**	**CHRISTMAS HOLIDAYS**		**10' = 14 x 30'':15''**		**10' COUPLES = 14 x 30'':15''**					**WINTER BREAK**	**10' COUPLES = 14 x 30'':15''**	POST-TEST	**LOCKDOWN**

5.3.6.1. Physical Fitness assessment

CRF and lower-body strength were assessed using the PACER and horizontal jump tests, respectively (Henriques-Neto et al. (2020). PACER consists of incremental shuttle running, starting from the speed of 8.5 km·h^{-1} and increasing progressively 0.5 km·h^{-1} every minute until exhaustion. Each shuttle run consists of 2 × 20 m. Within each speed stage, there are several shuttle runs. Running speed is prescribed by a pre-recorded audio track. Participants must reach the 20 m line by the time each audio is heard. The test is finished if the participant is unable to maintain the required speed for the second time during the shuttle running bout. The total number of laps will be used to estimate maximal aerobic capacity (i.e., VO_2 max), using the following equation: 41.76799 + (0.49261 x PACER) – (0.00290 x PACER^2) – (0.61613 x BMI) + (0.34787 x gender x age), [R = 0.75, R^2 = 0.56, SEE = 6.17 ml.kg^{-1}.min^{-1}], where PACER is the number of laps completed; for gender, 1 = boy and 0 = girl; and age is in years (Mahar et al., 2011). HR was monitored by telemetric HR during testing. The peak HR recorded during the test was assumed to be representative of maximal HR (Krustrup et al., 2003).

The horizontal jump test started in the standing position, with the feet slightly apart from each other and below the shoulder line, immediately behind a line drawn on the floor. Then, the participant jumped as far as possible, landing with the feet together. The distance between the starting line, and the heel of the back foot was recorded. The best result of the two trials was considered.

5.3.6.2. Body Composition assessment

Participants' body composition was measured to the nearest 0.1 kg in light sportswear on a bioelectrical impedance scale (Tanita MC -780), and height was measured to the nearest 1 mm using a portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer). Body composition measurements (body fat, lean body mass and basal metabolic rate) were performed by bioelectrical body impedance analysis (BIA). Measurements were performed without accessories that have metal (earrings, belts, coins), and female adolescents were asked if they were on their menstrual period. When they were in their menstrual period, they repeated the assessment the following week. To ensure normal hydration status for BIA testing, participants were asked to adhere to the following pretest requirements: no vigorous exercise within 12 hours of the test and no caffeine or alcohol consumption within 12 hours of the test (Jackson et al., 1988).

5.3.7. Data analysis

All statistical analyses were performed with the Statistical Package for the Social Sciences v.24 (SPSS Inc., Chicago, IL, USA). The normality of data distribution was tested using the Kolmogorov-Smirnov test. When normality was observed, data were checked for significant differences between baseline and post-intervention applying student's t-test for paired samples and for significant differences between the two groups applying student's t-test for unpaired samples. Where the analysis suggested non-normality, simple effects were examined using the non-parametric Wilcoxon's signed ranks test for differences between baseline and post-intervention and the Mann-Whitney U test for significant differences between the two groups and genders.

To estimate effect sizes, Hedge's g was calculated for normally distributed measurements (one of the means from the two distributions is subtracted from the other, and the result is divided by the pooled sample standard deviation) and interpreted as follows: d = 0.2, d = 0.5, and d = 0.8, considered as small, medium, and large effect sizes, respectively (Fritz et al., 2012). For non-normal distributions, the z value was used to calculate the effect size, such as the r proposed by Cohen (1988, cit in Fritz et al., 2012); Cohen's guidelines for r are that a large effect is .5, a medium effect is .3, and a small effect is .1. Significance was set at $p < 0.05$.

5.4. Results

The mean training load response and volume during HIIT intervention are displayed in **Table *5.1***. Descriptive statistics and the effects of the intervention on physical fitness and body composition measures are displayed in **Table *5.2***. Due to activities and teaching breaks or climate condition, each class of HIIT-G participated on an average of 16.4 ± 1.3 (63%) of the 26 scheduled exercise sessions. The mean attendance for participants involved in the intervention was 12.2 ± 3.5 (47%). Absences were due to illness, medical appointments, lack of appropriate clothing or work placement attendance and, near the end of the intervention, home confinement.

Post-intervention measures revealed a significant difference between groups in CRF (U = 5313.5; $p < 0.05$; ES = 0.16) mainly because of the girls, since girls from CG lowered their CRF (Z = -2.1; $p < 0.05$; ES = 0.25) and girls from HIIT-G increased their CRF (t = 2.6; 0.5 to 3.9 95%IC; $p < 0.05$; ES = 0.35), with significant difference between female groups and a medium to large ES (t = -3.6; -5.9 to -1.7 95%IC; $p < 0.001$; ES = 0.65).

Within groups, HIIT-G increased muscular fitness (t = 3.2; 1.7 to 7.8 95%IC; $p < 0.005$; ES = 0.43), again mainly because of the girls (t = 2.4; 0.8 to 9.9 95%IC; $p < 0.05$; ES = 0.45) since boys did not reach significance (t = 2.0; -0.1 to 8.0 95%IC; $p = 0.005$; ES = 0.40).

Table 5.1 *Training load of HIIT Intervention*

	HIIT		
	Total (n =106)	**Girls (n =55)**	**Boys (n =51)**
Planned Sessions (n)	26		
Sessions, mean (sd)	12.2 (3.5)	12.2 (3.6)	12.2 (3.4)
Time in seconds >90%HRmáx/session, mean (sd)	179.9 (128.2)§	221.6 (127.8)	132.9 (112.4)
RPE/session, mean (sd)	17.4 (0.7)	17.6 (1.5)	17.4 (0.7)

Abbreviations: HR: heart rate; RPE: rating perceived exertion. Note: Values are presented as mean (SD).
§ Significant difference between genders

There was no significant difference in body composition between groups post-intervention. All groups and genders increased their lean body mass and lowered body fat; however, regarding body fat, only HIIT-G boys did not reach significance (Z = -1.6; $p = 0.12$; ES = 0.25).

5.5. Discussion

The aim of this study was to investigate whether 16 weeks of HIIT implemented on PEC, compared to 16 weeks of usual PEC warm-up, can improve physical fitness in high-school adolescents. The main findings from this study indicate that brief whole-body HIIT (10 min) of an extremely low volume, over 16 weeks (on average, 0.8 sessions per week), can improve CRF and muscular fitness in adolescent girls. Our study registered an increase of 9% in CRF in HITT-G girls and a decrease of 4% in CG girls, representing a medium to large ES (t = -3.6; -5.9 to -1.7 95%IC; $p < .001$; ES = 0.65). Within a 10-year scope, we find dozens of works with students aged 15-17 years, but only a few were implemented in the school setting. Notwithstanding some studies have been implemented in the school setting, only a few were implemented in PEC. Along this line of results, at the end of the seventh week, Alonso-Fernández et al. (2019), in a similar intervention with only 8 min twice a week, registered an increase of 10% in VO_2max to baseline ($p <$

.001; ES = 0.33), with only 13 female adolescents distributed by intervention and CG. Also in a seven week intervention, but with three sessions/week, using six min SPRINT as modality and only two female adolescents in HIIT-G, Buchan et al. (2012) observed, compared to CG, a significant increase of seven laps in PACER ($p < .005$), and a significant decrease in muscular fitness of CG ($p < .005$). Martin-Smith et al. (2019), using three sessions/week for only four weeks, replaced the entire PEC session with six min HIIT intervention, with nine female adolescents in HIIT-G, increased CRF 5 ml/kg/min with large ES ($p < .05$, ES = 0.92). Years earlier, the same researchers (Martin et al., 2015), with seven girls in HIIT-G, reached a large ES in intervention (0.93) due to the significant decrease in CRF of CG ($p < .05$) in a seven week intervention, three sessions/week. Costigan, Eather, Plotnikoff, Taaffe and Lubans (2015) also did not reach significance in CRF and muscular fitness improvements in an eight-week intervention, 10min/session, three sessions/week, with 12 female adolescents distributed in two HIIT-G. An increase in mitochondrial content and induced higher increases in citrate synthase maximal activity (MacInnis et al., 2017), type II fiber activation, and adenosine monophosphate-activated protein kinase activity (Kristensen et al., 2015) can be some of the physiological mechanisms explaining why HIIT may improve CRF. According to Bond et al. (Bond et al., 2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. Moreover, this could explain the absence of improvements in CRF observed in males. Because this is a high-intensity methodology, it is necessary to regulate the intensity to ensure that subjects hit a high enough threshold in their exercises. The difference in the findings between girls and boys may be a consequence of the higher average intensity, represented as the average time in seconds above 90%HRmax/session, of the girls observed in this study compared with the boys (222s vs 133s, respectively; t = 3.8; 42.0 to 135.5 95%IC; $p < .000$; ES = 0.74). Despite men's ability to produce more power, some studies reveal that women may have a higher resistance to exhaustion and/or better recovery during bouts of repetitive activity (Laurent et al., 2014). These data support the idea that women may recover faster from high-intensity exercise because they self-select intensities that put their hearts under more pressure.

Regarding body composition, in our study, all groups and genders increased their lean body mass and lowered body fat. Alonso-Fernández et al. (2019) registered a decrease of 8% in % of body fat to baseline ($p < .001$; ES = 0.58) and an increase of 6% in lean body mass (p < .001; ES = 0.15). In Buchan et al. (2012) intervention, there were no significant changes in body composition in both groups, and Martin-Smith et al. (2019) did not reach significance in the waist and hip circumference. Costigan, Eather, Plotnikoff, Taaffe and Lubans (2015) reduced significantly compared to CG 2 cm in waist circumference (p < .05; ES = 0.70).

Table 5.2 *Characteristics of physical fitness and body composition variables: Control group and HIIT at baseline and post-intervention*

		Baseline, Mean (SD)			Change to 16 weeks, Mean (95% CI)			Intervention effect					
		Total	**Girls**	**Boys**	**Total**	**Girls**	**Boys**	**Total**	***ES***	**Girls**	**ES**	**Boys**	***ES***
Cardiorespiratory Fitness (n)								229		124		105	
PACER (shuttles)	CG (n = 123)	52.6 (24.0)§§	36.1 (11.1)	73.7 (19.1)	-1.4 (-3.1 to 0.2)	-1.6 (-2.9 to -0.3)*	-1.2 (-4.7 to 2.3)	**.016**	0.16*	**.000**	0.65†	.830	0.03*
	HIIT (n = 106)	50.9 (25.2)§§	33.9 (11.2)	69.3 (23.1)	0.0 (-2.2 to 2.3)	2.2 (0.5 to 3.9)†	-2.3 (-6.6 to 2.0)						
Muscular Fitness (n)								133		72		61	
Lower body muscular power (cm)	CG (n = 79)	178.2 (38.5)§§	148.8 (16.6)	213.4 (25.4)	2.8 (0.1 to 5.4)	1.1 (-2.7 to 4.9)	4.8 (1 to 8.6)*	.349	0.16†	.149	0.35†	.751	0.08*
	HIIT (n = 54)	162.8 (33.5)§§	142.1 (21.9)	186.8 (28.2)	4.7 (1.7 to 7.7)*	5.3 (0.8 to 9.9)*	3.9 (-0.1 to 8)						
Body Composition (n)								177		98		61	
Body Fat (%)	CG (n = 93)	24.6 (8.0)§§	29.8 (5.7)	17.4 (4.0)	-0.9 (-1.3 to -0.5)*	-1 (-1.6 to -0.4)*	-0.8 (-1.4 to -0.1)*	.430	0.12*	.488	0.14*	.735	0.08*
	HIIT (n = 84)	24.8 (7.1)§§	29.2 (5.8)	19.9 (5.0)	-0.7 (-1.1 to -0.2)†	-0.7 (-1.4 to -0.1)*	-0.6 (-1.3 to 0.1)						
Lean Body Mass (kg)	CG (n = 93)	43.7 (8.7)§§	38.3 (4.5)	51.0 (7.6)	1.2 (0.9 to 1.5)*	1.0 (0.7 to 1.4)*	1.4 (0.9 to 1.9)†	.874	0.02*	.772	0.03*	.778	0.06*
	HIIT (n = 84)	44.2 (8.1)§§	39.1 (4.8)	49.9 (7.0)	1.2 (0.8 to 1.5)*	0.8 (0.4 to 1.2)†	1.5 (1.0 to 2.1)†						

Abbreviations: PACER Progressive Aerobic Cardiovascular Endurance Run, CG control group, HIIT High-Intensity Interval Training group, CI confidence interval. §§Paired samples Mann-Whitney U test was used to establish differences between genders. †Paired samples t-test and *Paired samples Mann-Whitney U test was used to establish differences between post-intervention measures for each group, and between groups

Physical fitness is considered a significant health indicator, as well as a predictor of cardiovascular disease morbidity and mortality (Carnethon et al., 2003). Given the time limits of school curricula, adding a HIIT protocol to the PEC curriculum may help students increase their fitness levels and enhance their health.

5.5.1. Strengths and Limitations

This study has several strengths, including the randomized design, intervention applied to older adolescents, objectively and subjectively measured internal load and in a PEC real context without, interfering with other aspects of the curriculum. Adolescents, especially older ones, are underrepresented in studies implemented in the school context (Leahy et al., 2019). Notwithstanding the fact that some studies have been implemented in the school setting, only a few (Alonso-Fernández et al., 2019; Bogataj et al., 2021; Buchan et al., 2012; Costigan, Eather, Plotnikoff, Taaffe, Pollock, et al., 2015; Costigan et al., 2018; Ketelhut et al., 2020; Martin-Smith et al., 2019; Martin et al., 2015) were implemented in PEC, some of which replaced the entire session with the intervention (Martin-Smith et al., 2019; Martin et al., 2015). Adjusting exercise intensity using HR has been a valid option, mainly in prolonged and submaximal periods. Few studies have objectively measured internal load by monitoring HR (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013) or RPE (Alonso-Fernández et al., 2019; Engel et al., 2019). HR has become one of the most used outcomes to assess intensity. On adolescents, almost all programs are limited to sprints, and most choose 1:1 density (Eddolls et al., 2017). With this study, the authors aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), which include resistance exercises through calisthenic exercises and plyometrics.

However, some limitations should also be acknowledged, such as the high missing values due to school activities, teaching breaks, weather conditions and lockdown, or the absence of a detailed evaluation to determine intervention fidelity to confirm treatment/protocol adherence. Due to the negative consequences of home confinement, we experienced a significant number of dropouts in several outcomes, so the primary analysis of the data set was not carried out according to the 'intention to treat' principle. These simple effects were examined either using separate independent repeated measurement analysis, such as t-tests or – where the analysis of the residuals suggested non-normality – using the non-parametric Wilcoxon's signed ranks test. The mean attendance for participants involved in the intervention was 12.2 ± 3.5 (47%) of the 26 scheduled exercise sessions. One of the gaps in HIIT research is the small number of volunteers and the short duration of interventions so that significant impacts on public health can be inferred (Biddle & Batterham, 2015). However, in a school context, more than seven weeks can be problematic due to activities and teaching breaks provided for in planning and the school calendar (Martin-Smith et al., 2019). Although we planned to include a pre- and post-nutrition control and a PA enjoyment scale, home confinement did not allow that assessment.

5.6. Conclusions

Despite the extremely low volume (on average, 10 min/week), brief whole-body HIIT over 16 weeks can improve CRF and muscular fitness in adolescent girls. It should be noted that there is no need for external loads to implement these protocols; the use of all-out bouts and plyometrics are also simple approaches. The actual PEC time is still restricted due to activities and teaching breaks, as well as absences due to illness, medical appointments, and a lack of appropriate clothing, making it difficult to find content that can positively influence healthy physical fitness in students due to an objective lack of time. Replacing the traditional warm-up without interfering with other curricular content provided in PEC with this time-efficient approach could have a prominent role in improving female students' CRF. Investigations of dose-response relationships and the potential upper limits of HIIT volume and intensity are unsettled and highly relevant for healthy and clinical populations. Since HIIT did not improve CRF in boys, we recommend increasing the intensity and frequency of this type of exercise.

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CHAPTER 6

6. Study 5. The Mediating Effect of Motivation on the Relationship of Physical Fitness with Volitional High-Intensity Exercise in High School Students

Bento, A., Carrasco, L., & Raimundo, A. (2023). Mediating Effect of Motivation on the Relationship of Fitness with Volitional High-Intensity Exercise in High-School Students. *Healthcare*, *11*(6), 800. https://www.mdpi.com/2227-9032/11/6/800

6.1. Abstract

We aimed to investigate the relationship between physical fitness and motivation in adolescents and analyze if the associations of physical fitness with volitional exercise intensity in adolescents are mediated by motivation. The participants were 109 adolescents (59 girls 16.0 ± 0.92 years). Cardiorespiratory fitness (CRF) was assessed using the Yo-YoITL1, and the push-up test was used to evaluate strength. BCs were measured on an electrical weight scale. Volition intensity was assessed throuh a forearm wearable plethysmography heart rate sensor to ensure compliance with the exercise stimulus at the predetermined target HR zone (>=90%HR_{max}). Motivation was estimated with a validated questionnaire (BREQ-3). Mediation effects were estimated using bootstrapped 95% confidence intervals and were deemed significant if zero was not included in the intervals. The mediation analysis revealed a non-significant indirect effect of physical fitness through motivation on exercise intensity, specifically on CRF (B = 0.0044, 95% BootCI [-0.5089; 0.4458]), muscular fitness (B = -0.5797, 95% BootCI [-1.8695; 0.2584]) and body fat (B = 0.4044, 95% BootCI [-0.4292; 1.5525]). These results suggest that high or low values of motivation did not increase or decrease volitional high-intensity exercise, and lower levels of fitness (CRF, muscular and body fat) were associated with higher volitional exercise intensity.

Keywords:, Body composition, Health, HIIT, Fitness, Physical Education.

6.2. Introduction

Despite the numerous benefits of regular physical activity (PA), western children and adolescents spend too much time in sedentary behaviors, which is worsening every decade (Herget et al., 2016; Logan et al., 2016; Logan et al., 2014; Marques et al., 2015). The World Health Organization (WHO) stated that adolescents should achieve at least an average of 60 minutes per day of moderate-to-vigorous PA (MVPA) and must limit sedentary time (Bull et al., 2020). The suggested 150 minutes per week of moderately vigorous exercise or PA is frequently not achieved by individuals due to a lack of motivation (Garber et al., 2011).

