**Universidade de Lisboa**

**Faculdade de Motricidade Humana**

# HEALTH-RELATED CARDIORESPIRATORY FITNESS IN THE SCHOOL CONTEXT

Miguel Pedro Fernandes de Almeida Fragoso Peralta

Orientadores: Prof. Doutor Adilson Passos da Costa Marques

Prof. Doutora Diana de Aguiar Pereira dos Santos

Tese especialmente elaborada para obtenção do grau de Doutor em Educação na especialidade de Educação para a Saúde

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2021

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# Abstract

**Background:** Cardiorespiratory fitness is a health marker, being physical activity the primary means of improving it. However, a concerning secular decline in youth's cardiorespiratory fitness has been observed. Among young people, several strategies for improving physical activity and cardiorespiratory fitness levels are focused on the school context, as schools provide opportunities for regular physical activity, such as physical education. Despite the importance of the school context and physical education for promoting cardiorespiratory fitness, evidence of its role is scarce. Therefore, this thesis aims to investigate the promotion of health-related cardiorespiratory fitness in the school context taking into account the contribution of physical education classes and its evolution throughout the school-year and summer break in children and adolescents.

**Methods:** Four investigations were performed to achieve the aim of the study: a systematic review following the Preferred Reporting Items for Systematic Review and Meta-analysis guidelines, which included 24 studies; and three observational longitudinal design original investigations. Two different samples were used, one comprising 212 7th and 8th grade students (mean age 12.9 years) and the other comprising 440 6th to 8th grade students (mean age 12.3 years). Also, 11 physical education teachers (6 men, 5 women) participated in two of the studies. Cardiorespiratory fitness was assessed using the Progressive Aerobic Cardiovascular Endurance Run. Physical education classes, including physical activity during classes, lesson context, and teacher behaviour, were examined using a direct observation tool, the System for Observing Fitness Instruction Time. Daily physical activity was assessed using accelerometers. Statistical analysis performed included, depending on specific research aims and data available, descriptive statistics, Student's t-test, chi-square, McNemar's test, linear regression models, and analysis of covariance.

**Results:** The systematic review did not provide conclusive findings. However, higher intensity physical education classes consistently had a positive contribution in promoting students' cardiorespiratory fitness. In the original investigations, it was observed that the percentage of students in the cardiorespiratory fitness healthy fitness zone increased from the beginning to the end of the school-year. Several factors associated with the change in cardiorespiratory fitness were identified. Among boys, the percentage of time being very active in physical education classes was associated with positive changes in cardiorespiratory fitness, while class time spent in fitness situations was negatively associated. Only for girls, time spent by the teacher promoting fitness was positively related to cardiorespiratory fitness improvements. For both sexes, class time spent in gameplay and time spent by the teacher in instruction tasks were associated with positive changes in cardiorespiratory fitness. On the other hand, class time spent in general content and time spent by the teacher in management tasks were negatively associated with cardiorespiratory fitness. Lastly, it was found that cardiorespiratory fitness increased from the beginning to the end of each school-year, but remained unchanged during summer break.

**Conclusion:** Physical education and the action of the physical education teacher are important for the improvement of cardiorespiratory fitness and thus for the promotion of health-related cardiorespiratory fitness. Therefore, physical education is a valuable health promotion setting capable of providing adequate physical activity opportunities and impact young peoples' health. Investing in physical education can be a successful strategy to improve children and adolescents' cardiorespiratory fitness levels.

**Keywords:** aerobic fitness; health promotion; physical activity; physical education; school

## Resumo

**Introdução:** A aptidão cardiorrespiratória é um marcador de saúde, sendo a prática de atividade física a principal forma de a melhorar. Todavia, nas crianças e adolescentes tem vindo a ser observado um preocupante declínio da aptidão cardiorrespiratória ao longo do tempo. Entre os jovens, diversas estratégias para a melhoria dos níveis de atividade física e aptidão cardiorrespiratória estão focadas no contexto escolar, uma vez que as escolas oferecem oportunidades para a prática regular de atividade física, como por exemplo a disciplina de educação física. Apesar da importância do contexto escolar e da educação física para a promoção da aptidão cardiorrespiratória, a evidência acerca do seu papel é escassa. Nesse sentido, esta tese tem como objetivo investigar a promoção da aptidão cardiorrespiratória relacionada à saúde no contexto escolar, considerando a contribuição das aulas de educação física e a sua evolução ao longo do ano letivo e nas férias de verão em crianças e adolescentes.

**Métodos:** Para atingir o objetivo da tese foram desenvolvidas quatro investigações: uma revisão sistemática seguindo as normas *Preferred Reporting Items for Systematic Review and Meta-analysis*, que incluiu 24 estudos; e três investigações originais com desenho de estudo observacional longitudinal. Foram utilizadas duas amostras diferentes, uma composta por 212 alunos do 7º e 8º ano de escolaridade (média de idade 12,9 anos) e a outra composta por 440 alunos do 6º ao 8º ano de escolaridade (média de idade 12,3 anos). Adicionalmente, participaram 11 professores de educação física (6 homens, 5 mulheres) em dois estudos. A aptidão cardiorrespiratória foi avaliada pelo teste do vaivém. As aulas de educação física, incluindo atividade física durante a aula, o contexto da aula e o comportamento do professor, foram analisadas usando uma ferramenta de observação direta, o *System for Observing Fitness Instruction Time*. A atividade física habitual foi avaliada por acelerometria. A análise estatística realizada incluiu estatística descritiva, teste t de Student, teste do qui-quadrado, teste de McNemar, modelos de regressão linear e análise de covariância.

**Resultados:** A revisão sistemática não facultou resultados conclusivos. No entanto, aulas de educação física de maior intensidade demonstraram consistentemente uma contribuição positiva para a promoção da aptidão cardiorrespiratória. Nas investigações originais, observou-se que a percentagem de alunos na zona saudável de aptidão cardiorrespiratória aumentou entre o início e o final do ano letivo. Vários fatores associados à mudança na aptidão cardiorrespiratória foram identificados. Nos rapazes, a percentagem de tempo despendida em atividade física muito ativa nas aulas de educação física estava associada à melhoria da aptidão cardiorrespiratória, enquanto o tempo de aula em tarefas de aptidão física estava negativamente associado. Nas raparigas, o tempo despendido pelo professor a promover a aptidão física estava associado a mudanças positivas na aptidão cardiorrespiratória. Para ambos os sexos, o tempo da aula em jogos e o tempo despendido pelo professor em tarefas de instrução estavam associados à melhoria da aptidão cardiorrespiratória. Contrariamente, o tempo de aula em conteúdo geral e o tempo despendido pelo professor em tarefas de gestão estavam negativamente associados à aptidão cardiorrespiratória. Por fim, constatou-se que a aptidão cardiorrespiratória melhorou durante o ano letivo, mas manteve-se inalterada durante as férias de verão.