A school is a place where adolescents spend most of their day. It is known that the school and PEC are privileged spaces and promoters of positive changes for the rest of life (Chen et al., 2021; Domaradzki et al., 2022; Duncombe et al., 2022; Harris et al., 2021; Popowczak et al., 2022), in which time-efficient approach interventions have a prominent role. There are several reasons why Physical Education classes (PEC) should be taught in schools, but the effectiveness of current methods for PEC is frequently challenged notwithstanding this point of view (Lubans et al., 2022; McKenzie & Lounsbery, 2014). It has also been demonstrated that most PEC programs have difficulty attaining the full range of health and educational outcomes included in the PEC curriculum (Bailey et al., 2009; Popowczak et al., 2022). Professionals consistently cite an overloaded curriculum causing additional time pressures as a primary obstacle to attaining these concurrent educational and health goals in response to the criticism (Bossmann et al., 2022; Duncombe et al., 2022; Harris et al., 2021; Morgan & Hansen, 2008).

Recreational sport and exercise can be performed for the associated enjoyment or for the challenge of participating in an activity (Teixeira et al., 2012). Volition consists of meta-motivational processes; when higher-level action control processes fail, volition may consist of increasing vigor. Research on the importance of volition in the area of exercise psychology is very limited; however, volitional skills have proven to be a sound predictor of performance in other areas of sport, such as elite sports (Elbe et al., 2005).

According to the Self-Determination Theory (SDT), two types of motivation influence personal behavior: the intrinsic (doing a task for the inherent pleasure) and the extrinsic (doing an activity for instrumental reasons, obtaining separable outcomes, or to avoid disapproval). Extrinsically motivated behaviors are expressed in four regulations: external (influenced by external contingencies), introjected (performing to obtain social approval or avoiding internal pressure), identified (recognition and acceptance of the behavior) and integrated (accepting and integrating behavior in other aspects of the self) (Deci & Ryan, 2008).

The vast majority of studies included an examination of the relationships between behavioral regulation and exercise behavior. Of these, most included some or all of the individual regulations specified within SDT, whereas others have collapsed autonomous and controlled forms of regulation into summary scales or adopted the Relative Autonomy Index (RAI) (Teixeira et al., 2012). RAI represents the self-determination continuum where lower scores indicate less autonomous motivation, whereas higher scores indicate more autonomous motivation (Verloigne et al., 2011).

Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014). Notwithstanding the limited number of people willing to engage in moderate-to-vigorous physical e exercise (MVPE), and the high attrition of those who participate (Courneya, 2010), the evidence shows a high effectiveness of intense exercise to reduce mortality, even considering a long lifespan (Wen et al., 2011). According to Bond et al. (2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. Clearer definitions of the nature of the exercise behaviors under analysis (type, intensity, volume, density), which may differ between studies, as well as their potential interest to the individual, may offer more information on this topic.

The growing evidence of the usefulness of SDT-based interventions for promoting the adoption and maintenance of exercise is a significant advance, but few studies included biological markers of successful exercise-related outcomes (Teixeira et al., 2012), such as volitional intensity. Adjusting exercise intensity using heart rate (HR) has been a valid option, mainly in prolonged and submaximal periods. HR has become one of the most used outcomes to assess intensity, and several authors suggest that high-intensity exercise corresponds to a value equal to or higher than 90% HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007).

Nevertheless, to the best of our knowledge, no studies formally tested the mediating role of motivation in exercise intensity and physical fitness relationships in PEC. Based on the need and importance of increasing the knowledge about the relationship between exercise intensity and motivation, we aimed to analyze the level of exercise intensity, motivation and fitness in a sample of a Portuguese adolescent population. Therefore, the main purpose of this study was to analyze the indirect (motivation-mediated) effects of physical fitness on adolescents from the 10^{th} to 12^{th} grades on volitional exercise intensity. More precisely, the study sought to know how these variables are associated, allowing us to identify possible indicators to guide national strategies in promoting healthy lifestyles in young people. Exploring the mechanisms or processes that mediate the effects of fitness on exercise intensity is crucial for developing effective interventions in PEC.

6.3. Methods

6.3.1. Study Design

Data were retrieved from the baseline assessment and intervention group of a randomized controlled trial investigating the effects of High-Intensity Interval Training (HIIT) in High-School PEC. This project was registered on ClinicalTrials.gov (ID: NCT04022642) and approved by the Ethics Committee of the University of Évora (doc. 19017). In all aspects, this trial was conducted according to the Declaration of Helsinki on Human Research.

6.3.2. Participants

Two public schools in the city of Beja (Portugal) were invited to participate. Written consent was obtained from the school principal and parents before. After an invitation, the researchers met with the school principal and provided information on the project. After accepting to participate, 109 adolescents from the 10th to 12th grades (50 boys and 59 girls, mean age 16.0 ± 0.9 years) and their parents were informed of a detailed description of the scientific background, objectives, and safety. Students were ineligible if they did not provide parental consent to participate, had physical limitations, or revealed intellectual disabilities.

6.3.3. Measurements

Motivation and physical fitness (CRF, upper-body strength) were assessed by the Principal Investigator at the schools participating in the study. Participants' body composition and body mass assessments were conducted sensitively through the presence of a same-sex research staff when possible. The Principal Investigator provided a brief verbal description and demonstration of each fitness test before evaluation.

6.3.3.1. Motivation

Motivation was assessed with the Behavioral Regulation in Exercise Questionnaire 3 (BREQ-3) (Cid et al., 2018). BREQ-3 is a valid and reliable measurement instrument to measure behavior regulation underlying the self-determination theory in the exercise domain and consists of 18 items with a five-point Likert scale, which varies between 1 ("not true for me") and 5 ("very true for me"). The scores from each BREQ subscale (amotivation, external, introjected, identified and intrinsic motivation) were weighted and subsequently aggregated to form a solitary numerical index, the RAI, representing the self-determination continuum where lower scores indicate less autonomous motivation, whereas higher scores indicate more autonomous motivation: (amotivation multiplied by -3) + (external regulation multiplied by -2) + (introjected regulation multiplied by -1) + (identified regulation multiplied by 2) + (intrinsic regulation multiplied by 3) (Verloigne et al., 2011).

6.3.3.2. Physical Fitness

CRF was assessed using the Yo-Yo Intermittent Endurance Test level one. This test has been previously confirmed as valid and reliable to assess aerobic fitness and intermittent high-intensity endurance in 9-to 16-year-old children (Póvoas et al., 2016). This test consists of incremental shuttle running starting from the speed of 8 $km \cdot h^{-1}$ until exhaustion. The maximum running speed is 14.5 $km \cdot h^{-1}$. Each shuttle run consists of 2 × 20 m interspersed by 10 seconds of active recovery (slow jog or walk) for a short 2.5 m shuttle. Within each speed stage, there are several shuttle runs. Running speed is prescribed by a pre-recorded audio track. Participants must reach the 20 m line by the time each audio is heard. The test is finished if the participant is unable to maintain the required speed for the second time during the shuttle running bout. HR was monitored by telemetric HR during testing. The peak HR recorded during the test was assumed to be representative of maximal HR (Krustrup et al., 2003).

Upper-body strength was assessed using the push-up test (Henriques-Neto et al., 2020). The test starts with the participant's hands and feet touching the floor, and the body in a plank position, with feet apart and the hands positioned below the shoulder line. The participants should lower the body until forming a 90° angle between the arm and the forearm and then return to the starting position. This action was repeated with a previously defined cadence of 20 push-ups per minute.

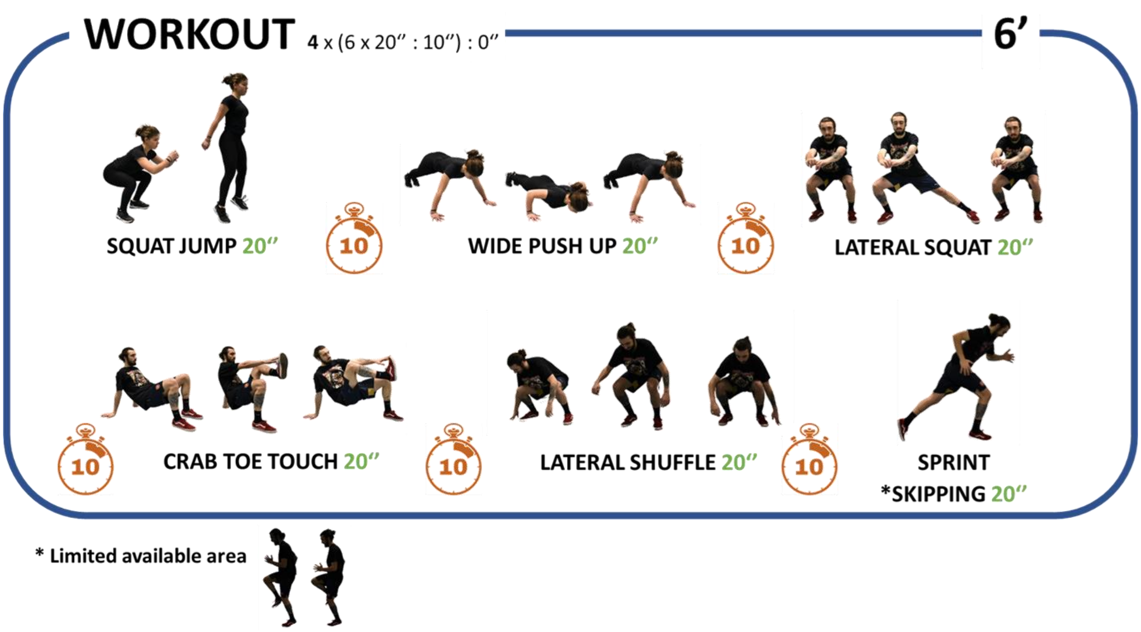
6.3.3.3. Body Composition

Participants' body composition and body mass were measured to the nearest 0.1 kg in light sportswear on a bioelectrical impedance scale (Tanita MC -780), and height was measured to the nearest 1 mm using a portable stadiometer (Seca 213 Portable Height Measuring Rod Stadiometer). Body composition measurements were performed through bioelectrical body impedance analysis (BIA). Measurements were performed without accessories that contain metal (earrings, belts, coins), and female adolescents should not have a menstrual period. To ensure normal hydration status for BIA testing, participants were asked to adhere to the following pretest requirements: no vigorous exercise within 12 hours of the test and no caffeine or alcohol consumption within 12 hours of the test (Jackson et al., 1988). Both weight and height were measured twice to reduce the risk of measurement error. BMI were calculated using the standard formula (weight [kg]/height [m^2]).

6.3.1. Intervention Program

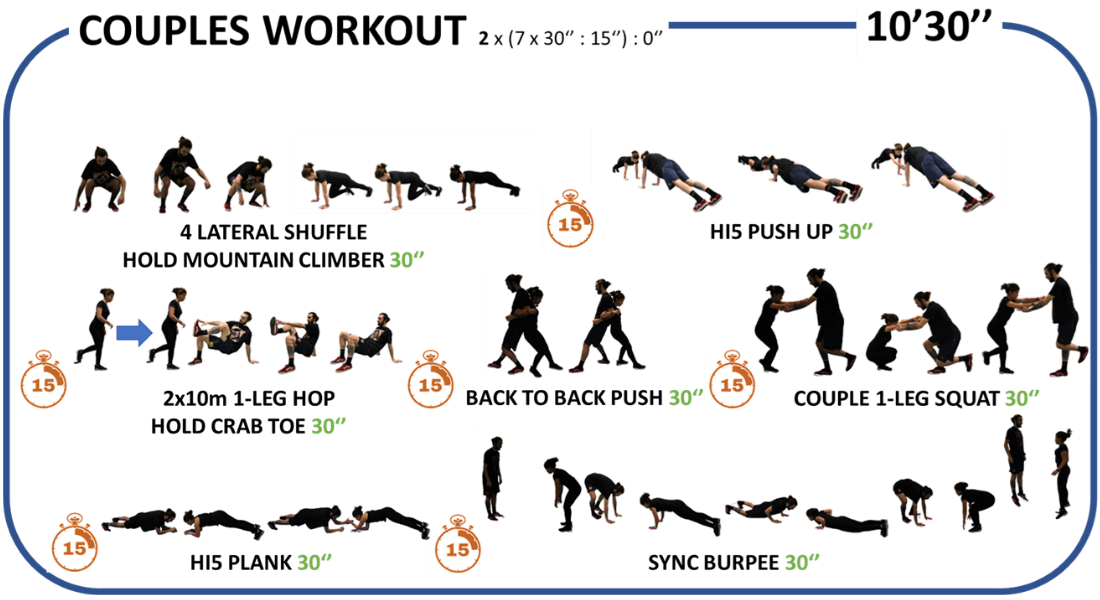
Throughout the 16 weeks, students took part in the regular 90min PEC twice a week, conducted by the schools' PEC teachers following the regular curriculum. Students replaced the warm-ups established in the PEC curriculum with the proposed HIIT training sessions. After the HIIT sessions, students completed the planned PEC. The HIIT sessions were applied in the first 10-15 minutes of each PEC, including a brief warm-up, ranged from 14 to 20 all-out bouts intervals, adopting a 2:1 work-to-rest ratio, involving a combination of aerobic and body weight muscle-strengthening exercises, and designed to be fun and engaging, as well as vigorous in nature (**Fig. *6.1***). Sessions were designed progressively from four minutes in week zero to 10 minutes in week three using the Tabata protocol (20s intense work, followed by 10s rest). From week four to week seven, the same volume of exercises was applied but using 30s-intense work, followed by 15s-rest. From weeks nine to 15, sessions were completed in pairs (**Fig. *6.2***).

Fig. 6.1 *Graphical description of an example session*



A cut-point of >=90% of maximal HR was a criterion for satisfactory compliance to high-intensity exercise. HR has become one of the most used outcomes to assess the intensity, and several authors suggest that each interval corresponds to a value equal to or higher than 90%HR_{max} (Bonsu & Terblanche, 2016; Hanssen et al., 2015; Helgerud et al., 2007). During the supervised intervention, the researchers recorded HR using the Heart Zones Move™ software application which uses a forearm wearable plethysmography heart rate sensor (Scosche Industries, CA, USA) to ensure compliance with the exercise stimulus at the predetermined target HR zone. Besides, rating perceived exertion (RPE) was also measured in each exercise session to estimate effort, fatigue, and training load, targeting >17 on the 6−20 Borg scale (Borg, 1970; Williams et al., 1991).

Fig. 6.2 *Graphical description of an example session (couples)*

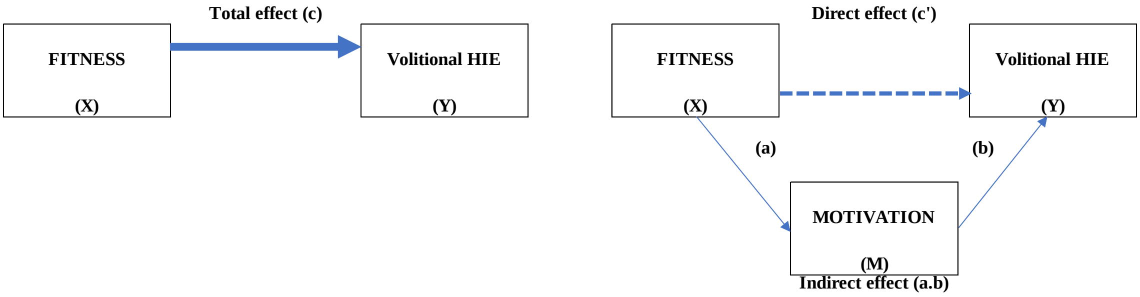


6.3.2. Data analysis

All statistical analyses were performed with the Statistical Package for the Social Sciences v.24 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to characterize the subjects and exercise test results. All variables were assessed for normality using the Kolmogorov-Smirnov test. A Bivariate analysis, using the parametric Pearson correlation coefficient or the nonparametric Spearman correlation coefficient (r_s), was used to indicate the strength of the association between variables. Interpretation of correlation coefficients was as follows: $r \leq 0.49$ weak relationship; $0.50 \leq r \leq 0.74$ moderate relationship; and $r \geq 0.75$ strong relationship (Portney & Watkins, 2000). All p-values were two-tailed, and values below 0.05 were considered to indicate statistical significance. To examine whether motivation mediated the relationship of physical fitness with exercise intensity, separate models were created for each outcome with physical fitness as a predictor and motivation as a mediator.

Fig. *6.3* illustrates the overall mediation models used in the analysis. The diagram on the left side shows the total effect (*path c*), which represents the effect of predictor X on outcome Y without considering mediation. Also, the total effect of X on Y is equal to the sum of the direct and indirect effects of X. This path quantifies how much two cases that differ by a unit on X are estimated to differ on Y. The diagram on the right side shows a simple mediation model that represents the effect of predictor X on outcome Y including mediation (M). In this model, there are two pathways by which (X) can influence (Y), the indirect effect (*path a.b*) and the direct effect (*path c´*). The indirect effect is the product of *path a* (the effect of the predictor on the mediator) and *path b* (the effect of the mediator on outcomes partially out the effect of the predictor) and represents how Y is influenced by X through M. The indirect effect quantifies how much two cases that differ by one unit on X are estimated to differ by *a.b* units on Y because of the effect of X on M, which, in turn, affects Y. The direct effect represents the effect of (X) on outcome (Y) that cannot be attributed to mediator (M). So, this path quantifies how much two cases that differ by one unit on X are estimated to differ by *c´* units on Y holding M. Mediation analyses were performed according to Hayes (2009), who advises that mediation can occur even when the total effect (the relationship between (X) and (Y), represented by *path c*) is not statistically significant. This is because the total effect is estimated by a different statistical model from the indirect effect, often having a lower power than the indirect effect test. Requiring total effect also ignores the risk of opposing direct and indirect effects, which might combine to produce a nonsignificant total effect. Yet, before testing mediation, *path a* and *path b* were quantified with regression coefficients. SPSS macro developed by Preacher and Hayes (2004) (PROCESS version 4.0) was used to test mediation. This tool tests the significance of indirect effects using bootstrap confidence intervals. The bootstrap method does not require assumptions of normality of the sampling and has higher power and better Type I error control when compared with the product-of-coefficients approach, most well known as the Sobel test (Hayes, 2009; Preacher & Hayes, 2004; Sobel, 1982). The indirect effects were deemed significant if 0 was not included in the bootstrap confidence intervals. We report the results of bootstrapping procedures, with the resampling of 10000 bootstrap replicates (95% confidence intervals, 95% BootCIs). Finally, the indirect effects were described by unstandardized (B) and completely standardized effects (β).

Fig. 6.3 *Conceptual model of mediation analysis: indirect effect through motivation*



Note: path a = effect of X on M; path b = effect of M on Y; path c' = direct effect of X on Y controlling for M; path a.b = indirect effect of X on Y through M; path c = total effect of X on Y (direct and indirect). HIE, high-intensity exercise.

6.4. Results

Data for 109 students (54.1% female) aged 16.0 ± 0.92 years that presented valid volitional intensity data were available for analysis (**Table *6.1***). **Fig. *6.4*** A to C show the results of the mediation analysis for each outcome according to the conceptual model (**Fig. *6.3***). Total effect (*path c*) was significant in models A (CRF) and C (body fat) mediated through motivation. Regarding bivariate correlation, exercise intensity showed positive correlations with body fat (r = .318, $p < .01$), and a negative correlation with CRF and muscular fitness (ρ = -.449, $p < .01$; r = -.190, $p < .05$).