**Conclusão:** A educação física e a ação do professor de educação física são importantes para a melhoria da aptidão cardiorrespiratória e, portanto, para a promoção desta componente da aptidão física. Desta forma, a educação física é um importante contexto para a promoção da saúde, capaz de oferecer oportunidades adequadas para a prática de atividade física e impactar a saúde dos jovens. Investir em educação física pode ser uma estratégia de sucesso para melhorar os níveis de aptidão cardiorrespiratória de crianças e adolescentes.

**Palavras-chave:** aptidão cardiorrespiratória; atividade física: educação física; escola; promoção da saúde

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## List of abbreviations

ANCOVA – analysis of covariance

BMI – body mass index

CI – confidence interval

CRF – cardiorespiratory fitness

IOM – Institute of Medicine

OECD – Organisation for Economic Co-operation and Development

PA – physical activity

PACER – Progressive Aerobic Cardiovascular Endurance Run

PE – physical education

PESSOA – Physical Activity and Family-based Intervention in Paediatric Obesity Prevention in the School Setting

PHV – peak height velocity

PRISMA – Preferred Reporting Items for Systematic Review and Meta-analysis

SOFIT – System for Observing Fitness Instruction Time

SPSS – Statistical Package for the Social Sciences

$VO_{2max}$ – Maximal oxygen uptake

$VO_{2peak}$ – Peak oxygen uptake

WHO – World Health Organization

UNESCO – United Nations Educational, Scientific and Cultural Organization

USDHHS – United States Department of Health and Human Services

# Chapter [1]

# 1. Introduction

Gathering evidence-based health promotion is key for improving the populations health (Smith et al., 2006). Thus, it is important to use information from research to identify causes and contributing factors to health needs and the most effective actions to promote health in given contexts and populations. Taking this into account, the present thesis aspires to contribute to the evidence-based health promotion framework regarding health-related cardiorespiratory fitness (CRF) in the school setting, especially in physical education (PE) classes as it provides an opportunity for youth to be physically active and promote healthy lifestyles (Bocarro et al., 2012; Kelly et al., 2019).

CRF can be defined as the ability of the body to deliver atmosphere oxygen to the skeletal muscles and to use it to generate energy to support muscle activity during exercise. Among children and adolescents, CRF is associated with present and future cardiometabolic health being an important health marker (Henriksson et al., 2021; Raghuveer et al., 2020). Although up to half of the CRF is hereditable (Bouchard et al., 1998) participation in physical activity (PA) is still considered as the primary means of improving fitness (Lang, Tomkinson, et al., 2018). Despite its associations with health, recent evidence has shown a substantial decline in CRF since 1981 in upper-middle- and high-income countries (Tomkinson et al., 2019), which is a cause of concern.

Through the health promotion lens, the school has been purposed as an important setting to promote PA and CRF (Bocarro et al., 2012; Kelly et al., 2019). School-based PA interventions are known to be effective strategies to promote children and adolescents' PA levels and CRF (Kriemler et al., 2011; Lonsdale et al., 2013; Messing et al., 2019), however these interventions are not universal and may not be sustainable over long periods if senior leaders and staff that are knowledgeable, skilled and motivated to continue delivering health promotion through ever-changing circumstances are not retained (Herlitz et al., 2020). Therefore, there is a need to promote sustainable health promotion actions, that can maintain their benefits beyond initial stage of implementation and that can deliver within the limits of the resources available.

Within the school activities, PE, which is part of the school curriculum in most countries (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014), allows children and adolescents to engage in structured and appropriate PA (Harris & Cale, 2019; Mersh & Fairclough, 2010). Thus, PE classes are a privileged context for health promotion actions, through its regular implementation across most education years. Despite this, little is known about the associations between changes in CRF and curricular PE over time. In this regard, it is key to investigate the role of the school setting and PE in particular for improving young people's CRF and explore possible avenues to promote CRF in the school context in a sustainable fashion. This thesis is focused on this literature gap to provide a rationale for a line of action in the promotion of CRF among children and adolescents.

## 1.1. Structure of the thesis

The present thesis is organized into four chapters, reflecting the background, methodology, results and conclusions of the investigations. A total of four studies were performed and are presented here, one study is a systematic review and the other three studies are original investigations.

Chapter 1 is the introduction of the thesis, where the literature review, conceptual model and aims are exposed. This chapter reflects on the associations between CRF and health, and health promotion in the school setting and PE. Also, it establishes the importance and pertinence of the thesis in the current literature.

Chapter 2 presents an overview of the methodology used in this thesis and each study, including study designs, procedures, participants, measures and instruments, data analysis and ethical considerations.

Chapter 3 incorporates a collection of four studies, two published and two under review at international peer-reviewed journals. This chapter refers to the results of the investigations and the thesis, as well as their discussion and detailed methodology and rationale, for each study.

Chapter 4, the last one, provides the general discussion of the principal research findings, the implications of the thesis' investigation for future research and current practice, and the main conclusions.

## 1.2. List of publications and manuscripts

The studies that constitute the present thesis, published or under review at international peer-reviewed journals, were structured from the specific aims presented later in this chapter, are the following:

**Study 1**

Peralta, M., Henriques-Neto, D., Gouveia, E. R., Sardinha, L. B., & Marques, A. (2020). Promoting health-related cardiorespiratory fitness in physical education: A systematic review. *PLoS One, 15*(8), e0237019. https://doi.org/10.1371/journal.pone.0237019

**Study 2**

Peralta, M., Santos, D. A., Henriques-Neto, D., Ferrari, G., Sarmento, H., & Marques, A. (2020). Promoting health-related cardiorespiratory fitness in physical education: the role of class intensity and habitual physical activity. *International Journal of Environmental Research and Public Health, 17*(18). https://doi.org/10.3390/ijerph17186852

**Study 3**

Peralta, M., Gouveia, E. R., Ferrari, G., Catunda, R., Henriques-Neto, D., & Marques, A. Promoting health-related cardiorespiratory fitness in physical education: the role of lesson context and teacher behaviour in an observational longitudinal study (under review).

**Study 4**

Peralta, M., Marques, A., Santos, D. A., Martins, J., López-Flores, M., Minderico, C., & Sardinha, L. B. The effect of school-year and summer break in health-related cardiorespiratory fitness: a 2-year longitudinal analysis (under review).

# 2. Literature review

## 2.1. Physical activity, physical fitness and cardiorespiratory fitness

The terms PA, exercise and physical fitness are often used interchangeably since they are closely related, however they do not represent the same construct. Thus, it is perhaps best to start by defining each one. This distinction is of importance as throughout the text these term will be used often. PA can be defined as any body movement produced by the skeletal muscle that results in energy expenditure (Caspersen et al., 1985). PA represents a full range of intensities, including light intensity PA (<3 metabolic equivalents of task), moderate PA (≥3 and <6 metabolic equivalents of task) and vigorous PA (≥6 metabolic equivalents of task) (Bull et al., 2020). On the other hand, exercise is a subcategory of PA that is normally planned, structured and requires repetitive body movements with the aim of maintaining or improving one or more components of physical fitness (Caspersen et al., 1985). Lastly, physical fitness is a multi-component construct that can be understood as a set of attributes an individual has or can achieve. From a broader perspective, physical fitness is a physiologic attribute that represents an individual's capacity to performed muscle-powered activities (United States Department of Health and Human Services [USDHHS], 2018). Physical fitness can be divided into its health-related and skill-related components. Health-related physical fitness includes CRF, muscular strength, muscular endurance, muscular flexibility, and body composition (Caspersen et al., 1985). Independently of physical activity, health-related physical fitness is linked to a lower prevalence of chronic disease and has a strong relationship with health and wellness (Blair et al., 2001; USDHHS, 2018).