The bootstrap derived 95% confidence intervals included zero for all outcomes mediated through motivation, revealing a non-significant indirect effect of physical fitness through motivation on exercise intensity, specifically on CRF (B = 0.0044, 95% BootCI [-0.5089; 0.4458]), muscular fitness (B = -0.5797, 95% BootCI [-1.8695; 0.2584]) and body fat (B = 0.4044, 95% BootCI [-0.4292; 1.5525]). There were direct effects (*path c'*) of CRF ($p < 0.0001$) and body fat (p < 0.001) on exercise intensity, suggesting that high values of CRF decrease volitional exercise intensity and high values of body fat increase physical exercise intensity, without mediation through motivation.

Table 6.1 *Descriptive statistics of study variables (mean ± sd)*

	Total
ANTHROPOMETRIC (n)	109 (f = 59)
Body Fat (%)	23.9 (7.3)
BMI ($kg.m^{-2}$)	21.6 (3.6)
MOTIVATION (n)	109 (f = 59)
Relative Autonomy Index	13.9 (5.5)
Cardiorespiratory Fitness (n)	109 (f = 59)
Yo-Yo IE L-1 (laps)	23.9 (18.4)
Muscular Fitness (n)	109 (f = 59)
Push ups (reps)	16.5 (9.8)
VOLITIONAL HIE (n)	109 (f = 59)
Averahe time >90% HRmax (s)	177.9 (129.4)

BMI: Body mass index; HIE: High-intensity exercise; HR: Heart rate; IE L-1, Intermittent Endurance Test level one

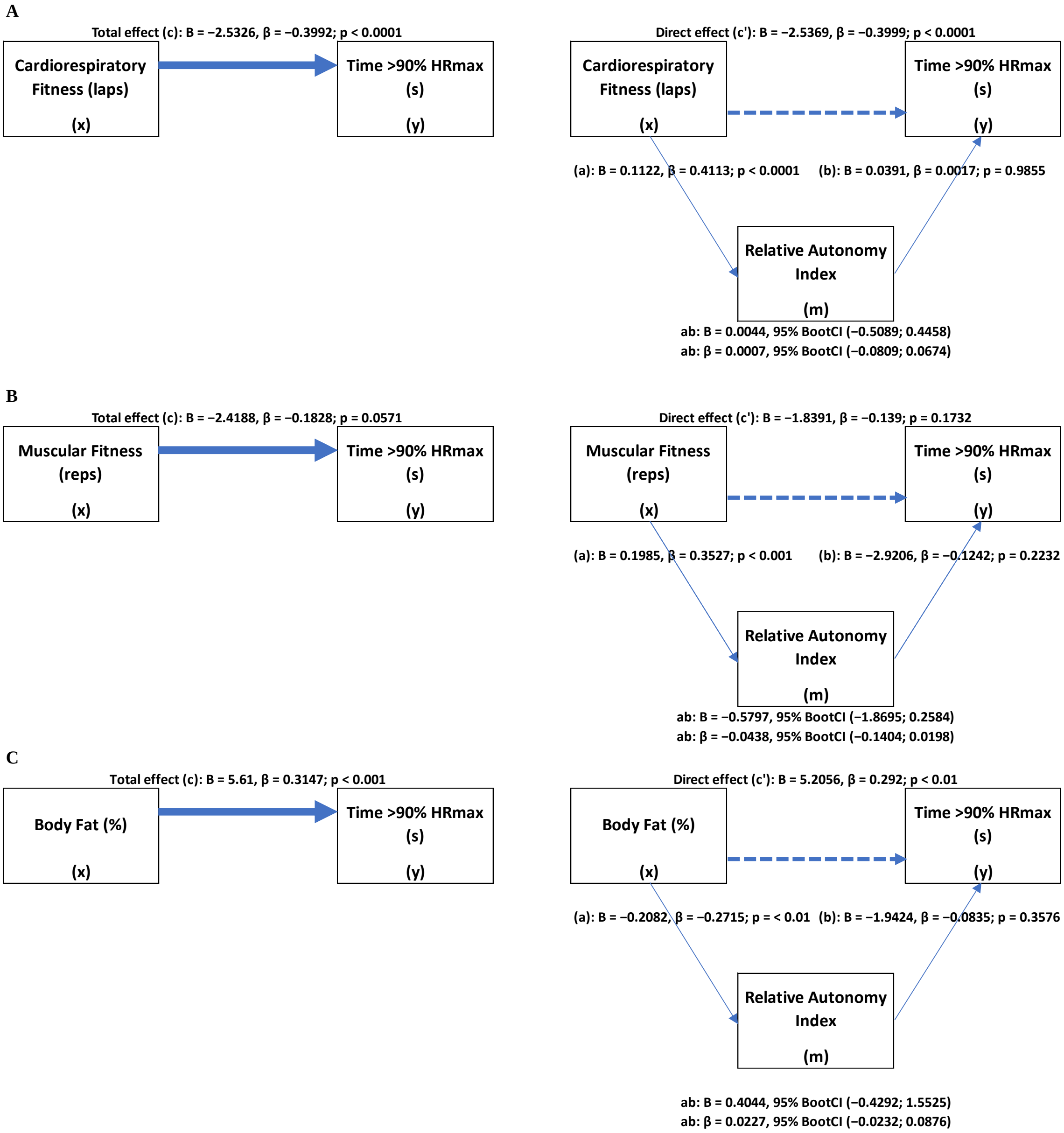
In *path a* (the effect of physical fitness on motivation) all models reveal a significance, but no significance in *path b* (the effect of motivation on exercise intensity), confirmed by bivariate correlations: a negative correlation with body fat ($\rho = -0.287$, $p < 0.01$) and positive correlations with CRF and muscular fitness ($\rho = 0.417$, $p < 0.001$; $\rho = 0.356$, $p < 0.001$). Regarding to *path b*, motivation did not reveal correlation with exercise intensity ($\rho = -0.163$, $p = 0.074$). Direct effects (*path c′*) remain significant on models A (CRF) and C (body fat) mediated through motivation. Therefore, the absence of an indirect effect suggested that high or low values of RAI did not increase or decrease volitional high-intensity exercise.

6.5. Discussion

The present study examined the relationship between physical fitness, motivation and volitional high-intensity exercise in adolescents. This study aimed to assess whether physical fitness had an indirect effect on exercise intensity (through motivation). The major findings of this study imply that the absence of an indirect effect suggested that high or low values of RAI did not increase or decrease volitional high-intensity exercise. Nevertheless, studies have shown that exercise behavioral regulation was found to be predictive of vigorous exercise, where introjected regulation, identified regulation, and intrinsic motivation were associated positively with strenuous exercise behaviors (Edmunds et al., 2006). Still, intrinsic motivation appears to be a more consistent predictor of moderate and vigorous exercise than identified regulation, and autonomous motivation was predictive of long-term moderate-to-vigorous exercise (Silva et al., 2010). The mediation mechanism assumes that the independent variable influences the mediator, and the mediator affects the dependent variable. So, the independent variable's total effect is divided into indirect effects through a mediator. In our work, we used this statistical method to test whether motivation was a mediator of the relationship of physical fitness with volitional exercise intensity. In this study, mediation analyses indicate that adolescents with a higher physical fitness and/or more motivation did not show better biological markers of successful exercise-related outcomes such as volitional intensity. This research adds to the existing literature by examining the indirect effect of physical fitness on volitional exercise intensity in adolescents via motivation. It is critical to define and measure the mechanisms through which physical fitness may be linked to volitional exercise intensity in order to improve recommendations and interventions. This is because investigating mediators can aid in identifying critical aspects that require more attention in order to enhance outcomes.

In children and adolescents, higher amounts of sedentary behavior are associated with increased adiposity, poorer cardiometabolic health and fitness (Bull et al., 2020). Short leisure time, reduced access to facilities, and low motivation to engage in physical activities are frequently reported barriers to poor adherence to exercise programs (Cvetkovic et al., 2018; Lau et al., 2015; Martin-Smith et al., 2019). Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014). However, in our study, lower levels of fitness (CRF, muscular and body fat) were associated with higher volitional exercise intensity. Notwithstanding the limited number of people willing to engage in MVPE, and the high attrition of those who participate (Courneya, 2010), the evidence shows high effectiveness of intense exercise to reduce mortality, even considering a long lifespan (Wen et al., 2011). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of 90%VO_{2max} (Buchheit & Laursen, 2013). Interventions designed to increase MVPE in PEC indicate that interventions can increase the proportion of time students spend in higher intensities during PEC and reduce sedentary behavior, since motivational climates that emphasize effort and improvement and provide opportunities to demonstrate leadership and make decisions have a positive impact on PA (Lonsdale et al., 2013). Physical self-perception could be considered for adherence to MVPE, although Rey et al. (2017) suggest that the adolescents' psychological perception and health might be improved in response to morphological adaptations, without concomitant improvements in objectively measured physical characteristics or performances.

Fig. 6.4 *Mediation models showing the effects (total, direct and indirect) of physical fitness variables on volitional high-intensity exercise.*



These findings highlight the need for regular MVPE for maintaining or improving physical fitness, regardless of motivation regulations, and emphasize the importance of new strategies in PEC with acute vigorous-intensity activities that retain the health-enhancing effects.

Despite the novelty and interest of our findings, some limitations must be addressed. First, the use of a cross-sectional design, which prevents the determination of the temporality of the effect of physical fitness, motivation on exercise intensity, and the inference of causality from our hypothesized path models is limited by the use of cross-sectional data. Second, our sample was limited to adolescents from the 10^{th} to 12^{th} grades from a public school in the city of Beja (Portugal). This means that our findings cannot be applied to other populations. Despite this, our selected bootstrapping method has strong statistical power and is considered a useful tool for avoiding Type I error (Hayes, 2009). Third, other mediator variables may contribute to the links between physical fitness and volition exercise since most studies opted to set intensity through external load, expressed in speed or distances. Few studies have objectively measured internal load by monitoring HR (Alonso-Fernández et al., 2019; Buchan et al., 2013; Costigan et al., 2018; Cvetkovic et al., 2018; Leahy et al., 2019; Martin-Smith et al., 2019; Racil et al., 2013) or RPE (Alonso-Fernández et al., 2019; Engel et al., 2019), but only some defined cut lines considering as high intensity >85%HR_{max} (Costigan et al., 2018; Leahy et al., 2019) or >90%HR_{max} (Cvetkovic et al., 2018). HR has become one of the most used outcomes to assess intensity. Adjusting exercise intensity using HR has been a valid option, mainly in prolonged and submaximal periods. It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response.

6.6. Conclusions

In conclusion, high or low values of RAI did not increase or decrease volitional high-intensity exercise, and lower levels of fitness (CRF, muscular and body fat) were associated with higher volitional exercise intensity. To the best of our knowledge, this is the first study addressing the indirect effect (through motivation) of physical fitness on volitional exercise intensity using a mediation model in a sample of older adolescents; however, future studies are needed to confirm these findings. The idea that public health gains will be higher if we help the least motivated become more motivated due to the lack of sufficient motivation to participate in moderately intense exercise or PA is being challenged. In modern society, it is unlikely that individuals will ever return to the high average PA levels of the past. The results of this study emphasize the importance of new strategies in PEC with acute vigorous-intensity activities. Time-efficient interventions have a preeminent role; moreover, exercise protocols that result in short-term physiological health improvements are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals.

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CHAPTER 7

7. Discussion

The general purpose of this thesis aimed to evaluate the utility of a HIIT program integrated into high-school PEC, on physical fitness, PA, and motivation for exercise. For this purpose, it was necessary to use a systematic review for 1) to evaluate the utility of a HIIT program integrated into high-school PEC, on physical fitness, PA, and motivation for exercise; and 2) to evaluate the effects of protocols and periodization on previous outcomes. The small sample sizes do not warrant analysis for the potential influence of sex or age on the results, may not be generalizable, and may lack external validity. None of the studies in the review reported any adverse events, either acute or chronic. All works reveal significant improvements, as well as moderate effect sizes, in at least two of the dimensions evaluated: physical fitness and PA. Only Costigan et al. (2015; 2018) measured student's and teacher's program receptivity, recording an average of 4.2 on the Likert scale. Although it was not measured, the researcher's perception was that students liked the intervention more than the classic alternative (Racil et al., 2013) due to spending less time, being more competitive, fun, and effective in improving physical fitness (Martin-Smith et al., 2019). Even in the case where the teachers themselves implemented for the HIIT program, reported that interest, performance, and behavior tend to improve in PEC (Leahy et al., 2019). The introduction of HIIT in the school context has a high potential for improving physical fitness and PA, and a moderate effect on improving body composition in adolescents. Some studies that did not report improvements in body composition (Buchan et al., 2013; Lau et al., 2015) revealed that the CG significantly worsened, which gives HIIT a possible protective effect on body composition in these populations. Like body composition, a possible protective effect of HIIT was observed when the improvements in physical fitness were not significant, as the CG significantly worsened the performance (Buchan et al., 2013; Buchan et al., 2012; Martin-Smith et al., 2019; Martin et al., 2015). Ultimately, it can serve as protective factor against loss of functional capacity in youth, weight gain, and risk factors associated with physical inactivity, as teenagers tend to become more inactive as their age increases. The motivational dimension did not show significant improvements; however, only two studies evaluated it (Costigan et al., 2015; Leahy et al., 2019). Considering that intense efforts have been deemed inappropriate for the general/sedentary population due to feelings of incompetence (Hardcastle et al., 2014), no negative associations in these studies are encouraging.

Moreover, exercise protocols that result in physiological improvements and adaptations in terms of health in a short time are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals. The authors aimed to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), to implement PA interventions, which retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety. Recently, some studies present HIIT programs targeting school-aged children, and in a scope of 10 years, we find dozens of works with students aged 10-19 years, but only a few were implemented in the school setting. Of them, just a few were implemented in PEC, or replacing the entire session with the intervention. It should be also emphasized that the studies that record Large Effect Sizes chose to use all-out bouts instead of a percentage of MAS (Engel et al., 2019; Martin-Smith et al., 2019; Martin et al., 2015), reinforcing the importance of including resistance training as a HIIT modality. On adolescents, despite differences in protocols on intensity like all-out bouts or % of MAS, modality (sprints vs calisthenics), and volume (6min-35min/session), most of them opted for 1:1 density (Eddolls et al., 2017). Almost all programs are limited to sprints, but some were designed to be implemented in couples, or individually through calisthenic exercises and plyometrics. The more traditional HIIT methodology reflects a temporal efficiency in the improvement of several health markers and aerobic/anaerobic performance but lowered impact strength, muscle strength, and power. New protocols that also include resistance exercises, can induce a higher amount of beneficial adaptations in young people (Bento & Loureiro, 2018).

MVPA has a positive indirect effect on body composition through physical fitness. These findings highlight the need of regular MVPA for maintaining or improving physical fitness, which has a positive impact on body composition. In children and adolescents, higher rates of sedentary behavior are associated with increased adiposity, as well as poorer cardiometabolic health and fitness (Bull et al., 2020). In our study, the time spent doing light or moderate PA did not reveal any correlation with body composition. Even when the adolescents reported a higher time spent in sedentary behavior, their body fat did not show a positive correlation. PA is reported to be associated with adiposity, and higher levels of activity may be associated with healthy weight status; moreover, recent evidence reaffirms that increased PA improves CRF and muscular fitness (Poitras et al., 2016). In our study, we only found a positive association between adiposity and PA when adolescents reported a higher time spent in vigorous PA or combined vigorous plus moderate intensity, and in both dimensions of physical fitness: CRF and muscular fitness. These results provide support that youth and adolescents should do regular vigorous-intensity activity to improve CRF and muscular fitness. Despite high-calorie foods promoting a positive energy balance and leading to a significant decline in the body composition of the youngest (Jebeile et al., 2021), we found a non-significant indirect effect of MVPA for energy intake on both components of body composition.

A brief whole-body HIIT (10 min) of an extremely low volume, over 16 weeks (on average, 0.8 sessions per week), can improve CRF and muscular fitness in adolescent girls. Our study registered an increase of 9% in CRF in HITT-G girls and a decrease of 4% in CG girls, representing a medium to large ES. Notwithstanding some studies have been implemented in the school setting, only a few were implemented in PEC. Along this line of results, at the end of the seventh week, Alonso-Fernández et al. (2019), in a similar intervention with only 8 min twice a week, registered an increase of 10% in VO_2max to baseline, with only 13 female adolescents distributed by intervention and CG. Also in a seven week intervention, but with three sessions/week, using six min SPRINT as modality and only two female adolescents in HIIT-G, Buchan et al. (2012) observed, compared to CG, a significant increase of seven laps in PACER, and a significant decrease in muscular fitness of CG. Martin-Smith et al. (2019), using three sessions/week for only four weeks, replaced the entire PEC session with six min HIIT intervention, with nine female adolescents in HIIT-G, increased CRF 5 ml/kg/min with large ES. Years earlier, the same researchers (Martin et al., 2015), with seven girls in HIIT-G, reached a large ES in intervention due to the significant decrease in CRF of CG in a seven-week intervention, three sessions/week. Costigan et al. (2015) also did not reach significance in CRF and muscular fitness improvements in an eight-week intervention, 10min/session, three sessions/week, with 12 female adolescents distributed in two HIIT-G. An increase in mitochondrial content and induced higher increases in citrate synthase maximal activity (MacInnis et al., 2017), type II fiber activation, and adenosine monophosphate-activated protein kinase activity (Kristensen et al., 2015) can be some of the physiological mechanisms explaining why HIIT may improve CRF. According to Bond et al. (Bond et al., 2015), time spent in high-intensity activities is the most important factor in promoting vascular health and autonomic cardiac modulation. Moreover, this could explain the absence of improvements in CRF observed in males. Because this is a high-intensity methodology, it is necessary to regulate the intensity to ensure that subjects hit a high enough threshold in their exercises. The difference in the findings between girls and boys may be a consequence of the higher average intensity, represented as the average time in seconds above 90%HRmax/session, of the girls observed in this study compared with the boys. Despite men's ability to produce more power, some studies reveal that women may have a higher resistance to exhaustion and/or better recovery during bouts of repetitive activity (Laurent et al., 2014). These data support the idea that women may recover faster from high-intensity exercise because they self-select intensities that put their hearts under more pressure. Regarding body composition, in our study, all groups and genders increased their lean body mass and lowered body fat. Alonso-Fernández et al. (2019) registered a decrease of 8% in % of body fat to baseline and an increase of 6% in lean body mass. In Buchan et al. (2012) intervention, there were no significant changes in body composition in both groups, and Martin-Smith et al. (2019) did not reach significance in the waist and hip circumference. Costigan et al. (2015) reduced significantly compared to CG 2 cm in waist circumference. Physical fitness is considered a significant health indicator, as well as a predictor of cardiovascular disease morbidity and mortality (Carnethon et al., 2003). Given the time limits of school curricula, adding a HIIT protocol to the PEC curriculum may help students increase their fitness levels and enhance their health.