The most studied health-related component of physical fitness is the CRF. CRF relates to the capacity of the circulatory and respiratory systems to supply oxygen to muscles during a sustained physical effort, i.e. reflects the capacity of the respiratory and cardiovascular system to bear prolonged exercise (Taylor et al., 1955). Even though a large part of the variability of CRF, up to half, is biologically and genetically determined (Bouchard et al., 1998;

Ross et al., 2019), hereditability is not the only determinant of CRF. Socio-environmental factors and PA, particularly exercise, also influence CRF to a large extent (Lang, Tomkinson, et al., 2018).

Childhood and adolescence are crucial periods of life marked by several morphological, physiological, psychologic, and behavioural changes. Sex and maturity are two determinants of CRF that shape its improvement in these ages. It is widely known that boys' CRF is higher than those of girls, at least from late childhood onward, and that this difference increases throughout adolescence reaching about a 40% gap in post-pubertal 18-year-old boys (Armstrong & Welsman, 1994). This difference is greatly explained by boys' marked increase in fat-free mass (about 90% increase between 11 and 16 years old, compared to a 40% increase in girls) driven by maturation (Armstrong & Welsman, 2019). Besides sex, maturity status is also an important determinant of CRF, as the growth and development processes are not linear and do not happen simultaneously in young people, between and within each sex (Armstrong & Welsman, 2001).

Although CRF is mostly dependent on genetics, sex, and maturation. Other environmental and behavioural factors are also important determinants of aerobic capacity, such as weight status, sleep, nutrition or PA levels. Between those factors, PA has the greatest impact on CRF. Engaging in PA and exercise activates almost all biological systems to support muscle contraction and energy production (Bouchard et al., 2012). In response to PA, the cardiovascular and respiratory systems increase the availability of oxygen for energy production in the muscle; when regularly stimulated muscles improve their ability to function optimally (Gastin, 2001). Therefore, PA is considered the primary means of promoting CRF (Lang, Tomkinson, et al., 2018). Within PA, exercise seems to contribute the most to improvements in CRF, mainly because of the higher activity intensity and regularity of practice. Engaging in regular moderate-to-vigorous, especially vigorous, PA is most beneficial for improving CRF (Collings et al., 2017; Ruiz et al., 2006). Also, previous investigations have demonstrated that children and adolescents participating in organized sports have better CRF than their non-participating peers and that appropriate exercise training is known to increase

CRF levels in youth, irrespective of sex, age or maturity (Armstrong & Barker, 2011; Silva et al., 2013). More specifically, programs to benefit CRF usually involve 20-45 minute sessions of continuous moderate-to-vigorous or vigorous-intensity training or high-intensity interval training over a period of at least two to three months (Armstrong & Barker, 2011; Baquet et al., 2002).

In summary, PA, exercise, and physical fitness are related concepts that warrant differential interpretations. Furthermore, PA, especially higher intensity, exercise, and CRF are positively associated. Because of that, better CRF performances can be seen as a marker of PA levels, total amount or volume essentially of higher intensities, with evidence highlighting vigorous activities (Ruiz et al., 2006). Therefore, from a monitoring perspective, CRF provides a robust measure and stable reflection of recent and past PA levels, as well as an indication of biological systems functioning (Lang, Tomkinson, et al., 2018; Lang, Wolfe Phillips, et al., 2018).

### 2.2. Physical activity, cardiorespiratory fitness and health

The health benefits evidence of PA and fitness, namely CRF, in children and adolescents is undisputable. For that reason, promoting PA and healthy lifestyles has become a priority for education and health authorities worldwide (World Health Organization [WHO], 2018). Among young people, engaging in PA and having better physical fitness is beneficial for several health outcomes, such as obesity, cardiometabolic health, bone health, and mental health, as well as for pro-social behaviour, sleep, and cognitive outcomes (Bull et al., 2020; Chaput et al., 2020). Promoting PA has been consistently shown to be an effective strategy to improve health in general and is considered as a ‘best buy’ in health promotion (WHO, 2017).

In youth, regular PA is positively associated with beneficial cardiometabolic health outcomes, including improved blood pressure, lipid profile, glucose control, and insulin sensitivity, and bone health, while being inversely associated with overweight and obesity (Bull et al., 2020; Chaput et al., 2020; Janssen & Leblanc, 2010). Furthermore, the benefits of PA seem to be greater with increasing intensity. For example, children and adolescents who engage in higher levels of PA have lower resting blood pressure and triglycerides concentration (Cesa et al., 2014) and more favourable indicators of arterial stiffness (Heil et al., 2020). Also, recent evidence reinforces the idea that PA, especially when participating in 30-60 minutes of moderate-to-vigorous PA for three or more days per week, improves CRF and musculoskeletal fitness in children and adolescents (Poitras et al., 2016; USDHHS, 2018). Besides physical health, the promotion of mental health, and the development and maintenance of cognitive function are essential across the entire lifespan. Scientific evidence has shown that PA has positive effects on overall mental health and health-related quality of life (Biddle & Asare, 2011; USDHHS, 2018; Wu et al., 2017), and the prevention or treatment of depression and anxiety (Brown et al., 2013; Korczak et al., 2017). Furthermore, PA has positive effects on cognitive function and academic outcomes (Alvarez-Bueno et al., 2017; Donnelly et al., 2016; Marques et al., 2018).

Several hypotheses have been proposed regarding the underlying mechanisms responsible for the effects of PA on mental health. On a physiological level, PA may promote mental health through the release of endorphins and neurogenesis (Cotman et al., 2007; Lubans et al., 2016). On a psychological level, PA is associated with several aspects related to mental health, such as positive relationships with others, social learning, making new friends, self-esteem (Eime et al., 2013; Lubans et al., 2016; Rodriguez-Ayllon et al., 2019).

Independently of PA, CRF is a well-known indicator of young peoples' current (Ruiz et al., 2015) and future health (Henriksson et al., 2021; Raghuveer et al., 2020), which is associated with cardiovascular health, cholesterol and blood lipids levels, obesity and mental health (Janssen & Leblanc, 2010; Ortega et al., 2008; Ruiz et al., 2009). Figure 1 presents a summary of the associations between CRF and health in youth.