When examined the relationship between physical fitness, motivation and volitional high-intensity exercise in adolescents, the major findings imply that the absence of an indirect effect suggested that high or low values of RAI did not increase or decrease volitional high-intensity exercise. Nevertheless, studies have shown that exercise behavioral regulation was found to be predictive of vigorous exercise, where introjected regulation, identified regulation, and intrinsic motivation were associated positively with strenuous exercise behaviors (Edmunds et al., 2006). Still, intrinsic motivation appears to be a more consistent predictor of moderate and vigorous exercise than identified regulation, and autonomous motivation was predictive of long-term moderate-to-vigorous exercise (Silva et al., 2010). In this study, mediation analyses indicate that adolescents with a higher physical fitness and/or more motivation did not show better biological markers of successful exercise-related outcomes such as volitional intensity. This research adds to the existing literature by examining the indirect effect of physical fitness on volitional exercise intensity in adolescents via motivation. It is critical to define and measure the mechanisms through which physical fitness may be linked to volitional exercise intensity in order to improve recommendations and interventions. Intense efforts have been considered inappropriate and not motivating for the general/sedentary population due to feelings of incompetence (Biddle & Batterham, 2015; Hardcastle et al., 2014). However, in our study, lower levels of fitness (CRF, muscular and body fat) were associated with higher volitional exercise intensity. Notwithstanding the limited number of people willing to engage in MVPE, and the high attrition of those who participate (Courneya, 2010), the evidence shows high effectiveness of intense exercise to reduce mortality, even considering a long lifespan (Wen et al., 2011). An optimal stimulus that promotes cardiovascular and peripheral adaptations implies several minutes per session in the so-called *red zone*, which usually means a minimum intensity of 90%VO_{2max} (Buchheit & Laursen, 2013). These findings highlight the need for regular MVPE for maintaining or improving physical fitness, regardless of motivation regulations, and emphasize the importance of new strategies in PEC with acute vigorous-intensity activities that retain the health-enhancing effects.

7.1. Limitations and future prospects

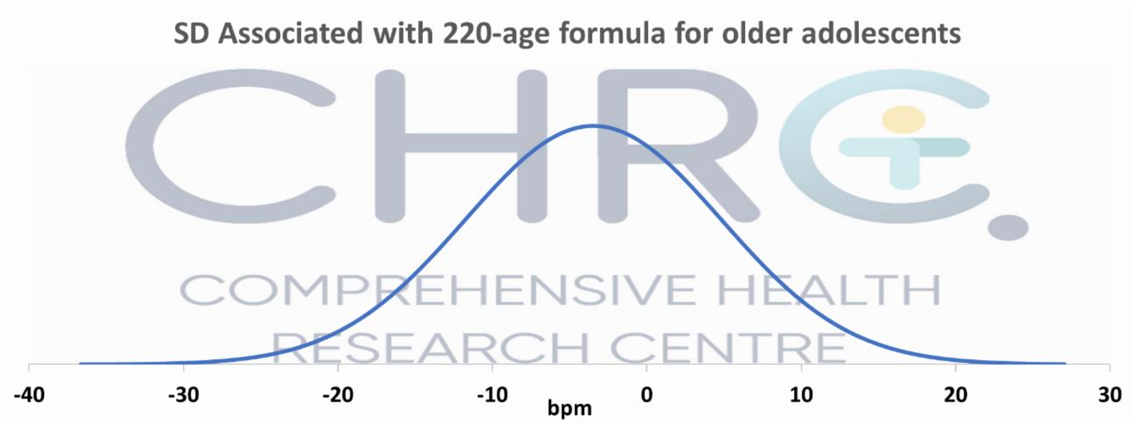
It is important that the main limitations regarding our investigation are acknowledged and that future research directions are discussed.

The main limitation of the systematic review (Study 1) is the high risk of bias. Therefore, there is a high risk that the results will overestimate the benefits and underestimate the lack of effect. According to the Dutch CBO guidelines (Rosenbrand et al., 2008), the review has a level 3 of evidence, since all studies are classified as B, that is, these studies are not double randomized clinical trials of good quality and sufficient power. The small sample sizes do not warrant analysis for the potential influence of sex or age on the results, may not be generalizable, and may lack external validity. Despite the possibility of studies being missed out on the search strategy, only 14 studies were included in this review, most of which were produced on younger children. Regarding the defined interval (2008-2020), it is our understanding that, on the one hand, the 11-year timeframe would be a sufficiently long period to include a considerable number of articles. On the other hand, we believe that older articles (prior to 2008) would have already been included in previous systematic reviews. We also believe that, as scientific knowledge is advancing at great speed, the most recent years may translate the most up-to-date procedures on the application of HIIT in the target context (students in the context of PEC).

Despite some limitations, as the absence of a detailed evaluation to determine intervention fidelity to confirm treatment/protocol adherence, Study 2 aimed to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), to implement PA interventions, which retain the health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety

In study 3 and 5, despite the novelty and interest of our findings, some limitations must be addressed. First, the use of a cross-sectional design is limiting, which prevents the determination of the temporality of the effect of MVPA, physical fitness, and energy intake on body composition, or the effect of physical fitness, motivation on exercise intensity; additionally, the inference of causality from our hypothesized path models is limited by the use of cross-sectional data. Second, our sample was limited to adolescents from the 10th to 12th grades from a public school in the city of Beja (Portugal), concluding that our findings cannot be applied to other populations. However, our selected bootstrapping method has strong statistical power and is considered a useful tool for avoiding Type I errors (Hayes, 2009). Third, using accelerometry to assess PA in Study 3 does not provide inferences about the form of physical activity undertaken. Furthermore, accelerometers do not detect all activities that may benefit physical fitness and body composition. The higher the intensity of PA, however, the more likely fitness and body composition adjustments are. To discover the specificities of PA required for the maintenance or improvement of physical fitness and body composition in adolescents, more intervention studies employing real-life scenarios are needed. Fourth, other mediator variables may contribute to the links between PA and body composition. Measures of energy intake and expenditure are not precise enough, and the quality of the diet may exert its effect on energy balance through complex hormonal and neurological pathways that influence satiety, and, possibly, through other mechanisms (Romieu et al., 2017). Finally, in Study 5 other mediator variables may contribute to the links between physical fitness and volition exercise since most studies opted to set intensity through external load, expressed in speed or distances. Few studies have objectively measured internal load by monitoring HR or RPE, but only some defined cut lines considering as high intensity >85%HR_{max} (Costigan et al., 2018; Leahy et al., 2019) or >90%HR_{max} (Cvetkovic et al., 2018). HR has become one of the most used outcomes to assess intensity, but programs built around the mathematical concept of HRmax have inherent limitations (**Fig. *7.1***). Adjusting exercise intensity using HR has been a valid option, mainly in prolonged and submaximal periods. It is expected that HR reaches maximum values (>90-95% HR_{max}) close to the speed/power associated with VO_{2max}, which does not always happen, especially in very short exercises (<30 seconds) (Hanssen et al., 2015; Helgerud et al., 2007). It may be related to the known delay in HR response at the beginning of exercise, which is slower than the VO_2 response.

Fig. 7.1 *Standard deviation associate with 220 – age formula (Bento et al., 2022)*



In our RCT, some limitations should also be acknowledged, such as the high missing values due to school activities, teaching breaks, weather conditions and lockdown, or the absence of a detailed evaluation to determine intervention fidelity to confirm treatment/protocol adherence. Due to the negative consequences of home confinement, we experienced a significant number of dropouts in several outcomes, so the primary analysis of the data set was not carried out according to the ‘intention to treat’ principle. These simple effects were examined either using separate independent repeated measurement analysis, such as t-tests or – where the analysis of the residuals suggested non-normality – using the non-parametric Wilcoxon’s signed ranks test. The mean attendance for participants involved in the intervention was 12.2 ± 3.5 (47%) of the 26 scheduled exercise sessions. One of the gaps in HIIT research is the small number of volunteers and the short duration of interventions so that significant impacts on public health can be inferred (Biddle & Batterham, 2015). However, in a school context, more than seven weeks can be problematic due to activities and teaching breaks provided for in planning and the school calendar (Martin-Smith et al., 2019).

The inclusion of individuals from both sexes would provide additional limitation to the current study because it is possible that the menstrual cycle may have an impact on participants' responses to exercise. Matsuda et al. (2022) findings indicate that although menstrual cycle does not affect exercise duration, it does affect how much muscle glycogen is used up during high-intensity intermittent exercise in habitual active females. Therefore, more study is required to determine whether different HIIT training methods can affect metabolic effects caused by hormonal changes in the female ovarian cycle as well as the possible impacts of HIIT on body composition and overall oxidative metabolism (Aparecido et al., 2022). Although we planned to include a pre- and post-nutrition control, pre- and post- accelerometry to assess PA and a PA enjoyment scale, home confinement did not allow that assessment, which result in a lack of control over habitual behaviors related to physical activity and food consumption during the intervention period. As such, the results presented may need to be interpreted with caution.

HIIT is a time-effective way to increase aerobic capacity, insulin sensitivity, blood pressure, and body composition compared to MICT according to evidence from laboratory research, however there is a lack of studies conducted in real world settings without the use of expensive equipment (i.e. cycle ergometers and treadmills), performed in small spaces and easy to implement in outdoor environment (Gillen & Gibala, 2014). There is a clear need for more studies on HIIT in non-clinical, non-laboratory settings that facilitate the application of these laboratory protocols to ‘‘real world’’ scenarios.

This study has several strengths, including the randomized design, intervention applied to older adolescents, objectively (HR) and subjectively (RPE) measured internal load and in a PEC real context without, interfering with other aspects of the curriculum. The study was carried out in a school context to be performed by adolescents, regardless of sex, the BMI status and where there is a wide range in the fitness levels of the students. These findings highlight the need for regular MVPE for maintaining or improving physical fitness, regardless of motivation regulations, and emphasize the importance of new strategies in PEC with acute vigorous-intensity activities that retain the health-enhancing effects.

With this study, the authors aim to provide novel HIIT protocols for schools with less volume (only twice a week) and higher density (less rest in each interval), which include resistance exercises through calisthenic exercises and plyometrics. Despite the extremely low volume (on average, 10 min/week), brief whole-body HIIT over 16 weeks can improve CRF and muscular fitness in adolescent girls. It should be noted that there is no need for external loads to implement these protocols; the use of all-out bouts and plyometrics are also simple approaches. The actual PEC time is still restricted due to activities and teaching breaks, as well as absences due to illness, medical appointments, and a lack of appropriate clothing, making it difficult to find content that can positively influence healthy physical fitness in students due to an objective lack of time. Replacing the traditional warm-up without interfering with other curricular content provided in PEC with this time-efficient approach could have a prominent role in improving female students' CRF. Investigations of dose-response relationships and the potential upper limits of HIIT volume and intensity are unsettled and highly relevant for healthy and clinical populations. Since HIIT did not improve CRF in boys, we recommend increasing the intensity and frequency of this type of exercise.

7.2. Conclusions

HIIT shows a high potential impact on fitness and PA in adolescents. The application of HIIT in schools is feasible: shorter duration is more appealing to deconditioned youth; logistical constraints and material resources are minimal, and HIIT is possible even in a classroom; the variety of stimuli (strength, speed, dance, fight, sports, games, individual, couples, etc.) allows enjoyable protocols. This study suggests that the introduction of HIIT in the school context has high potential on improving physical fitness and PA, and a moderate effect on improving body composition in adolescents. Ultimately, it can serve as prophylaxis by acting as a sanitary cord in an expected reduction of functional capacity in youth, weight gain, and risk factors associated with physical inactivity, as teenagers tend to become more inactive as their age increases.

Our findings suggest that MVPA is beneficial to adolescents' health by promoting physical fitness maintenance or improvement; however, more research is needed to corroborate these findings. Moreover, exercise protocols that result in short-term physiological health improvements are of interest to physical education teachers, as well as to rehabilitation, health, and exercise professionals. The results of this study emphasize the importance of new strategies in PEC with acute vigorous-intensity activities, as well as those that strengthen muscle, which retain their health-enhancing effects and satisfy the adolescents' desire for enjoyment and variety. The idea that public health gains will be greater if we help the least active become more active, or will be higher if we help the least motivated become more motivated due to the lack of sufficient motivation to participate in moderately intense exercise or PA, is being challenged. In a modern society, it is unlikely that individuals will ever return to the high average PA levels of the past. This study highlights that time-efficient interventions have a preeminent role.

Considering the results put forth, it seems evident the efficiency that HIIT protocols implemented in schools translate in the improvement of physical fitness and reduction of sedentary behaviors, compared to other types of less intense and higher volume activities. This efficiency, resulting from the reduced time required (on average, about 10 minutes), reflects the wide applicability that these protocols can have in PEC, and the great adaptation to the facilities (including classrooms).

7.3. References

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APPENDICES

APPENDIX 1 – Scientific Ethical Document

Documento 19017

Comissão de Ética para a Investigação Científica
nas Áreas de Saúde Humana e Bem-Estar
Universidade de Évora

A Comissão de Ética para a Investigação Científica nas Áreas da Saúde Humana e do Bem-Estar vem deste modo informar que os seus membros,

Prof. Doutor Luís Sebastião,
Prof. Fernando Capela
e Prof.ª Doutora Margarida Amoedo,

deliberaram dar

Parecer Positivo

para a realização do Projeto:
"*Efeitos de um programa de Treino Intervalado de Alta Intensidade integrado nas aulas de Educação Física do Ensino Secundário, na Condição Física, Atividade Física e Motivação dos alunos*" pelo investigador **André Filipe Paulino da Silva Bento** (Doutorando) sob a supervisão do Prof. Doutor Armando Raimundo (responsável académica).

Universidade de Évora, 10 de Julho de 2019

O Presidente da Comissão de Ética

(Professor Doutor Jorge Quina Ribeiro de Araújo)

APPENDIX 2 – Systematic Review registration

NIHR | National Institute for Health Research

PROSPERO
International prospective register of systematic reviews

Citation

André Bento, Armando Raimundo, Luis Páez. School-based high-intensity interval training (HIIT) programs for promoting physical activity and fitness in children and adolescents. PROSPERO 2019 CRD42019138771 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019138771

Review question

What are the effects of a high-intensity interval training program integrated in high-school physical education classes, on physical condition, physical activity and motivation for exercise?

Searches

We will search the following electronic bibliographic databases: PubMed, MEDLINE, SPORTDiscus, CINAHL, MEDICLATINA, COCHRANE and Web of Science.

The search strategy will include MeSH and Thesaurus terms relating to or describing the intervention. The search strategy is available in the published protocol. The search terms will be adapted for use with other bibliographic databases in combination with database-specific filters for controlled trials, where these are available.

There will be language restrictions, only English, Spanish and Portuguese studies. Studies published between January 2008 and the date the searches are run will be sought. The searches will be re-run just before the final analyses and further studies retrieved for inclusion.

Types of study to be included

We will include randomised trials to assess the beneficial effects of intervention

Condition or domain being studied

Levels of activity and physical condition among adolescents are low, increasing the risk of chronic diseases. The most recent literature suggests that physical activity and physical condition are correlated with improved biopsychosocial variables of the young. The School and, concretely, the Physical Education classes are privileged spaces, promoters of positive changes for the rest of the life. HIIT is an efficient alternative to the invested time compared to aerobic training, being a powerful stimulus in improving cardiorespiratory performance, muscles oxidative capacity and sensitivity to insulin.

Participants/population

Inclusion: adolescents 10-19 years of age.

Exclusion: intellectual or physical disabilities

Intervention(s), exposure(s)

This study intends to verify the effectiveness and feasibility in the implementation of HIIT in schools.

Comparator(s)/control

Inclusion: only trials with control group

Main outcome(s)

Physical condition (cardiorespiratory fitness, muscular endurance), physical activity (sedentary behaviour) and motivation for exercise

Measures of effect

Baseline, post-intervention and 2 month de-training

Additional outcome(s)

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Methodological information about HIIT: intensity, density, ratios, series, repetitions, recovery, type of exercise, the place where it was developed (classroom, hallways, playground, gym), the period of time (recess, physical education class, etc).

Measures of effect

Baseline, post-intervention and 2 month de-training

Data extraction (selection and coding)

Duplicate papers will be deleted using EndNote. A reviewer will apply the inclusion/exclusion criteria to all titles and abstracts. Where decisions are unable to be made from title and abstract alone, the full paper will be retrieved.
The full text of these potentially eligible studies will be retrieved and independently assessed for eligibility by two review team members. Any disagreement between them over the eligibility of particular studies will be resolved through discussion with a third reviewer.

Risk of bias (quality) assessment

The reviewers will use the checklist included in the application RevMan 5.3 (RevMan 2014), for assessing the quality of the intervention studies. In addition, reviewers will use Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) to resolve those cases where doubts may arise regarding the diagnostic validation studies.

Studies results will be inserted in RevMan 5.3 (RevMan 2014) application including clinical characteristics, context items and details of the intervention.

Also will be included on this form will be the RevMan 5.3 (RevMan 2014) check-list items for assessing the quality of diagnostic studies and, if applicable, those arising from the QUADAS-2 regulations for publication

Strategy for data synthesis

The Systematic Review will be performed depending on the degree of heterogeneity and comparability of studies. Using RevMan 5.3 (RevMan 2014), the sensitivity, specificity and positive and negative predictive, positive and negative likelihood ratios should be reported. In case of excessive heterogeneity, no meta-analysis will be carried out and a narrative review of the different studies will be performed.

Heterogeneity will be explored with visual inspection of the forest plot diagrams for sensitivity and specificity and the likelihood ratio test for these two dimensions and performing ?² test. Inconsistency will be also quantified using I^2 test. The heterogeneity will be stratified into three levels, following the criteria of Higgins et al. (2003).

In case of non-excessive heterogeneity, the data will be analysed using a meta-analysis based on random-effects and standardised mean difference. If standard deviations are not published, RevMan 5.3 software will be used for p values entrance. If no p values or standard deviations are published, the highest standard deviation will be used from similar studies to ensure results are conservative.

Analysis of subgroups or subsets

Studies will be grouped by exercise intensities according to the duration of the intervention (up to 6 weeks, 7–12 weeks, and more than 12 weeks).

Contact details for further information

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Organisational affiliation of the review

Comprehensive Health Research Center

Review team members and their organisational affiliations

Mr André Bento. Comprehensive Health Research Center
Professor Armando Raimundo. Comprehensive Health Research Center
Professor Luis Páez. BIOFANEX Research Group

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Type and method of review
Meta-analysis, Systematic review

Anticipated or actual start date
27 November 2018

Anticipated completion date [1 change]
31 March 2020

Funding sources/sponsors
Portuguese national funding agency for science, research and technology

SFRH/BD/136869/2018

Conflicts of interest
None known

Language
English

Country
Portugal

Stage of review [1 change]
Review Ongoing

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Adolescent; Child; Exercise; High-Intensity Interval Training; Humans; Schools

Date of registration in PROSPERO
25 September 2019

Date of first submission
04 July 2019

Stage of review at time of this submission [1 change]

Stage	Started	Completed
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	Yes	No
Risk of bias (quality) assessment	Yes	No
Data analysis	Yes	No

Revision note
End DateContacts

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The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.
The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions
25 September 2019
16 October 2020

APPENDIX 3 – Clinical Trial registration

ClinicalTrials.gov PRS
Protocol Registration and Results System

ClinicalTrials.gov Protocol Registration and Results System (PRS) Receipt
Release Date: July 13, 2019

ClinicalTrials.gov ID: [Not yet assigned]

Study Identification

Unique Protocol ID: SFRH/BD/136869/2018

Brief Title: Effects of HIIT Integrated in PE Classes, on Physical Condition, Physical Activity and Motivation for Exercise

Official Title: Effects of a High-Intensity Interval Training Program Integrated in High-School Physical Education Classes, on Physical Condition, Physical Activity and Motivation for Exercise

Secondary IDs:

Study Status

Record Verification: July 2019

Overall Status: Recruiting

Study Start: October 2019 [Anticipated]

Primary Completion: January 2020 [Anticipated]

Study Completion: June 2020 [Anticipated]

Sponsor/Collaborators

Sponsor: University of Évora

Responsible Party: Principal Investigator
Investigator: André Filipe Paulino da Silva Bento [abento]
Official Title: Fellowship Researcher
Affiliation: University of Évora

Collaborators: Agency for Science, Technology and Research

Oversight

U.S. FDA-regulated Drug: No

U.S. FDA-regulated Device: No

U.S. FDA IND/IDE: No

Human Subjects Review: Board Status: Approved
Approval Number: 19017
Board Name: University of Évora Ethics Committee
Board Affiliation: University of Évora
Phone: 00351 266 769522
Email: ammr@uevora.pt
Address:

- Page 1 of 4 -

Largo dos Colegiais 2, 7000-Évora- Portugal

Data Monitoring: No

FDA Regulated Intervention: No

Study Description

Brief Summary: Levels of activity and physical condition among adolescents are low, increasing the risk of chronic diseases. The most recent literature suggests that physical activity and physical condition are correlated with improved biopsychosocial variables of the young. The School and, concretely, the Physical Education classes are privileged spaces, promoters of positive changes for the rest of the life. HIIT is an efficient alternative to the invested time compared to aerobic training, being a powerful stimulus in improving cardiorespiratory performance, muscles oxidative capacity and sensitivity to insulin. This study intends to verify the effectiveness and feasibility in the implementation of HIIT in High-School Physical Education classes. The activity levels and physical condition of the adolescents will be evaluated and identified, before and after 16 weeks of implementation of the training program, as well as their effects on the motivation for the practice.

Detailed Description:

Conditions

Conditions: Adolescents

Keywords: HIIT
Adolescents
Physical Exercise
Health
Motivation

Study Design

Study Type: Interventional

Primary Purpose: Basic Science

Study Phase: N/A

Interventional Study Model: Parallel Assignment

Number of Arms: 2

Masking: None (Open Label)

Allocation: Randomized

Enrollment: 200 [Anticipated]

Arms and Interventions

Arms	Assigned Interventions
Experimental: HIIT Group Two HIIT sessions delivered at the beginning of Physical education classes	High-Intensity Interval Training The program will be applied in the first 10-15 minutes of each PE class, twice a week, including a brief warm-up, ranged from 14 to 20 intervals, adopting a 2:1 work to rest ratio (ie, 30-s work, followed by 30-

Arms	Assigned Interventions
	s rest) A cut-point of >=90% of maximal heart rate was used as our criterion for satisfactory compliance to high-intensity exercise In order to estimate effort, fatigue and training load, a subjective effort scale will be used throughout each session. The heart rate will be monitored throughout the session in real time through Bluetooth technology. Actigraph accelerometers (wGT3X-BT), randomly distributed by the students in each session, will be used to characterize the intensity of the sessions.
No Intervention: Control Group Usual programmed Physical education classes	

Outcome Measures

Primary Outcome Measure:

1. Change from baseline Cardio-respiratory fitness at 4 months
   Assessed by Yo-Yo Intermitent Recovery Test 1(Tanner & Gore, 2014)

   [Time Frame: 4 months]
2. Change from 4 months Cardio-respiratory fitness at 6 months
   Assessed by Yo-Yo Intermitent Recovery Test 1(Tanner & Gore, 2014)

   [Time Frame: 6 months]
3. Change from baseline Muscular Strength at 4 months
   Assessed using push-up and curl-up tests (Plowman, 2013)

   [Time Frame: 4 months]
4. Change from 4 months Muscular Strength at 6 months
   Assessed using push-up and curl-up tests (Plowman, 2013)

   [Time Frame: 6 months]
5. Change from baseline Body Mass Index (BMI) at 4 months
   Assessed by Height and Weight (Dobbelsteyn, Joffres, MacLean, & Flowerdew, 2001)

   [Time Frame: 4 months]
6. Change from 4 months Body Mass Index (BMI) at 6 months
   Assessed by Height and Weight (Dobbelsteyn, Joffres, MacLean, & Flowerdew, 2001)

   [Time Frame: 6 months]
7. Change from baseline Physical Activity at 4 months
   Assessed by International Physical Activity Questionnaire (iPAQ), and accelerometry (Actigraph - wGT3X-BT)

   [Time Frame: 4 months]
8. Change from 4 months Physical Activity at 6 months
   Assessed by International Physical Activity Questionnaire (iPAQ), and accelerometry (Actigraph - wGT3X-BT)

   [Time Frame: 6 months]
9. Change from baseline Motivation at 4 months
   Assessed by Behavioral Regulation In Exercise Questionnaire (Cid et al., 2018).

   [Time Frame: 4 months]
10. Change from 4 months Motivation at 6 months
    Assessed by Behavioral Regulation In Exercise Questionnaire (Cid et al., 2018).

    [Time Frame: 6 months]

Eligibility

Minimum Age:	15 Years
Maximum Age:	17 Years
Sex:	All
Gender Based:	No
Accepts Healthy Volunteers:	Yes
Criteria:	Inclusion Criteria: • Students enrolled in years 10-12 Exclusion Criteria: • Students will be ineligible if they do not provide parental consent to participate

Contacts/Locations

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References

Citations:

Links:

Available IPD/Information:

APPENDIX 4 – Informed Consent for participants

SFRH/BD/136869/2018

Consentimento informado

Título do Projeto: Efeitos de um programa de Treino Intervalado de Alta Intensidade integrado nas aulas de Educação Física do Ensino Secundário, na Condição Física, Atividade Física e Motivação dos alunos

Estamos a convidar o seu educando a participar, voluntariamente, num estudo sobre a prevalência do excesso de peso e sedentarismo nos adolescentes, e efeitos biopsicossociais. Por favor, leia com atenção todo o conteúdo deste documento. Não hesite em solicitar mais informações ao investigador responsável se não estiver completamente esclarecido(a). Verifique se todas as informações estão corretas. Se entender que está tudo em conformidade e se estiver de acordo com a proposta que lhe está a ser feita, então assine este documento.

1. Fui informado(a) que o programa de Exercício Físico visa avaliar os efeitos de um programa HIIT em contexto escolar na promoção de saúde, aptidão física e motivação para a prática.
2. No âmbito do programa de Exercício Físico, foi solicitada a participação do meu educando num estudo de investigação.
3. Com este estudo pretende-se analisar as alterações ao nível da composição corporal, da aptidão física, da qualidade de vida, de parâmetros psicossociais, entre outros fatores clínicos associados excesso de peso e sedentarismo nos adolescentes, ao longo de 8 meses.
4. A participação do seu educando irá incluir a realização dos seguintes exames:
   - Avaliação objetiva do nível atividade física por acelerometria.
   - Avaliação subjetiva do nível atividade física através do *International Physical Activity Questionnaire* (iPAQ).
   - Avaliação da aptidão física funcional através duma bateria de testes físicos específica para esse efeito.
   - Determinação da capacidade aeróbia máxima, força, resistência e flexibilidade pela Bateria de Testes do Fitnessgram.
   - A massa corporal e percentagem de massa gorda serão avaliadas através de uma balança de bioimpedância elétrica calibrada (SC-0330, Tanita, Tokyo, Japan)
   - Caracterização nutricional através do diário de sete dias, relativo ao registo da ingestão alimentar durante o período de uma semana, e do questionário semi-quantitativo de frequência alimentar, referente ao período de 8 meses anterior aos momentos de avaliação.
   - Motivação para a prática através do *Behavioral Regulation In Exercise Questionnaire* (BREQ3)
5. O estudo de investigação é gratuito e implica a utilização dos acelerómetros, bem como a realização de todos os exames indicados no ponto quatro deste consentimento informado.
6. Comprometo o meu educando a comparecer aos momentos de avaliação indicados no ponto quatro deste consentimento informado.
7. Os riscos da participação do meu educando no estudo de investigação são os associados à participação num programa de exercício com supervisão clínica.
8. O estudo de investigação não se responsabiliza por danos ou lesões causados pelo não cumprimento, ou cumprimento diferente das instruções e/ou recomendações dos especialistas intervenientes no mesmo.
9. Nenhuma das especificações do presente consentimento informado deverá ser interpretada ou considerada como promessa ou garantia do progresso e/ou resultados por parte do participante.
10. Compreendo que através da sua participação estarei a contribuir para a evolução do conhecimento científico nesta área e que é, também, possível que, a longo prazo, os resultados deste estudo contribuam para que ocorra uma melhoria nos cuidados a prestar a adolescentes com excesso de peso/obesidade e/ou sedentários.

11. Percebo que a informação sobre o meu educando e a sua saúde, recolhida para este estudo, será utilizada para os objetivos do estudo e para pesquisa científica adicional associada. A informação será arquivada em papel e em formato eletrónico, com um número de código para proteger a minha privacidade. Assim, mesmo que os resultados do estudo venham a ser publicados, a sua identidade permanecerá confidencial.
12. Entendo que as autoridades reguladoras e os membros da comissão de ética podem ter acesso à informação arquivada e examinar os registos efetuados no âmbito do estudo, estando sujeitos a dever de sigilo quanto aos mesmos. Ao assinar este formulário estou a autorizar o acesso direto a esses registos, nos termos aqui descritos.
13. Sei que, através do investigador principal, poderei ter acesso a toda a informação recolhida sobre o meu educando, bem como pedir a retificação de qualquer incorreção que detete. Este acesso à sua informação poderá ser adiado, no caso de poder atrasar a continuação do estudo, mas não poderá ser negado.
14. Fui informado que não serei recompensado monetariamente pela participação do meu educando no estudo de investigação.
15. Eu percebo que tenho a possibilidade de me dirigir aos responsáveis pelo estudo de investigação sempre que sentir que o meu educando foi colocado em risco.
16. Eu li toda a informação acima. Foram-me explicados a natureza, riscos e benefícios do estudo de investigação. Eu assumo os riscos envolvidos e entendo que posso retirar o meu consentimento e parar a sua participação em qualquer momento, sem que isso afete o acompanhamento que ele irá receber e sem que tal implique a perda de quaisquer benefícios a que ele teria direito se tivesse tomado outra opção. Ao assinar este consentimento, eu não estou a renunciar a quaisquer direitos legais, reclamações, medicação ou tratamento. Ser-me-á fornecida uma cópia deste formulário.

____

Nome completo do(a) participante

____ ____________________

Assinatura do(a) encarregado de educação Data

Eu certifico que expliquei ao encarregado de educação do participante neste estudo de investigação, a natureza, objectivo, potenciais benefícios e riscos associados à participação no mesmo. Eu providenciei uma cópia deste formulário ao encarregado de educação do participante no estudo.

____ ____________________

Assinatura do(a) investigador(a) que obteve o consentimento Data

APPENDIX 5 – International Physical Activity Questionnaire (i-PAQ)

SFRH/BD/136869/2018

Data (dd/mm/aaaa):___/___/____ Turma:___________ Idade:___________

Nome:____

Género (M/F):___ Data Nascimento (dd/mm/aaaa):___/___/_____

Questionário Internacional de Avaliação da Atividade Física – Versão Portuguesa (curta)

Este questionário inclui questões sobre a actividade física que realiza habitualmente para se deslocar de um lado para outro, no trabalho, nas actividades domésticas (femininas ou masculinas), na jardinagem e nas actividades que efectua no seu tempo livre para entretenimento, exercício ou desporto. As questões referem-se à actividade física que realiza numa **semana normal**, e **não em dias excepcionais**, como por exemplo, no dia em que fez a mudança da casa.
Por favor responda a todas as questões mesmo que não se considere uma pessoa activa.
Ao responder às seguintes questões considere o seguinte:
Actividade física vigorosa *refere-se a actividades que requerem muito esforço físico e tornam a respiração muito mais intensa que o normal.*
Actividade física moderada *refere-se a actividades que requerem esforço físico moderado e torna a respiração um pouco mais intensa que o normal.*
Ao responder às questões considere apenas as actividades físicas que realize durante ***pelo menos 10 minutos seguidos.***

1a Durante a última semana, quantos **dias** fez actividade física **vigorosa** como levantar e/ou transportar objectos pesados, cavar, realizar ginástica aeróbica, correr, nadar, jogar futebol ou andar de bicicleta a uma velocidade acelerada?
_________dias por semana
_________Nenhum (passe para a questão **2a**)
1b Quanto **tempo**, no total, despendeu num desses dias, a realizar actividade física vigorosa?
_________horas ________ minutos

2a Durante a última semana, quantos **dias** fez actividade física **moderada** como levantar e/ou transportar objectos leves, andar de bicicleta a uma velocidade moderada, actividades domésticas (ex: esfregar, aspirar), cuidar do jardim, fazer trabalhos de carpinteria, jogar ténis de mesa? **Não inclua** o andar/caminhar.
_________dias por semana
_________Nenhum (passe para a questão **3a**)
2b Quanto **tempo**, no total, despendeu num desses dias, a realizar actividade física moderada?
_________horas ________ minutos

3a Durante a última semana, quantos **dias andou/caminhou** durante **pelo menos 10 minutos seguidos**? Inclua caminhadas para o trabalho e para casa, para se deslocar de um lado para outro e qualquer outra caminhada que possa fazer somente para recreação, desporto ou lazer.
_________dias por semana
_________Nenhum (passe para a questão **4a**)
3b Quanto **tempo**, no total, despendeu num desses dias a andar/caminhar?
_________horas ________ minutos
3c A que **ritmo** costuma caminhar?
_____ **Vigoroso**, que torna a sua respiração muito mais intensa que o normal;
_____ **Moderado**, que torna a sua respiração um pouco mais intensa que o normal;
_____ **Lento**, que não causa qualquer alteração na sua respiração.

As últimas questões referem-se ao tempo que está sentado diariamente no trabalho, em casa, no percurso para o trabalho e durante os tempos livres. Estas questões incluem por exemplo ***o tempo*** *em que está* ***sentado à mesa ou à secretária,*** *a* ***visitar amigos***, *a* ***ler ou sentado/deitado*** *a* ***ver televisão.***

4a Quanto **tempo**, no total, passou sentado(a) durante **um dos dias de semana** (segunda-feira a sexta-feira)?
_________horas ________ minutos
4b Quanto **tempo**, no total, passou sentado(a) durante **um dos dias de fim-de-semana** (sábado ou domingo)?
_________horas ________ minutos

1

APPENDIX 6 – Behavioral Regulation in Exercise Questionnaire 3 (BREQ-3)

BREQ3p

Behavioural Regulation in Exercise Questionnaire

Cid, L., Monteiro, D., Teixeira, D., Moutão, J., Teques, P., Teixeira, D., Silva, M., & Palmeira, A. (submetido; versão já publicada em congresso).

Considerando os níveis indicados, coloque um círculo em redor do número que melhor reflete a sua opinião. Não existem respostas certas ou erradas, mas sim a sua resposta. Por isso, responda com a máxima sinceridade, pois todas as respostas serão confidenciais! **Porque é que faz exercício?**	Não é verdade para mim		Algumas vezes é verdade para mim		Muitas vezes é verdade para mim
1) Sinto-me culpado(a) quando não faço exercício.	0	1	2	3	4
2) Dou valor aos benefícios/vantagens do exercício.	0	1	2	3	4
3) Faço exercício porque isso está relacionado com os meus objetivos de vida.	0	1	2	3	4
4) Não percebo porque é que tenho de fazer exercício.	0	1	2	3	4
5) Participo no exercício porque os meus amigo(a)s/família dizem que devo fazer.	0	1	2	3	4
6) É importante para mim fazer exercício regularmente.	0	1	2	3	4
7) Gosto das minhas sessões de exercício.	0	1	2	3	4
8) Não percebo o objetivo de fazer exercício.	0	1	2	3	4
9) Faço exercício porque os outros vão ficar insatisfeitos comigo se não fizer.	0	1	2	3	4
10) Sinto-me fracassado(a) quando não faço exercício durante algum tempo.	0	1	2	3	4
11) Penso que é importante fazer um esforço por fazer exercício regularmente.	0	1	2	3	4
12) Considero que fazer exercício é uma parte fundamental daquilo que eu sou.	0	1	2	3	4
13) Acho o exercício uma atividade agradável.	0	1	2	3	4
14) Penso que o exercício é uma perda de tempo.	0	1	2	3	4
15) Sinto-me pressionado(a) pela minha família e amigos para fazer exercício.	0	1	2	3	4
16) Sinto-me ansioso(a) se não fizer exercício regularmente.	0	1	2	3	4
17) Considero que fazer exercício está em harmonia com os meus valores.	0	1	2	3	4
18) Fico bem-disposto(a) e satisfeito(a) por praticar exercício.	0	1	2	3	4

2

APPENDIX 7 – Semiquantitative food frequency questionnaire

18535 NOME:______________________________ DATA ● ☐☐☐☐☐☐☐☐☐

TURMA:______________________________

O questionário seguinte tem como objectivo avaliar a sua alimentação. Por favor, procure responder às questões de uma forma sincera, indicando aquilo que realmente come e não o que gostaria de comer, ou pensa que seria correcto comer.

O questionário pretende identificar o consumo de alimentos do ano anterior. Assim para cada alimento, deve assinalar, no respectivio círculo, quantas vezes por dia, semana ou mês comeu em média , **nos últimos 12 meses**, cada um dos alimentos referidos nesta lista. Não se esqueça de assinalar os alimentos que **nunca** comeu, ou que come **menos de 1 vez por mês** na coluna nunca ou menos de 1 por mês.

Não se esqueça de ter em conta não só as vezes que o alimento é consumido sozinho mas também, aquelas em que é adicionado a outros alimentos ou pratos (ex: o café do café com leite, os ovos das omeletas, etc).