Children and adolescents with greater CRF levels have healthier cardiovascular and metabolic profiles (Ekelund et al., 2007; Ortega et al., 2008). Furthermore, CRF is inversely associated with total adiposity, and having high levels of CRF can counteract the harmful consequences attributed to having a higher inflammatory profile (Ortega et al., 2008; Ruiz et al., 2009). Therefore, CRF is related to the clustering of cardiometabolic risk factors and is an important marker of health (Anderssen et al., 2007; Klasson-Heggebo et al., 2006). CRF is also associated with mental health in youth (Janssen et al., 2020; Ruggero et al., 2015). CRF is related to greater global grey and white matter, brain volume and anterior hippocampal functional connectivity (Cadenas-Sanchez et al., 2020; Esteban-Cornejo et al., 2021). This is of importance and may explain why, among adolescents, higher CRF is related to better academic performance (Marques et al., 2018), either cross-sectionally (Sardinha et al., 2014) or prospectively (Garcia-Hermoso et al., 2021; Sardinha et al., 2016).

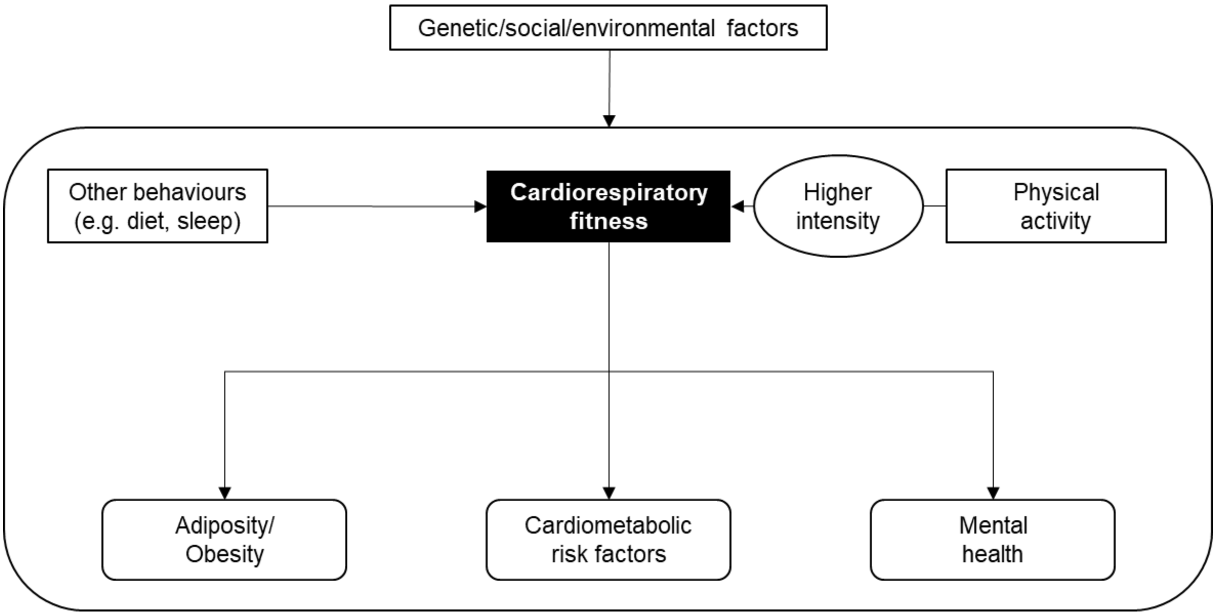


Figure 1. Associations between cardiorespiratory fitness and several health outcomes in children and adolescents (adapted from Ortega et al., 2008).

Although the adverse effects of non-communicable diseases are mainly manifested in adults and older adults, it is evident that the development of these conditions may start much earlier in life (Cook et al., 2009; Hallal et al., 2006). Additionally, it is known that CRF moderately tracks from childhood to adolescence and from adolescence to adulthood (Malina, 1996; Twisk et al., 2000). Therefore, it seems reasonable to conclude, that promoting PA and physical fitness, including CRF, in young people is essential to nurture healthy lifestyles that may help to prevent present and future non-communicable diseases and take the right steps to a healthier population.

Considering that PA is an important health behaviour (Bull et al., 2020) and CRF is a powerful marker of health (Ortega et al., 2008), PA should be part of our daily routine. Taking this evidence into account, the WHO recommends children and adolescents, aged 5-17 years old, to engage in at least 60 minutes of daily moderate-to-vigorous PA, to achieve health benefits (Bull et al., 2020; Chaput et al., 2020). It is further recommended that most of the daily PA should be aerobic and that muscle-strengthening activities should be performed at least three times per week (Bull et al., 2020; Chaput et al., 2020). Also, considering the health benefit of greater CRF, several specialists have stressed the importance of improving and promoting CRF in children and adolescents (Lang, Tomkinson, et al., 2018; Ortega et al., 2008; Ruiz et al., 2009).

## 2.3. Physical activity and cardiorespiratory fitness levels

Despite the health benefits summarized previously, PA and CRF levels among young people are low and declining globally. Recent evidence, using a pooled analysis of cross-sectional survey data from 146 countries, suggests that 81% of children and adolescents aged 11-17 years old do not meet the current recommendations for daily PA (Guthold et al., 2020). It was further observed that more girls than boys were insufficiently active in 2016, respectively 84.7% and 77.6%. In the same study, country-level data was available. Regarding Portugal, the prevalence of insufficient PA (i.e. not meeting the WHO PA recommendations) in 2001 and 2016 for boys and girls are presented in Figure 2. Globally, in 2016, 84.3% of children and adolescents did not meet the WHO PA recommendations. Furthermore, PA levels remained unchanged from 2001 to 2016, both in boys (78.6% to 78.1%) and girls (90.0% to 90.7%).

Similarly, the global matrix 3.0 PA report card project, which graded evidence to harmonize available data from 49 countries worldwide, has suggested that children and adolescents have low compliance with the WHO PA guidelines, only 27% to 33% (grade D) met the PA recommendations (Aubert et al., 2018); the same grade was attributed to Portugal.

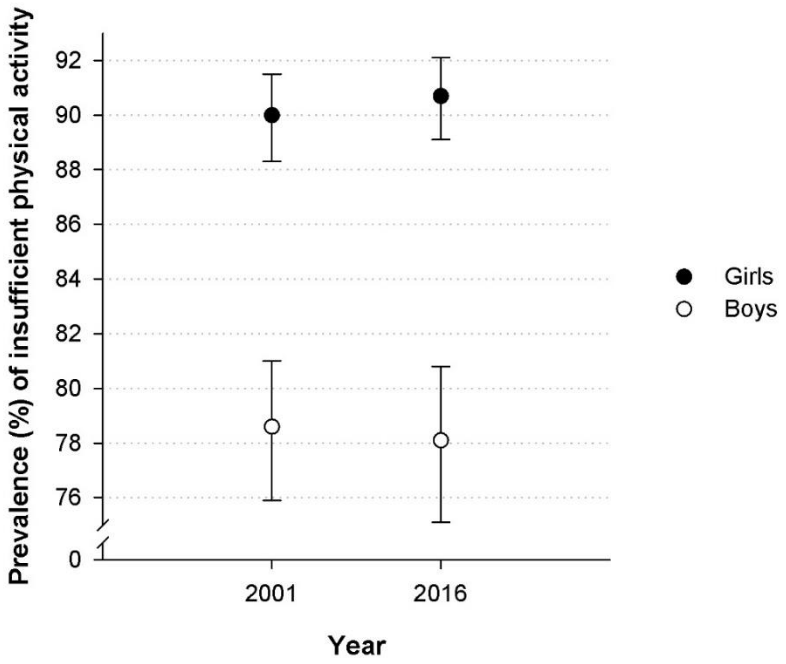


Figure 2. Prevalence of insufficient physical activity among Portuguese boys and girls in 2001 and 2016 (using data from Guthold et al., 2020).