Para os alimentos que só comeu em determinadas épocas do ano (por ex: cerejas ou diospíros), assinale as vezes em que comeu o alimento nessa época, colocando uma cruz **(x)** na **última coluna** (**Sazonal**).

No item nº 86, anote a frequência com que comeu sopa de legumes. Quando consome caldo verde, canja ou sopa instantânea, com uma frequência de **pelo menos 1 vez por semana**, deve assinalar a frequência com que comeu este alimento no quadro existente para "**OUTROS ALIMENTOS**", tendo o cuidado de não o contar na frequência que refere para a sopa de legumes.

Se houver algum alimento não mencionado na lista de alimentos e que tenha consumido pelo menos 1 vez por semana, assinale, no quadro que existe para "**OUTROS ALIMENTOS**", a respectiva frequência e indique a quantidade média que costuma comer de cada vez. **Por ex: frutos tropicais, sumos de fruta natural, farinha de pau, canja, alheiras, cevada, rebuçados, etc**.

Por exemplo: Uma pessoa que bebe leite 2 vezes por dia e o leite que bebe é meio gordo, se a maior parte dos gelados que come é no verão e nessa época come um gelado por dia deve assinalar:

I. PRODUTOS LÁCTEOS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
1. Leite gordo	1 chávena = 250 ml	●	○	○	○	○	○	○	○	○	☐
2. Leite meio-gordo	1 chávena = 250 ml	○	○	○	○	○	○	●	○	○	☐
3. Leite magro	1 chávena = 250 ml	●	○	○	○	○	○	○	○	○	☐
7. Gelados	Um ou 2 bolas	○	○	○	○	○	●	○	○	○	☒

Preencha assim: ● ☒

Não preencha assim: ⊗ ⊘ ☐ ☑

Por exemplo: se come sopa uma vez por dia, mas 1 vez por semana é canja e não sopa de legumes assinale:

VIII. BEBIDAS E MISCELANEAS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
86. Sopa de legumes	1 prato	○	○	○	○	●	○	○	○	○	☐

OUTROS ALIMENTOS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
CANJA	PRATO	○	○	●	○	○	○	○	○	○	☐

1

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Pense **nos últimos 12 meses** quantas vezes por dia, semana ou mês, em média, comeu cada um dos alimentos referidos. Não se esqueça de assinalar os alimentos que nunca comeu, ou comeu menos de 1 vez por mês na coluna **(Nunca ou menos de 1 por mês)**.

No grupo **I. PRODUTOS LÁCTEOS** - Não se esqueça de considerar o leite que bebe com o café (**exemplo**: meia de leite, galão,...).

I. PRODUTOS LÁCTEOS	Porção Média	Frequência alimentar									sazonal
		Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	
1. Leite gordo	1 chávena = 250 ml	○	○	○	○	○	○	○	○	○	□
2. Leite meio-gordo	1 chávena = 250 ml	○	○	○	○	○	○	○	○	○	□
3. Leite magro	1 chávena = 250 ml	○	○	○	○	○	○	○	○	○	□
4. Iogurte	Um =125g	○	○	○	○	○	○	○	○	○	□
5. Queijo (de qualquer tipo incluindo queijo fresco e requeijão)	1 fatia = 30g	○	○	○	○	○	○	○	○	○	□
6. Sobremesas lácteas: pudim flan, pudim de chocolate, etc	Um ou 1 prato de sobremesa	○	○	○	○	○	○	○	○	○	□
7. Gelados	Um ou 2 bolas	○	○	○	○	○	○	○	○	○	□

No grupo **II. OVOS, CARNES E PEIXES** - considere também as vezes que come cada um destes alimentos como elementos de outros pratos, por **exemplo**: o frango do arroz de frango, os ovos das omoletas, as salsichas dos cachorros.

II. OVOS, CARNES E PEIXES	Porção Média	Frequência alimentar									sazonal
		Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	
8. Ovos	Um	○	○	○	○	○	○	○	○	○	□
9. Frango	2 peças ou 1/4 de frango	○	○	○	○	○	○	○	○	○	□
10. Peru, Coelho	1 porção ou 2 peças	○	○	○	○	○	○	○	○	○	□
11. Carne: vaca, porco,cabrito	1 porção = 120g	○	○	○	○	○	○	○	○	○	□
12. Figado de vaca, porco, frango	1 porção = 120g	○	○	○	○	○	○	○	○	○	□
13. Língua, Mão de vaca, Tripas, Chispe, Coração, Rim	1 porção =100g	○	○	○	○	○	○	○	○	○	□
14. Fiambre, Chouriço, Salpicão, Presunto, etc	2 fatias ou 3 rodelas	○	○	○	○	○	○	○	○	○	□
15. Salsichas	3 médias	○	○	○	○	○	○	○	○	○	□
16. Toucinho, Bacon	2 fatias	○	○	○	○	○	○	○	○	○	□
17. Peixe gordo: sardinha, cavala, carapau, salmão, etc	1 porção =125g	○	○	○	○	○	○	○	○	○	□
18. Peixe magro: pescada, faneca, dourada, etc	1 porção =125g	○	○	○	○	○	○	○	○	○	□
19. Bacalhau	1 posta média	○	○	○	○	○	○	○	○	○	□
20. Peixe conserva: atum, sardinhas,etc	1 lata	○	○	○	○	○	○	○	○	○	□
21. Lulas, Polvo	1 porção = 100g	○	○	○	○	○	○	○	○	○	□
22. Camarão, Amêijoas, Mexilhão, etc	1 prato de sobremesa	○	○	○	○	○	○	○	○	○	□

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No grupo **III. ÓLEOS E GORDURAS** - responda apenas ao que é **adicionado** em saladas, no prato, no pão, etc, e **não** considere a utilizada para cozinhar.

III. ÓLEOS E GORDURAS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
23. Azeite	1 colher de sopa	O	O	O	O	O	O	O	O	O	☐
24. Óleos: girassol, milho, soja	1 colher de sopa	O	O	O	O	O	O	O	O	O	☐
25. Margarina	1 colher de chá	O	O	O	O	O	O	O	O	O	☐
26. Manteiga	1 colher de chá	O	O	O	O	O	O	O	O	O	☐

No grupo **IV. PÃO CEREAIS E SIMILARES** - não se esqueça de considerar também o que come fora das refeições, por **exemplo:** as batatas fritas da refeição e as que come fora das refeições.

IV. PÃO, CEREAIS E SIMILARES	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
27. Pão branco ou Tostas	Um ou 2 tostas	O	O	O	O	O	O	O	O	O	☐
28. Pão (ou tostas), integral,centeio, mistura	Um ou 2 tostas	O	O	O	O	O	O	O	O	O	☐
29. Broa, Broa de avintes	1 fatia = 80g	O	O	O	O	O	O	O	O	O	☐
30. Flocos cereais: muesli, corn-flakes, chocapic,etc.	1 chávena (sem leite)	O	O	O	O	O	O	O	O	O	☐
31. Arroz	½ prato	O	O	O	O	O	O	O	O	O	☐
32. Massas: esparguete, macarrão, etc.	½ prato	O	O	O	O	O	O	O	O	O	☐
33. Batatas fritas caseiras	½ prato	O	O	O	O	O	O	O	O	O	☐
34. Batatas fritas de pacote	1 pacote pequeno	O	O	O	O	O	O	O	O	O	☐
35. Batatas cozidas, assadas, estufadas e puré	2 batatas médias	O	O	O	O	O	O	O	O	O	☐

No grupo **V. DOCES E PASTEIS** - no item 42 (açúcar) considere quantas colheres ou pacotes de açúcar adiciona ao seus alimentos.

V.DOCES E PASTÉIS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
36. Bolachas tipo maria, água e sal ou integrais	3 bolachas	O	O	O	O	O	O	O	O	O	☐
37. Outras bolachas ou Biscoitos	3 bolachas	O	O	O	O	O	O	O	O	O	☐
38. Croissant, Pasteis, Bolicao, Doughnut ou Bolos caseiros	Um; 1 fatia	O	O	O	O	O	O	O	O	O	☐
39.Chocolate (tablete ou em pó)	3 quadrado; 1 colher sopa	O	O	O	O	O	O	O	O	O	☐
40. Snacks de chocolate (Mars, Twix, Kit Kat, etc)	Um	O	O	O	O	O	O	O	O	O	☐
41. Marmelada, Compota, Geleia, Mel	1 colher sobremesa	O	O	O	O	O	O	O	O	O	☐
42. Açúcar	1 colher sobremesa; 1 pacote	O	O	O	O	O	O	O	O	O	☐

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No grupo **VI - HORTALIÇAS E LEGUMES** - responda pensando nos que são **consumidos no prato** (cozidos ou em saladas) e **não** nos que entram na confecção da sopa. Nos que come só numa determinada época do ano não se esqueça de assinalar na coluna sazonal (x).

VI. HORTALIÇAS E LEGUMES	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
43. Couve branca, Couve lombarda	½ chávena	○	○	○	○	○	○	○	○	○	☐
44. Penca, Tronchuda	½ chávena	○	○	○	○	○	○	○	○	○	☐
45. Couve galega	½ chávena	○	○	○	○	○	○	○	○	○	☐
46. Brócolos	½ chávena	○	○	○	○	○	○	○	○	○	☐
47. Couve-flor, Couve-bruxelas	½ chávena	○	○	○	○	○	○	○	○	○	☐
48. Grelos, Nabiças, Espinafres	½ chávena	○	○	○	○	○	○	○	○	○	☐
49. Feijão verde	½ chávena	○	○	○	○	○	○	○	○	○	☐
50. Alface, Agrião	½ chávena	○	○	○	○	○	○	○	○	○	☐
51. Cebola	½ média	○	○	○	○	○	○	○	○	○	☐
52. Cenoura	1 média	○	○	○	○	○	○	○	○	○	☐
53. Nabo	1 médio	○	○	○	○	○	○	○	○	○	☐
54. Tomate fresco	3 rodelas	○	○	○	○	○	○	○	○	○	☐
55. Pimento	6 rodelas	○	○	○	○	○	○	○	○	○	☐
56. Pepino	¼ médio	○	○	○	○	○	○	○	○	○	☐
57. Leguminosas: feijão, grão de bico	1 chávena ou ½ prato	○	○	○	○	○	○	○	○	○	☐
58. Ervilha em grão, Fava	½ chávena ou ¼ prato	○	○	○	○	○	○	○	○	○	☐

No grupo **VII - FRUTOS** - recorde que para os alimentos que **só comeu em determinadas épocas do ano** (por exemplo, cerejas), deve assinalar as vezes em que comeu o alimento nessa época, colocando uma cruz (x) na última coluna (**Sazonal**).

VII. FRUTOS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
59. Maça, pêra	1 média	○	○	○	○	○	○	○	○	○	☐
60. Laranja, Tangerinas	1 média; 2 médias	○	○	○	○	○	○	○	○	○	☐
61. Banana	1 média	○	○	○	○	○	○	○	○	○	☐
62. Kiwi	1 médio	○	○	○	○	○	○	○	○	○	☐
63. Morangos	1 chávena	○	○	○	○	○	○	○	○	○	☐
64. Cerejas	1 chávena	○	○	○	○	○	○	○	○	○	☐
65. Pêssego, Ameixa	1 médio; 3 médias	○	○	○	○	○	○	○	○	○	☐
66. Melão, Melancia	1 fatia média	○	○	○	○	○	○	○	○	○	☐
67. Diospiro	1 médio	○	○	○	○	○	○	○	○	○	☐
68. Figo fresco, Nêsperas,Damascos	3 médios	○	○	○	○	○	○	○	○	○	☐
69. Uvas frescas	1 cacho médio	○	○	○	○	○	○	○	○	○	☐
70. Frutos conserva: pêssego, ananás	2 metades ou rodelas	○	○	○	○	○	○	○	○	○	☐
71. Amêndoas, Avelãs, Nozes, Amendoins, Pistachio, etc.	½ chávena descascado	○	○	○	○	○	○	○	○	○	☐
72. Azeitonas	6 unidades	○	○	○	○	○	○	○	○	○	☐

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No grupo **VIII - BEBIDAS E MISCELANEAS** - neste grupo **não** considere os sumos naturais (estes devem ser registados na tabela "**OUTROS ALIMENTOS**"), não se esqueça dos que são adicionados a outras bebidas, por **exemplo**: considere aqui o café da meia de leite.

VIII. BEBIDAS E MISCELANEAS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
73. Vinho	1 copo =125ml	O	O	O	O	O	O	O	O	O	☐
74. Cerveja	1 garrafa ou 1 lata	O	O	O	O	O	O	O	O	O	☐
75. Bebidas brancas: whisky, aguardente, brandy, etc	1 cálice = 40 ml	O	O	O	O	O	O	O	O	O	☐
76. Coca-cola, Pepsi-cola ou outras	1 garrafa ou 1 lata	O	O	O	O	O	O	O	O	O	☐
77. Ice-tea	1 garrafa ou 1 lata	O	O	O	O	O	O	O	O	O	☐
78.Outros refrigerantes, Sumos de fruta ou Néctares embalados	1 garrafa ou 1 copo	O	O	O	O	O	O	O	O	O	☐
79.Café (incluindo o adicionado a outras bebidas)	1 chávena café	O	O	O	O	O	O	O	O	O	☐
80. Chá preto e verde	1 chávena	O	O	O	O	O	O	O	O	O	☐
81. Croquetes, Rissóis, Bolinhos de bacalhau, etc.	3 unidades	O	O	O	O	O	O	O	O	O	☐
82. Maionese	1 colher sobremesa	O	O	O	O	O	O	O	O	O	☐
83. Molho de tomate, ketchup	1 colher sopa	O	O	O	O	O	O	O	O	O	☐
84. Pizza	Meia pizza-média	O	O	O	O	O	O	O	O	O	☐
85. Hambúrguer	Um médio	O	O	O	O	O	O	O	O	O	☐
86. Sopa de legumes	1 prato	O	O	O	O	O	O	O	O	O	☐

Coloque neste quadro informação relativa aos restantes alimentos ou bebidas que não estejam na lista anterior e que tenha consumido pelo menos 1 vez por semana mesmo em pequenas quantidades, ou numa época em particular. Por exemplo: **farinha de pau, canja, alheiras, farinheiras, frutos secos** (figos, ameixas, alperces)**, cevada**, etc.

OUTROS ALIMENTOS	Porção Média	Frequência alimentar: Nunca ou menos de 1 por mês	1 a 3 por mês	1 por semana	2 a 4 por semana	5 a 6 por semana	1 por dia	2 a 3 por dia	4 a 5 por dia	6 ou mais por dia	sazonal
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐
		O	O	O	O	O	O	O	O	O	☐

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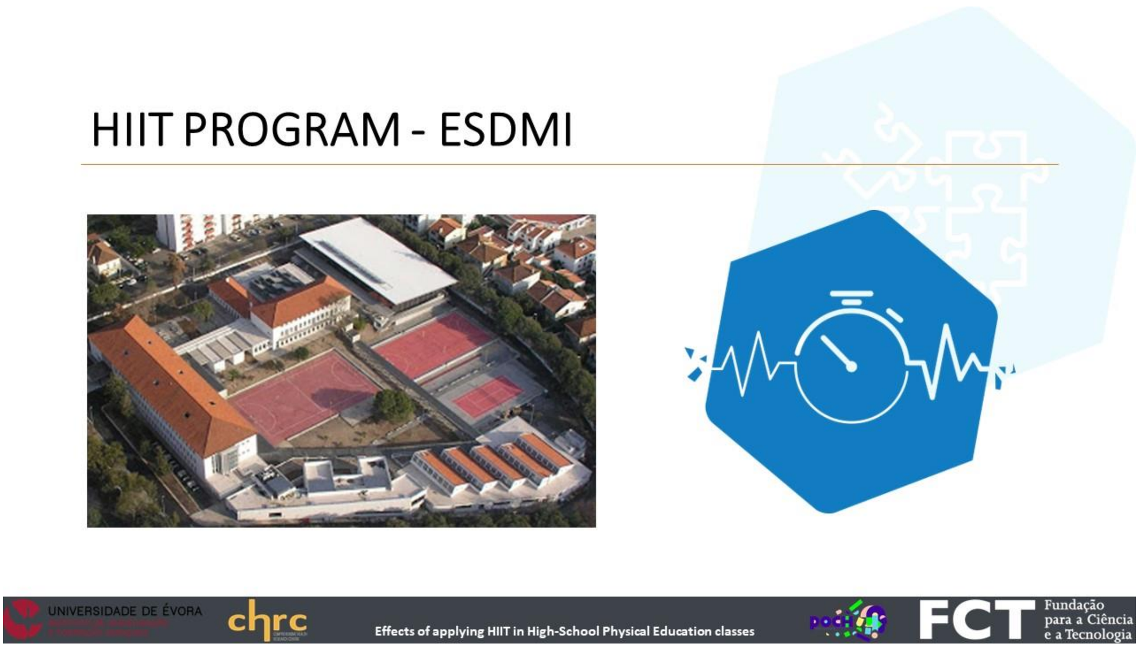
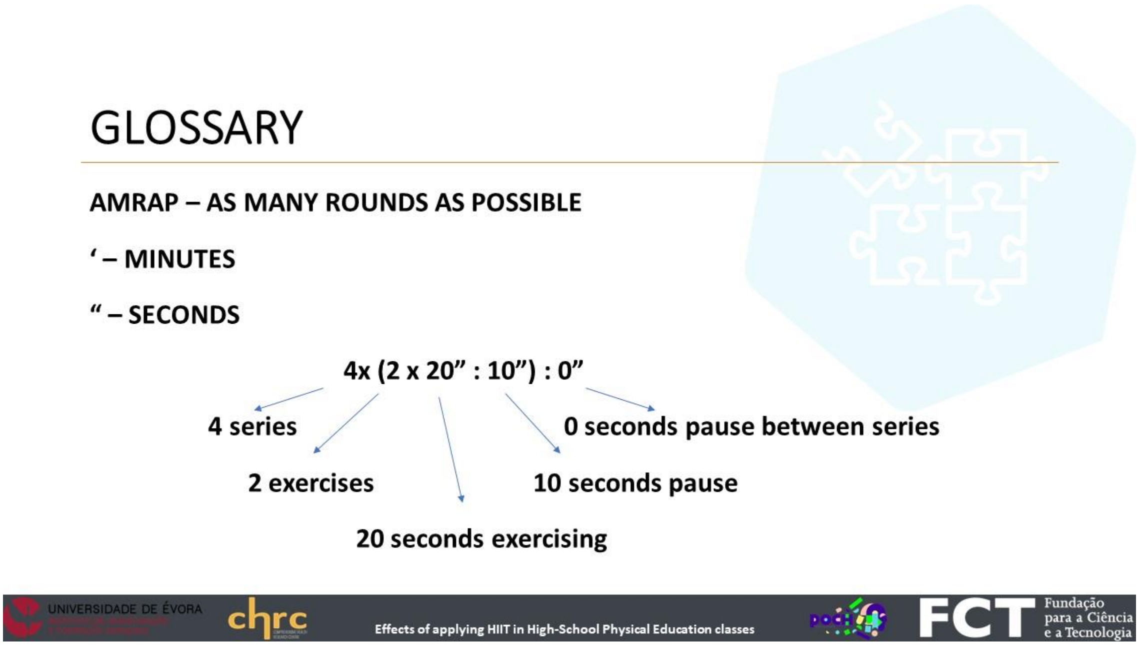
APPENDIX 8 – HIIT program




GLOSSARY
AMRAP – AS MANY ROUNDS AS POSSIBLE
' – MINUTES
" – SECONDS
4x (2 x 20" : 10") : 0"
4 series
2 exercises
20 seconds exercising
10 seconds pause
0 seconds pause between series
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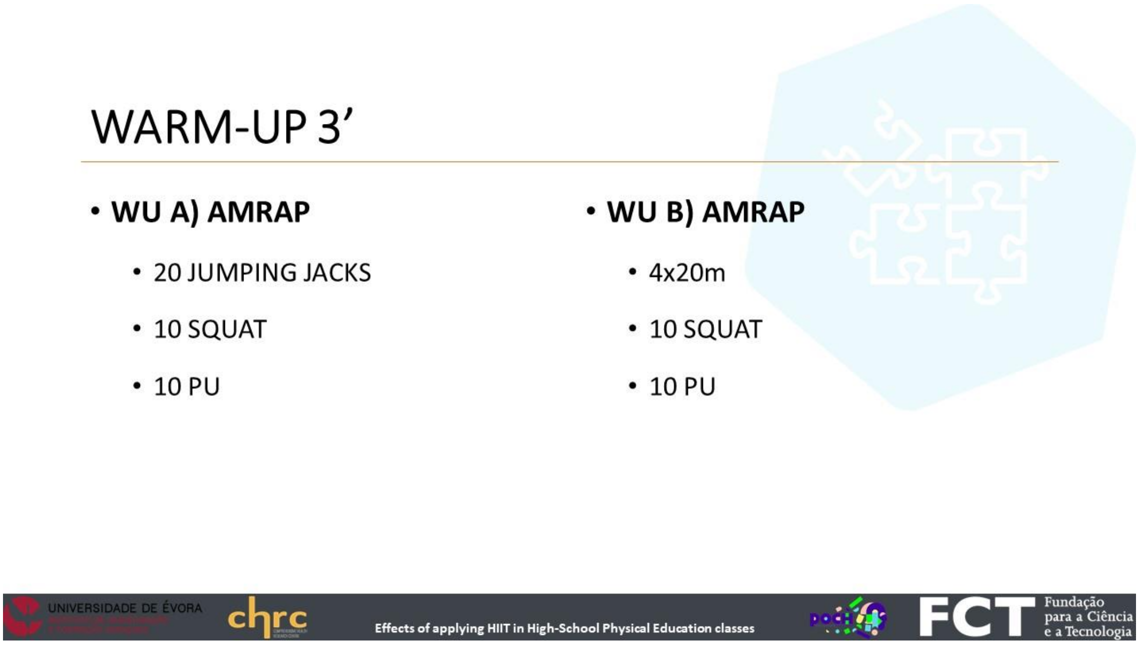
Effects of applying HIIT in High-School Physical Education classes
FCT
Fundação para a Ciência e a Tecnologia


WARM-UP 3'
• WU A) AMRAP
• 20 JUMPING JACKS
• 10 SQUAT
• 10 PU
• WU B) AMRAP
• 4x20m
• 10 SQUAT
• 10 PU
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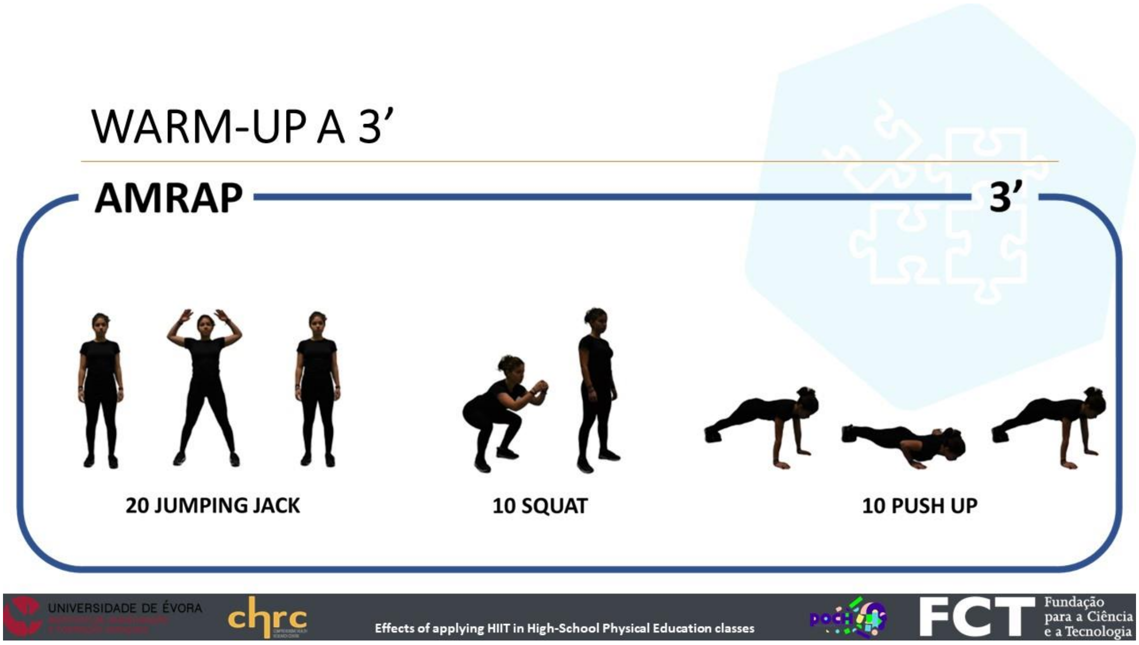
WARM-UP A 3’
AMRAP
3’
20 JUMPING JACK
10 SQUAT
10 PUSH UP
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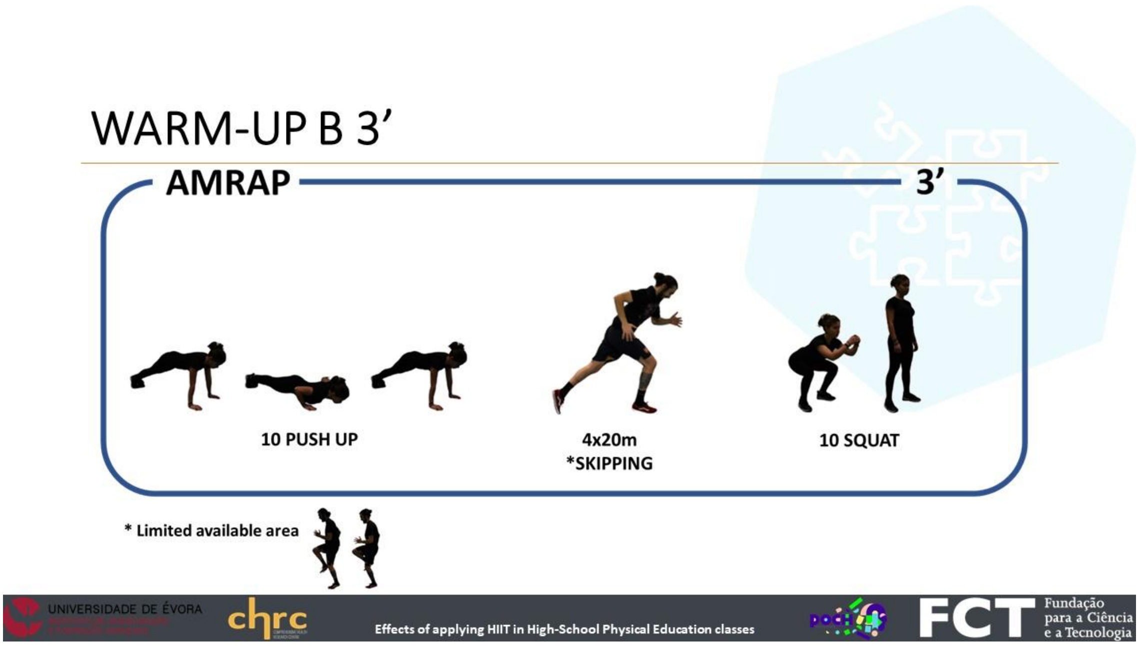
WARM-UP B 3’
AMRAP
3’
10 PUSH UP
4x20m
*SKIPPING
10 SQUAT
* Limited available area
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HIIT 4’

- 8 x 20'':10’’
  - JUMP. LUNGE
  - MOUNT. CLIMBER
- **WU 3’ + 4’ = 8 x 20'':10**
- **RED ZONE = 4'**

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HIIT 4’

WORKOUT **4** x (2 x 20’’ : 10’’) :0’’ **4’**

JUMPING LUNGE 20’’

MOUNTAIN CLIMBER 20’’

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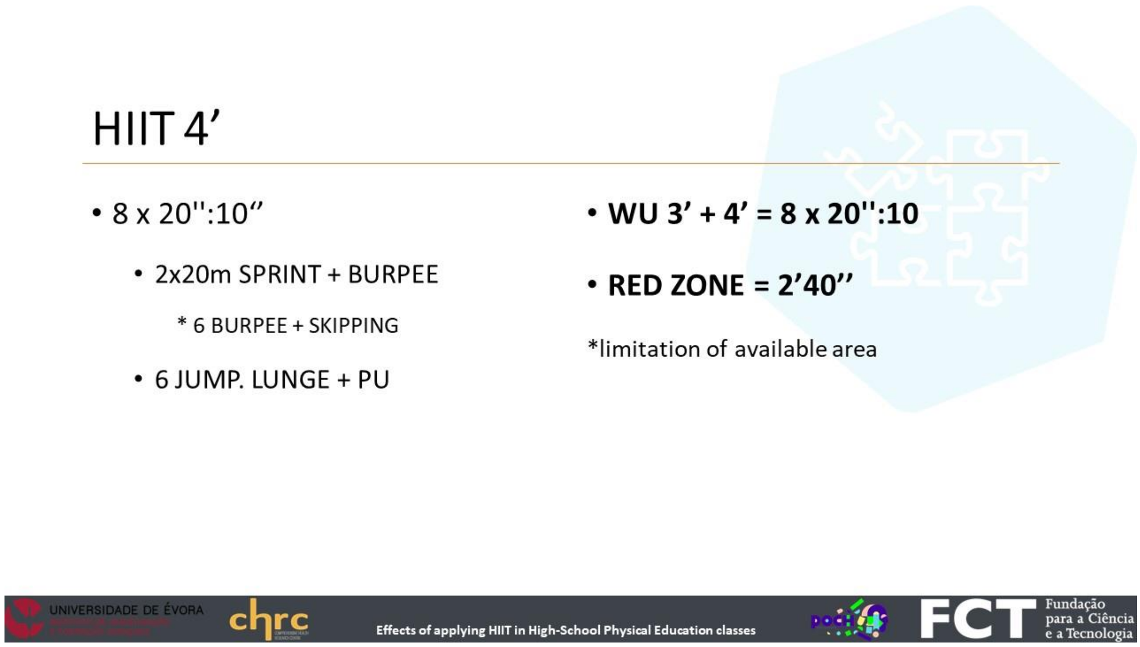
HIIT 4’
• 8 x 20'':10’’
• 2x20m SPRINT + BURPEE
* 6 BURPEE + SKIPPING
• 6 JUMP. LUNGE + PU
• WU 3’ + 4’ = 8 x 20'':10
• RED ZONE = 2’40’’
*limitation of available area
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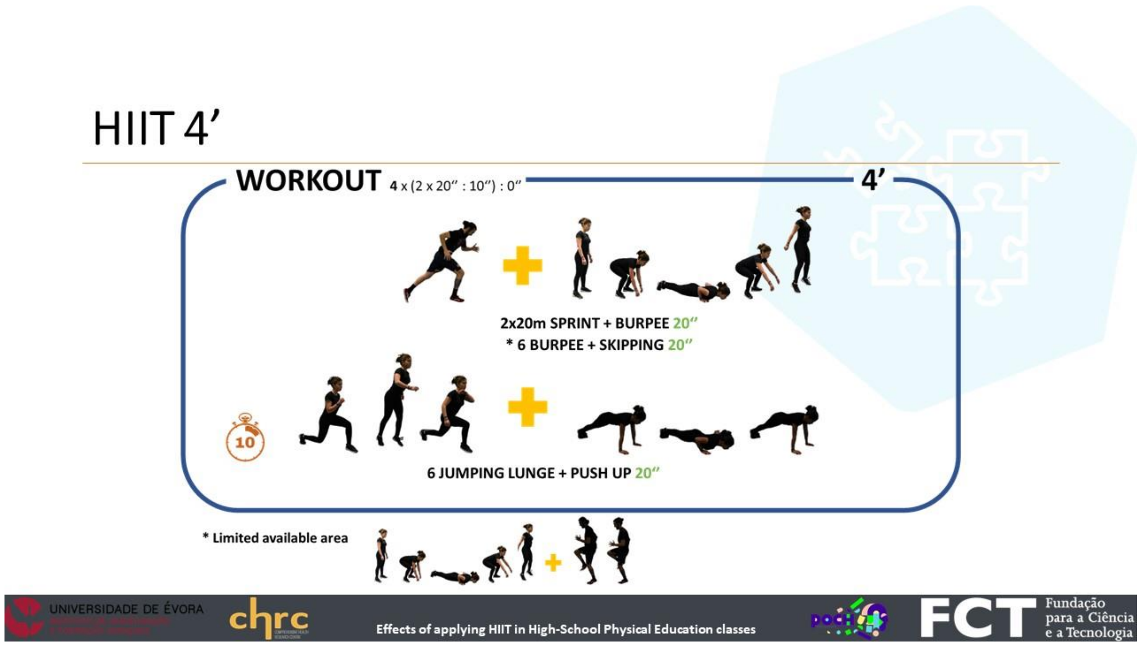
HIIT 4’
WORKOUT 4 x (2 x 20’’ : 10’’) : 0’’
4’
2x20m SPRINT + BURPEE 20’’
* 6 BURPEE + SKIPPING 20’’
10
6 JUMPING LUNGE + PUSH UP 20’’
* Limited available area
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HIIT 6’

- 12 x 20'':10’’
- 2x
  - SQUAT JUMP
  - WIDE PU
  - LATERAL SQUAT
  - CRAB TOE TOUCH
  - LATERAL SHUFFLE
  - SPRINT/SKIPPING*

- **WU 3' + 6' = 12 x 20'':10’’**
- **RED ZONE = 4'**

*limitation of available area

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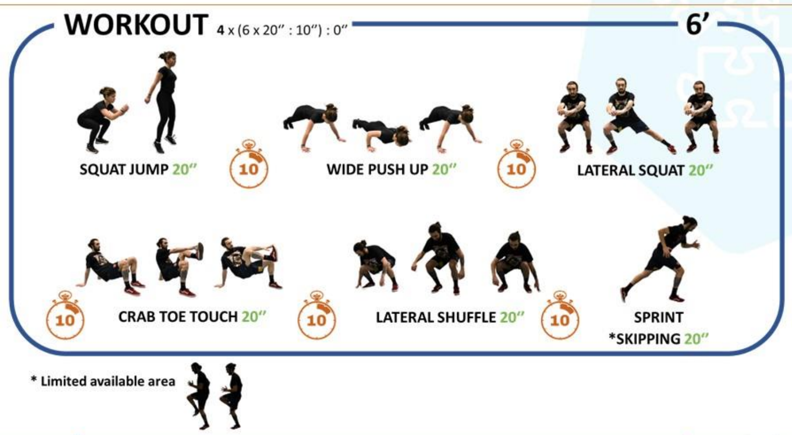
HIIT 6’



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HIIT 8'

- 16 x 20'':10''
- 2x
  - SPRINT/*SKIPPING
  - PIVOT LUNGE (RL)
  - SPRINT/*SKIPPING
  - PIVOT LUNGE (LL)
  - HOT FEET
  - GET UP
  - HOT FEET
  - GET UP

- **WU 3' + 8' = 16 x 20'':10**
- **RED ZONE = 5'20''**

*limitation of available area

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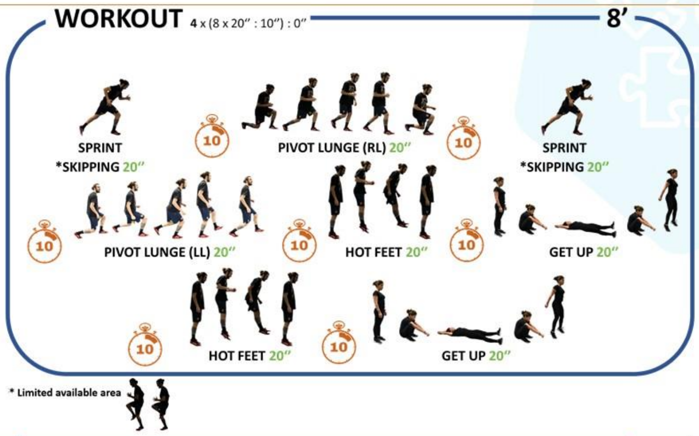
HIIT 8'



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HIIT 10’

- 20 x 20'':10’’
- 4x
  - 2x20m SPRINT + PU
    - * 6 PU + SKIPPING
  - 8 JUMP. LUNGE + MOUNTAIN CLIMBER
- 2x
  - SQUAT JUMP
  - WIDE PU
  - LATERAL SQUAT
  - CRAB TOE TOUCH
  - LATERAL SHUFFLE
  - SPRINT/SKIPPING*

- **WU 3' + 10' = 20 x 20'':10’’**
- **RED ZONE = 6'40''**

*limitation of available area

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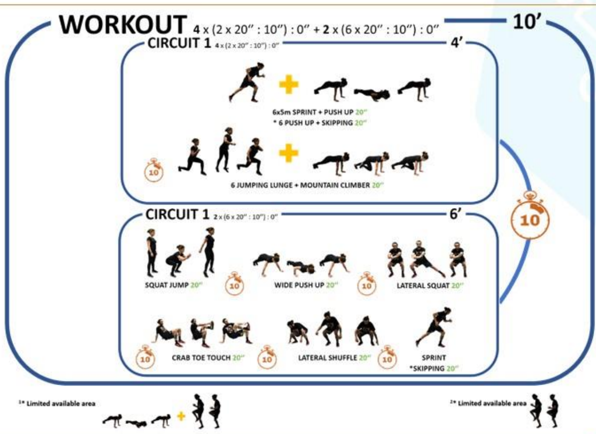
HIIT 10’



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HIIT 10’30’’

- 14 x 30'':15’’
- 2 x
  - 2 x
    - 6x5m SPRINT + PU
      - *10 PU + SKIPPING
    - 12 JUMP LUNGE + MOUNT. CLIMBER
  - GET UP
  - MONKEY WALK
  - CRAB TOE