In adults, insufficient PA has been identified as one of the leading risk factors for premature mortality and disease burden (Ding et al., 2016; Lee et al., 2012). Thus, the low PA levels in children and adolescents are alarming as they are associated with lower physical activity levels later in life (Telama et al., 2014; Telama et al., 2005) and might be one of the causes for the declining trend observed in CRF worldwide in this population (Blair et al., 2001; Masanovic et al., 2020; Tomkinson et al., 2019).

In a trend analysis from 1981 to 2014 Tomkinson et al. (2019) verified a moderate decline in young people's CRF living in 19 high-income and upper-middle-income countries, which included Portugal, between these years (-7.3% change). Furthermore, it was observed a substantial decline since 1981, which has slowed and stabilised internationally since 2000. In the same study, Portugal presented a -8% change pre-2000 and a -1.7% decline in CRF post-2000 (Tomkinson et al., 2019). Also, within the Portuguese context, a previous investigation has shown that only little over half (59.2% of girls and 63.1% of boys) of children and adolescents had a healthy CRF, and that this percentage declined with age (Santos et al., 2014).

Given the health benefits of being physically active and fit, worldwide and in Portugal, there is a concerning declining trend in both PA and CRF. Exactly because of that, the WHO has declared that one of their global health initiatives is to increase the populations' PA levels and reduce by 10% the prevalence of insufficient PA by 2025 (Guthold et al., 2018; WHO Regional Office for Europe, 2016). Therefore, there is an imperative need to develop strategies for the promotion of PA and CRF at the population level that are effective and sustainable.

### 2.4. Promoting physical activity and cardiorespiratory fitness in young people

Promoting PA and healthy lifestyles has become a priority for public health authorities worldwide (WHO, 2018). When developing PA and fitness promotion strategies among children and adolescents there are several contexts to consider, including organized sports participation, active commuting, unstructured leisure-time, and school (Messing et al., 2019; WHO, 2018; WHO Regional Office for Europe, 2016).

Among children and adolescents school is considered an important setting for health promotion, and PA and CRF are no exception (Messing et al., 2019). It is recognized that the single most important channel to address physical inactivity in youth is through school (IOM, 2013b; WHO, 2000; WHO Regional Office for Europe, 2016). Comprehensive whole-of-school approaches represent an effective strategy to address young people's physical inactivity levels (Inman et al., 2011; Naylor & McKay, 2009). The role of the school extends to encouraging children and adolescents to continue engaging in PA, by providing co-ordinated opportunities for all young people and develop partnerships with the wider community, both in the health and sports sector, to extend and to improve the opportunities available for students to remain physically active (Mountjoy et al., 2011).

Several reasons contribute to the proclamation of schools as a priority setting for promoting PA and fitness. In the first place, schools provide opportunities for children and adolescents to engage in PA during discrete periods of the day, including PE, recess, school sports programs, and other extra-curricular programs (Bocarro et al., 2012; Kelly et al., 2019; Stratton et al., 2008). This is especially important when considering youth from disadvantaged settings who have less access to PA (Hills et al., 2015). Secondly, many children and adolescents spend a great part of the day at school, about 40% of their wake time in a study from the United Kingdom (Fox et al., 2004) and between 903 to 995 hours per year in Portugal (Organisation for Economic Co-operation and Development [OECD], 2014). School-based interventions are thought to be the most universally applicable and effective way to counteract low PA and fitness since children and adolescents spend at least half of their waking hours in this setting (Mountjoy et al., 2011). Lastly, school is mandatory for children and adolescents in most countries worldwide (UNESCO, 2014), and thus its programs reach a great number of young people (Hills et al., 2015).

There is considerable evidence from middle- and high-income countries that school-based health interventions moderately promote PA and CRF (Dobbins et al., 2013; Hartwig et al., 2021). Thus, from a health promotion perspective, the school has been purposed as an important setting to promote PA and CRF (Bocarro et al., 2012; Kelly et al., 2019). However, there is a gap between demonstrating the effectiveness of such PA interventions and understanding the wide-scale implementation and/or dissemination of these interventions (Mountjoy et al., 2011). Furthermore, these interventions are not universal and may not be sustainable over long periods if senior leaders and staff that are knowledgeable, skilled and motivated to continue delivering health promotion through ever-changing circumstances are not retained (Herlitz et al., 2020). The implementation of effective school-based models into the real world setting is complex and demands a multi-partner investment over the long term (Mountjoy et al., 2011). Ecological approaches that integrate existing resources and institutions in the community are likely key to successful and sustained implementation (Mountjoy et al., 2011). Therefore, there is a need to promote sustainable health promotion actions, that can maintain their benefits for communities and populations beyond their initial stage of implementation and that can deliver within the limits of finances. One possibility for such action is through PE, which is already within the scope and budget of schools.

## 2.5. Promoting physical activity and cardiorespiratory fitness in physical education

The importance of PE to promote health is widely recognized, as PE is by far the most common method of promoting PA during the school day (Hills et al., 2015). Especially through PE, the school provides an opportunity for youth to be physically active and promote healthy lifestyles (Bocarro et al., 2012). PE, which is part of the school curriculum in most countries (UNESCO, 2014), allows children and adolescents to engage in structured, specialist-led, and appropriate PA (Mersh & Fairclough, 2010). In line with promoting health-enhancing PA, schools and PE are also important for promoting physical fitness (Institute of Medicine [IOM], 2013a). When performed appropriately and incorporated as one component of a broad and holistic health education program, fitness monitoring in PE serve as a valuable part of the curriculum and plays a role in supporting healthy lifestyles and PA (Harris & Cale, 2019).

One of the reasons why PE comprises a primacy setting for health promotion is throughout formative development which can influence positive attitudes and behaviours of young people during compulsory school attendance years (Mountjoy et al., 2011). PE makes a unique contribution to health education through the development of physical and health literacy, where students are prompt to develop the necessary skills to make healthy choices, but also through providing opportunities to engage in PA and promote fitness (IOM, 2013a; Mountjoy et al., 2011). Additionally, PE is, for the most of school curricula worldwide, the subject focused on the body's movement and physical development, helping young people to learn, respect and to value their bodies and abilities (Mountjoy et al., 2011).

PE is the only setting where all children, especially those from low socio-economic status and girls, have access to moderate-to-vigorous PA and learn important fundamental movement skills that may provide the foundation for a lifetime of PA (Harris & Cale, 2019; Hills et al., 2015). It has been shown that PE classes contribute to an increase in daily moderate-to-vigorous PA in children and adolescents (Froberg et al., 2017; Hollis et al., 2017). It is estimated that PE lessons increase daily moderate-to-vigorous PA in about 12.8 minutes compared to days without PE lessons (Mooses et al., 2017). Furthermore, PA opportunities in PE are often regular, mostly two to three times a week, and represent the most of school-based PA (Groffik et al., 2020). Participation in PE was determined as the single most important determinant of school-based PA recommendations of at least 500 steps per hour, at least 25% of school time spent in PA, and at least 20 minutes of moderate-to-vigorous PA (Groffik et al., 2020). This is especially important when considering the promotion of fitness, including CRF, as regular higher intensity PA is critical for improving it (Lang, Tomkinson, et al., 2018). Due to its importance PE guidelines often recommend that at least 50% of class time should be spent in moderate-to-vigorous PA (IOM, 2013a; Sallis et al., 2012). However, moderate-to-vigorous PA during PE is lower than the recommended levels (Hollis et al., 2017; Lonsdale et al., 2013).

Another important aspect related to PA offered in PE is the structuring and appropriateness of PA delivered (Harris & Cale, 2019; Mersh & Fairclough, 2010). PE is often delivered by specialists, namely PE teachers, with adequate training and capable of providing meaningful PA (McKenzie & Lounsbery, 2013). It is known that PE delivered by well-trained specialists increases PA during school hours in youth (IOM, 2013a). Furthermore, promoting PA and fitness in PE captures more than just the intensity of PA provided during the classes. Young people are more likely to engage in activities both in-class and outside of school, when activities are perceived as inherently meaningful, interesting and enjoyable, or hold personal relevance. Thus, Haerens et al. (2011) argue that PE can only promote an active lifestyle if the activities provided have these characteristics. This view is supported by the self-determination theory (Deci & Ryan, 2000) and reinforces the importance of promoting intrinsic motivation in PE. In this sense, PE teachers also have an important role in encouraging PA and fitness, as well as providing positive feedback which is associated with greater intentions to participate in PA (Mouratidis et al., 2008).

Besides the important action of PE in promoting PA and CRF in children and adolescents, it also has an important role in monitoring and informing about students' CRF

(Cale et al., 2014). There are several field tests available that allow the assessment of CRF in the school setting and whole school classes to be assessed in one session (Andersen et al., 2008; Leger et al., 1988), normally as a component of wider fitness testing batteries such as FITescola and FitnessGram. The most commonly used field-based CRF tests in the school setting are the Progressive Aerobic Cardiovascular Endurance Run (PACER), also known as the beep test or the 20-meter shuttle run, the 1-mile test, and the Cooper test. Therefore, PE teachers have several quality tools to assess the students' CRF. Notwithstanding, fitness testing in PE, including CRF tests, should be done within a positive and health-promoting context (Mercier & Silverman, 2014; Phillips et al., 2017). For that it is recommended that teachers (Silverman et al., 2008): a) provide meaningful practice opportunities so students become familiar with and develop value toward the tests, b) work with students to create personal goals toward physical fitness, and c) track individual progress across time.

Currently, there is a great deal of controversy regarding fitness testing in the PE curricula (Simonton et al., 2019). On the one hand, the advocates of this practice emphasise the importance of surveillance information on youth physical fitness and promoting students' self-awareness and knowledge regarding fitness and PA choices (Cohen et al., 2015; Welk, 2008). On the other hand, critics of this practice are concern about the lack of validity, misuse, and possibly harming common fitness testing practices cause students, such as negative experiences in PE that may hinder lifelong PA participation (Cale & Harris, 2009; Gard & Pluim, 2017). Both viewpoints have valid arguments that are supported by empirical evidence, thus the debate on the role and consequences of fitness testing in PE is bound to continue. A recent investigation focusing on this issue showed that fitness tests had limited associations with students' future attitudes and emotions toward PE either positive or negative (Cale & Harris, 2009). Give the well-known associations between fitness, namely CRF, and health, the importance of monitoring fitness and the role of PE in health promotion, and considering its advantages and drawbacks, we defend that fitness testing, if well performed, is an important hallmark in health promotion among children and adolescents.

Despite the potential and the benefits of PE and PA interventions in PE, scientific evidence on PE effects on CRF in children and adolescents is inconsistent (Erfle & Gamble, 2015; Park et al., 2017) and most studies examine school-based PA intervention programs (Kriemler et al., 2011) instead of curricular PE, i.e. PE lessons which were not altered by intervention components. Therefore, little is known about the associations between changes in CRF and curricular PE over time. Additionally, previous investigations focusing on the promotion of CRF in PE had mostly implemented cross-sectional or intervention designs. Cross-sectional design studies do not allow to establish the temporality and direction of the associations. On the other hand, intervention designs, by their nature, alter one or more components of PE classes, including content or intensity, which are important for the promotion of CRF. Taking that into account, there is a need for observational studies employing a longitudinal design. In this regard, it is important to investigate the role of the school setting and PE in particular for improving young people's CRF and explore possible avenues to promote CRF in the school context in a sustainable fashion. This thesis is focused on this literature gap, and provides a rationale for a line of action in the promotion of CRF among children and adolescents.

## 2.6. Physical education in Portugal

The 2013 worldwide survey of school PE, which included data of 232 countries from all continents, stated that 97% of countries include PE in their general education system (UNESCO, 2014). Portugal is one of those countries. Currently, in Portugal, PE is mandatory for all children and adolescents in the regular school until de 12$^{th}$ grade. Time allocated to PE classes ranges between 90 to 180 minutes per week depending on the grade. It is considered that PE is provided to a great proportion of children and adolescents, and that only few schools do not have available and adequate sports facilities and equipment (Mota et al., 2016).

In Portugal, for almost all schools and academic grades PE classes are provided by specialist teachers with a higher education degree in teaching PE. Currently, that degree is obtained with a master program in PE, while previously it was obtained with a bachelor program in PE.

Within the Portuguese PE curricula, it is reinforced the importance of promoting CRF, and its promotion is one of its aims. The existing PE curricula in Portugal has the following five main aims, which aims should be viewed from a quality of life, health and wellbeing perspective to promote healthy and active lifestyles (Ministério da Educação, 2001):

1. Improve physical fitness, raising physical capacities harmoniously and appropriately to the developmental needs of the student;
2. Promote knowledge regarding the improvement and maintenance of physical fitness;
3. Ensuring the learning of a set of subjects, which are representative of the different physical activities, promoting the student's multilateral and harmonious development;
4. Promote participation in PA and ensure the understanding of its importance as a health factor and component of culture, in the individual and social dimension;
5. Promote the acquisition of behaviours, attitudes, and knowledge related to interpretation and participation in social structures in which physical activities are developed.

# 3. Conceptual framework

The conceptual framework of this thesis and its investigations is presented in Figure 3.