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7'**

*limitation of available area

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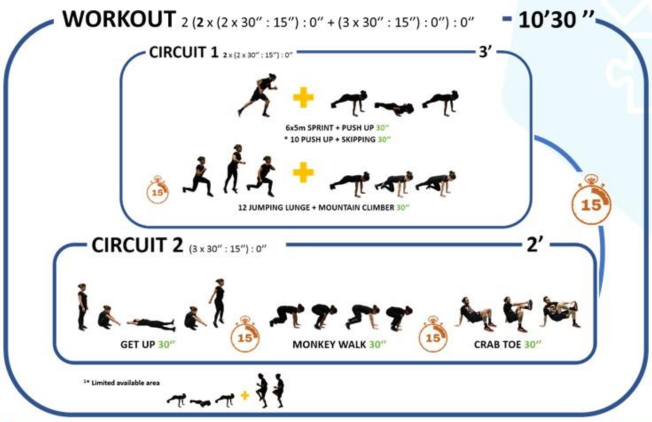
HIIT 10’30’’



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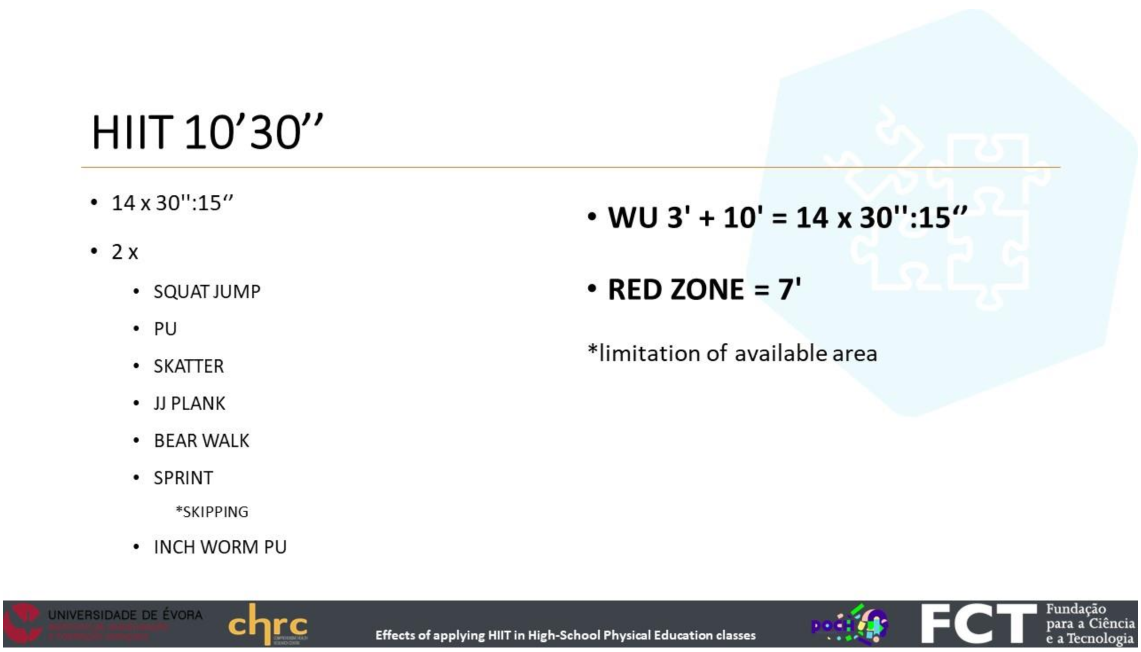
HIIT 10’30’’
• 14 x 30'':15’’
• 2 x
• SQUAT JUMP
• PU
• SKATTER
• JJ PLANK
• BEAR WALK
• SPRINT
*SKIPPING
• INCH WORM PU
• WU 3' + 10' = 14 x 30'':15’’
• RED ZONE = 7'
*limitation of available area
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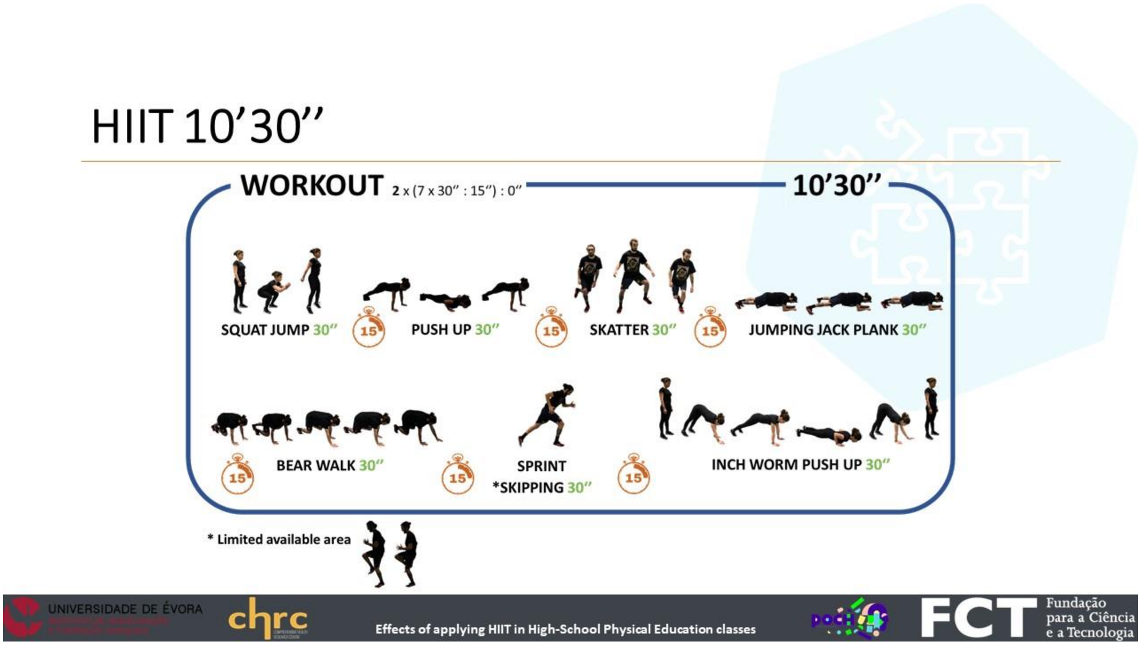
HIIT 10’30’’
WORKOUT 2 x (7 x 30’’ : 15’’) : 0’’
10’30’’
SQUAT JUMP 30’’
15
PUSH UP 30’’
15
SKATTER 30’’
15
JUMPING JACK PLANK 30’’
15
BEAR WALK 30’’
15
SPRINT
*SKIPPING 30’’
15
INCH WORM PUSH UP 30’’
* Limited available area
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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - SQUAT JUMP Hi5
  - COUPLE PUSH
  - 6 JUMPING LUNGE HOLD SKIPPING
  - COUPLE PULL
  - 4x10m SPRINT HOLD PU
    *8 PU HOLD SKIPPING
  - 2x5m BEAR WALK HOLD PLANK
  - INCH WORM PU

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

*limitation of available area

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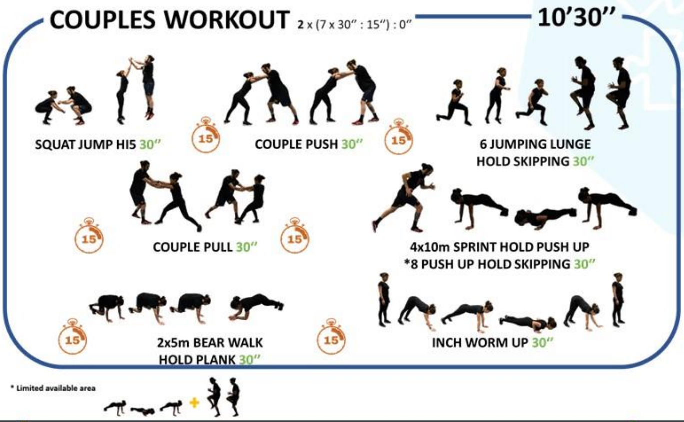
HIIT 10’30’’ - COUPLES



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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - 4 LATERAL SHUFFLE HOLD MOUNTAIN CLIMBER
  - Hi5 PU
  - 2x 1-LEG HOP HOLD CRAB TOE
  - BACK TO BACK PUSH
  - COUPLE 1-LEG SQUAT
  - Hi5 PLANK
  - SYNC BURPEE

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

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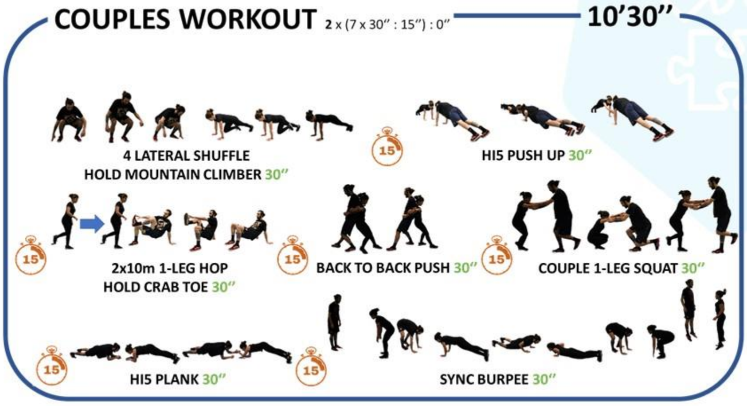
HIIT 10’30’’ - COUPLES



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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - 20 SKIPPING HOLD SQUAT
  - V-SIT JUMP ARROUND
  - V-SIT JUMP ARROUND
  - BURPEE JUMP OVER
  - PLANK WALK UNDER
  - FROG JUMP OVER
  - 4 SPRINT HOLD PU

    *10 PU HOLD SKIPPING

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

*limitation of available area

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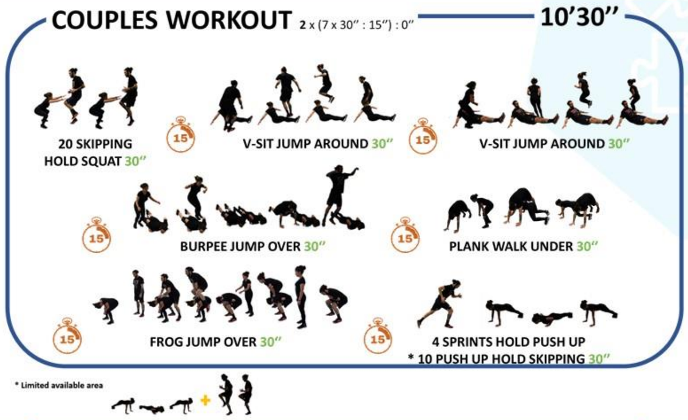
HIIT 10’30’’ - COUPLES



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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - SQUAT KNEE TAP
  - LATERAL JUMP HOLD PLANK
  - LATERAL JUMP HOLD PLANK
  - BURPEE + GET UP
  - 1-ARM SQUAT PULL
  - 1-ARM SQUAT PULL
  - 4SPRINTS HOLD PU

    *10 PU HOLD SKIPPING

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

*limitation of available area

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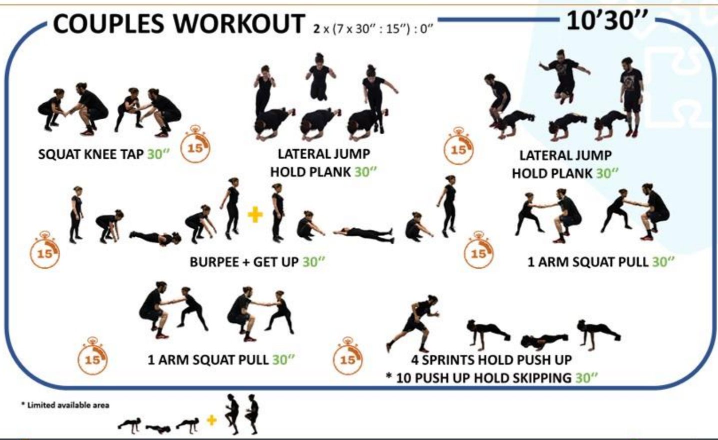
HIIT 10’30’’ - COUPLES



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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - HIGH KNEES SQUAT JUMP HOLD SQUAT
  - SHOULDER TAP PU
  - V SIT JUMP ARROUND
  - V SIT JUMP ARROUND
  - BEAR SHOULDER TAP
  - CRAB FOOT TAP
  - 4SPRINTS HOLD PU

    *10 PU HOLD SKIPPING

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

*limitation of available area

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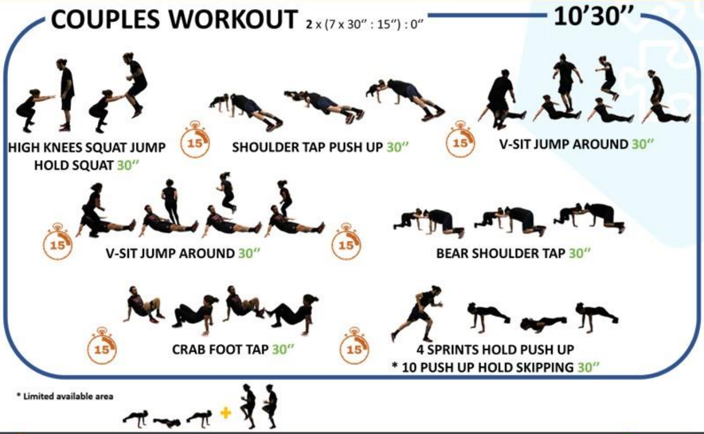
HIIT 10’30’’ - COUPLES



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HIIT 10’30’’ - COUPLES

- 14 x 30'':15’’
- 2 x
  - 4 KICKS SQUAT
  - Hi5 SUPER MAN PU
  - ASSYNCH PLYO JJ
  - PLANK DONKEY JUMP
  - PLANK DONKEY JUMP
  - PRISONER SQUAT
  - BURPEE 4 Hi5 JUMPS

- **WU 3' + 10' = 14 x 30'':15’’**
- **RED ZONE = 7’**

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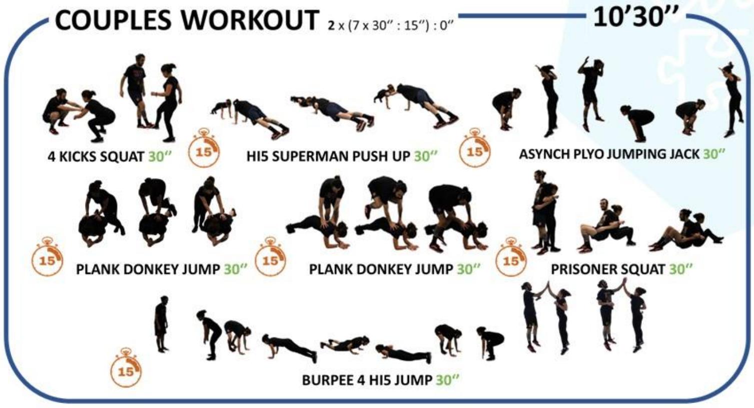
Effects of applying HIIT in High-School Physical Education classes

FCT Fundação para a Ciência e a Tecnologia

HIIT 10’30’’ - COUPLES



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Effects of applying HIIT in High-School Physical Education classes

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APPENDIX 9 – Ratings of perceived exertion (RPE)

	NENHUM ESFORÇO	
6		MUITO LEVE
7	EXTREMAMENTE LEVE	
8		
9	MUITO LEVE	
10		LEVE
11	LEVE	
12		MODERADA
13	UM POUCO FORTE	
14		ELEVADA
15	FORTE	
16		
17	MUITO FORTE	MUITO ELEVADA
18		
19	EXTREMAMENTE FORTE	
20	ESFORÇO MÁXIMO	MÁXIMA

APPENDIX 10 – Workout report

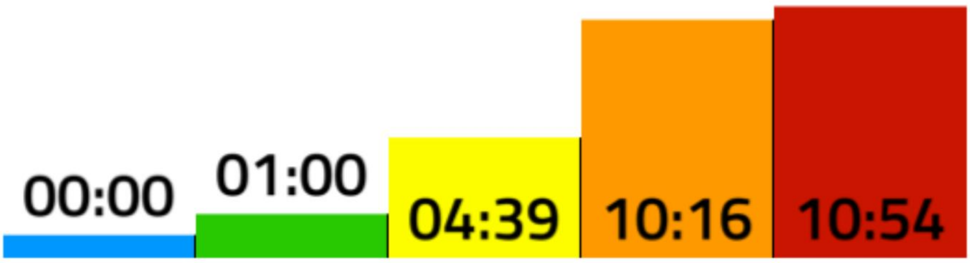
Max Heart Rate Report

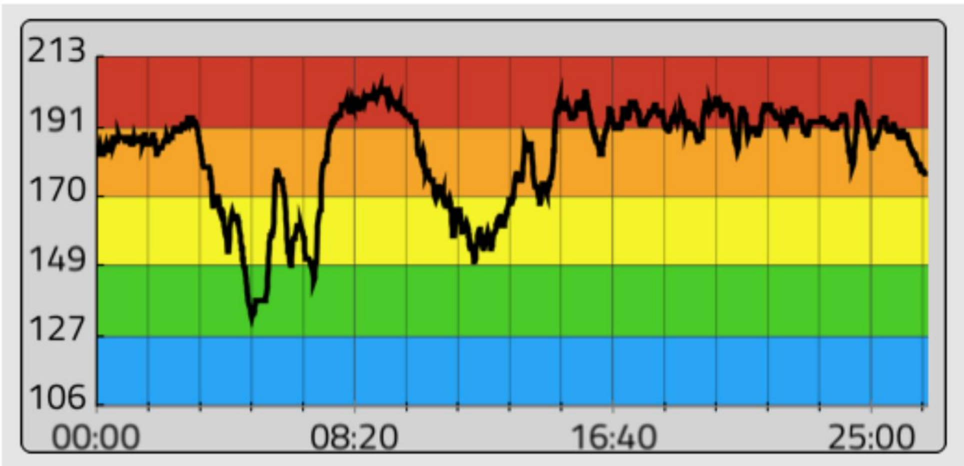
Name: [redacted]
Class: 12A
Teacher: Andre

HEARTZONES SYSTEM

Heart Zones PE Workout Summary

Date: 02/05/2020	**Start:** 10:16 AM	**Finish:** 10:43 AM	**Duration:** 0:27:10
Avg HR: 183bpm	**Peak HR:** 203bpm	**Min HR:** 133bpm	**%MVPA:** 100
Points: 124,9	**kCal:** 366,9kCal	**Zone Avg:** 4,6	**Stars:** 3,5
0 Sec Recovery:	0 Sec Recovery:	0 Sec Recovery:	
Starting HR/△:	Starting HR/△:	Starting HR/△:	
Recovery Rate: s	Recovery Rate: s	Recovery Rate: s	
Type:	Type:	Type:	





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