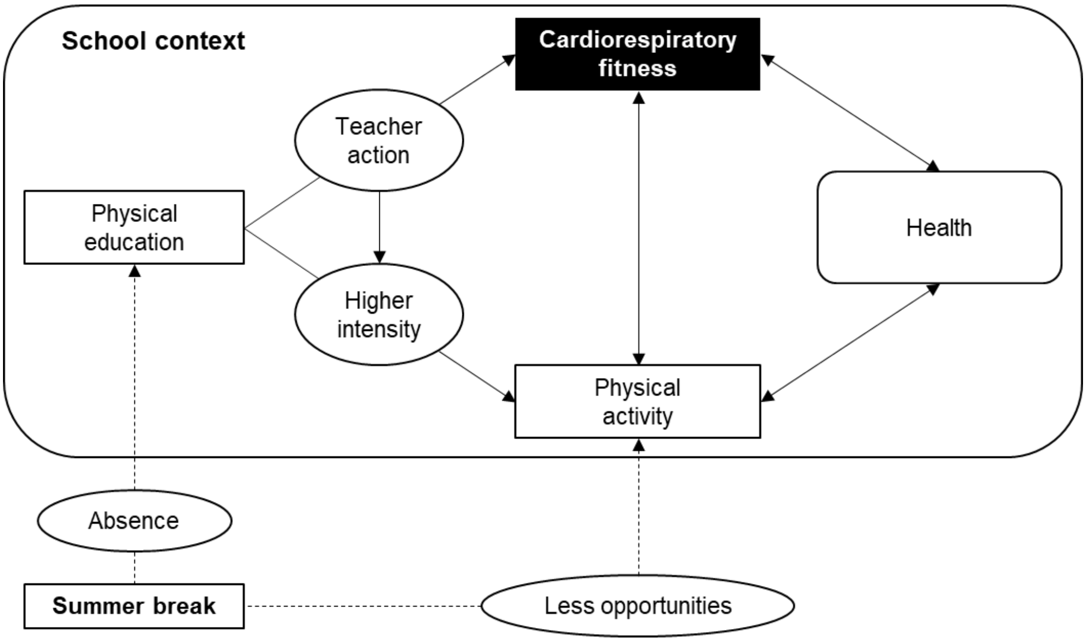


Figure 3. Conceptual framework of the thesis.

Taking into account the benefits of PA participation and greater CRF for health, and the low levels of both PA and CRF in young people, currently, there is a need to promote PA and CRF in this population. There are several contexts where PA and CRF can be promoted, however, concerning children and adolescents, school is considered as an essential context for health promotion.

Whole-of-school approaches to promote PA and CRF are often recommended because they can target specific opportunities throughout the school day such as PE, recess, class time, lunch, and commuting. Notwithstanding, PE is always considered one of the major components and the key component of these approaches. Also, PE, as an important part of the whole-of-school approach to promote PA, has a crucial role in improving fitness, including CRF, mainly because it provides structured PA that is appropriate, purposeful and overseen by specialist PE teachers.

When examining the role of school in promoting health among children and adolescents, it is also important to consider what happens when there is no school for a prolonged time, e.g. during summer break. Regarding this matter, a recent hypothesis explaining how the school setting benefits youth health and promotes PA and fitness has been proposed, the ‘Structured Days Hypothesis’. This hypothesis states that the presence of routine, and/or regulation in structured days, such as a school weekday, positively shapes the healthy behaviours of young people, with one of these behaviours being PA (Brazendale et al., 2017). Therefore, the several PA opportunities presented throughout structured days (e.g. physical education, recess, free play time before or after school hours, active transport to and from school) may positively influence young peoples’ CRF.

Despite the importance of school in general and PE in particular for promoting CRF evidence of its role is scarce, especially in the Portuguese context. Considering the conceptual framework presented hereby this thesis sought to narrow this literature gap and provide a rationale for a line of action in the promotion of CRF among children and adolescents.

# 4. Aims

Given the literature review and the conceptual framework presented before, the general and specifics aims of the thesis were established.

## 4.1. General aim

The general aim of this thesis is to investigate the promotion of health-related CRF in the school context taking into account the contribution of PE classes and its evolution throughout the school-year and summer break in children and adolescents.

## 4.2. Specific aims

To achieve the general aim of the thesis, the same was further detailed in six specific aims. The specific aims of the thesis are the following:

1. To summarize literature findings on the contribution of PE classes for promoting health-related CRF in children and adolescents;
2. To analyse the relationship between PE class intensity and change in CRF over one school-year in children and adolescents;
3. To analyse the relationship between PE class contexts and change in CRF over one school-year in children and adolescents;
4. To analyse the relationship between PE teacher behaviours and change in CRF over one school-year in children and adolescents;
5. To analyse the trends of CRF during two school-years with a 3-month summer break in children and adolescents.

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# Chapter [2]

# 5. Overall methods

This section is committed to present the general methodology and materials employed in this thesis, including the general study design, participants' recruitment, measures collected, data analysis and ethical considerations. Specific methodologies of each study that comprise the thesis are presented in Chapter 3.

## 5.1. Design and data sources

The proposed aims were accomplished by performing four studies with different study designs and data sources that warrant mentioning.

The first study conducted was a systematic review. The systematic review was performed and recorded following the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines (Moher et al., 2009; Moher et al., 2015). The PRISMA guidelines are widely followed and allow for a better understanding and clearer appraisal of the review methods and reporting.

The following two studies employed a longitudinal design where 7$^{th}$ and 8$^{th}$ grade (middle school) students from two schools were followed during one school-year (2017-2018). These observational studies used primary source data that was collected throughout the studies' period. Individual participants' data were collected in two moments, the fall of 2017 (baseline – beginning of the school-year) and spring of 2018 (follow-up – end of the school-year). This data was collected through self-reported questionnaires, physical examination and accelerometers. Data regarding PE lessons were collected in the second term, between January and April 2018, by directed observation.

The final study that is part of this thesis also followed a longitudinal study design. An observational study lasting two school-years where students from the 6$^{th}$, 7$^{th}$ and 8$^{th}$ grades (middle school) were followed was conducted. This study was based on secondary data from the Physical Activity and Family-based Intervention in Paediatric Obesity Prevention in the

School Setting (PESSOA) program. The PESSOA program aimed to develop a school-based intervention to promote healthy lifestyles knowledge and skills and was applied to children from the Oeiras municipality, in the Lisbon metropolitan area, between 2009 and 2011. More information about the PESSOA program can be found elsewhere (Sardinha et al., 2014). Participants' data were collected in four moments, the fall of 2009 and 2010 (beginning of each school-year) and spring of 2010 and 2011 (end of each school-year). Similarly, to the primary source data, secondary source data was collected through a self-reported questionnaire plus physical examination and accelerometers.

### 5.2. Participants and procedures

For the three studies that involved participants, two different samples were used. Study 2 and study 3 used a primary data sample that comprised 294 children and adolescents at baseline from 21 classes and 11 PE teachers (5 women, 6 men). From the 294 children and adolescents at baseline, five were lost to follow-up (1.7%). Participants were from two public schools located in Sintra, Portugal. The two schools are from urban areas and are located in middle-to-low income neighbourhoods. To recruit participants and perform these studies, in the first phase, school directors were contacted by the research team and authorization to conduct the study was granted. In a second phase, all PE teachers with classes in the target population grades in each school were approached to participate in the study. Afterward, in the third phase, students from classes with teachers that agreed to participate in the research were recruited by the research team in a PE lesson. Besides the participants' sample, 63 PE lessons were observed.

Study 4 used a secondary data sample from the PESSOA program. The sample comprised 440 participants with valid data on the dependent variable, all covariates, and at all time-points that were analysed. Similar to the procedures performed for studies 2 and 3, in the PESSOA program, in the first phase schools were invited to participate in the study through their directors. A total of 13 schools were invited and all of them agreed and gave their consent.

After that, both participants and their legal guardians were informed about the objectives of the study and invited to participate in the PESSOA program.

## 5.3. Measures

The main measures included in this thesis fall into the following categories: cardiorespiratory fitness, PA, PE lessons, anthropometry, maturity and sports participation. The particular measures used in each category are specified below. Additionally, participants sex and age (date of birth) were self-reported.

### 5.3.1. Cardiorespiratory fitness

CRF is the main dependent variables of all studies presented in this thesis. It was assessed using the PACER, also known as the beep test or the 20-meter shuttle run. The PACER is widely used by PE teachers in Portugal and is included in Portuguese curricula for PE (Henriques-Neto et al., 2020). The main aim of this test is to perform the maximum number of laps with a defined cadence. An audio signal was used to help the participants manage running speed during the test. The test starts with a cadence of 8.5 km per hour and increases progressively 0.5 km per hour every minute. The PACER was performed by participants at the beginning and the end of each school-year, i.e. baseline and follow-up measurements. Data were collected during PE lessons throughout one to two weeks. To ensure accurate completion of the PACER administration, one member of the researcher team and the class PE teacher supervised the entire data collection process.

Results from the PACER were recorded in the number of laps and $VO_{2peak}$. (mL/kg/min). For estimating $VO_{2peak}$ the equations of Saint-Maurice et al. (2015) were used. Participants were then classified as fit and unfit, being in or out of the CRF healthy fitness zone, according to existing standards (Welk et al., 2011). The classification was based on sex- and age-related criterion-referenced standards related to minimum levels of CRF that prevent metabolic diseases from a sedentary lifestyle.

### 5.3.2. Physical activity

Daily PA was assessed using accelerometers (ActiGraph, GT3X and GT1M models, Fort Walton Beach, FL) at baseline. The accelerometers used in this research ignored high-frequency vibrations associated with mechanical equipment. Participants were instructed to wear the accelerometer attached tightly on the hip, near the iliac crest, by an elastic belt on the right side during all waking hours except while bathing or doing other water-based activities. To increase compliance, study staff instructed children how to wear the accelerometer during the initial in-school assessment. Accelerometers were activated on the morning of the first wear day.

Individual data as recorded and downloaded into 15 seconds epochs, to allow a more refined estimate of PA intensity (Ward et al., 2005), which were reintegrated into 60 seconds epochs. This technique is consistent with previously published research (Judice et al., 2017). Data were downloaded to a computer and an automated data reduction program (MAHUffe, http/www.mrc-epid.cam.ac.uk; or ActiLife, v6.10.4) was used to analyse the raw outcome data. Periods consisting of at least 60 consecutive minutes of zero counts were considered as non-wear time (Trost et al., 2005). For a day to be considered valid participants needed to present at least 600 minutes (10 hours) of recorded wear time. Participants had to present at least three valid days (including at least 1 weekend day and 2 weekdays) to have valid accelerometer data.

Accumulated daily PA data was expressed as minutes. To differentiate between PA intensities a cut-off system was used. The cut-points capture the sporadic nature of children's activity and provide the best classification accuracy among the currently available cut-points for PA in children. Activity levels were expressed in terms of counts per minute, and intensity thresholds were defined according to pre-existing validated criteria (Evenson et al., 2008; Trost et al., 2011). Accelerometer counts ≥100 counts/min were identified as active time and posteriorly separated as moderate PA (2296 to 4011 counts/min) and vigorous PA (≥4012 counts/min).

### 5.3.3. Physical education lessons

PE lessons were assessed using the System for Observing Fitness Instruction Time (SOFIT) by a member of the research team. The SOFIT is a visual observation instrument, previously validated, that allows collecting data regarding PE lesson intensity, PE lesson context, and PE teacher behaviour (McKenzie et al., 1991; McKenzie & Smith, 2017). It uses momentary time sampling methods, specifically 10 seconds observe, 10 seconds record cycles, to code data. More information on the SOFIT protocol can be found in the procedures manual (McKenzie, 2015).

The SOFIT was performed in a total of 63 PE lessons of 21 classes. Three lessons from each class were observed, one in each of the three different spaces available in the participating schools. The spaces for PE classes were: a small gym, normally used to teach gymnastics, dance and aerobics; a large multiuse gym, usually for team games, such as volleyball, basketball, handball and football, and racket games; and an outdoor field, where team games, such as volleyball, basketball and handball, and athletics were performed. Mean values from the three PE lessons were calculated for each class.

PA levels and intensity during PE lessons were coded according to a 5-point Likert scale with the following options: 1) lying down; 2) sitting; 3) standing; 4) walking (moderate level of intensity); and 5) very active (vigorous level of intensity). Students were classified accordingly to those options. SOFIT has been previously validated as a measure of PA during PE classes (McKenzie et al., 1991). Also, it shows moderately strong correlations, ranging from 0.50 to 0.54, with ActiGraph accelerometers for PA levels during PE classes (Sharma et al., 2011). Intensity values were transformed to percentages of PE time because the class length was not equal for every class. In one school three PE classes of 50 minutes were performed per week. While, in the other school two PE classes, one of 50 minutes and one of 100 minutes were performed per week.

The PE lesson context dimension, i.e. how lesson time is being spent, was classified according to three categories, general content, knowledge content, and motor content. General content includes the lesson situations that students spent in transition, management, and break times. Knowledge content refers to situations where the primary focus is on student acquisition of knowledge related to PE, while not being physically active. Lastly, motor content includes the time when students are in motor engagement, this category is further divided into fitness, skill practice, game play, and free play.

Lastly, PE teacher behaviour, i.e. time spent in what the teacher is doing, was coded in six categories, including time spent promoting fitness, demonstrating fitness, instructing generally, managing, observing, or doing other tasks.

### 5.3.4. Anthropometry

Anthropometric measures include height, weight and body mass index (BMI). All participants were weighed to the nearest 0.01 kg on an electronic scale (model 799 SECA, Seca GmbH, Hamburg, Germany) while wearing minimal clothes (t-shirt and shorts) and without shoes. Height was measured to the nearest 0.1 cm with a flexible anthropometric tape on the wall or using a portable stadiometer (model 220 SECA, Seca GmbH, Hamburg, Germany), without shoes. Body mass (kg) was divided by the square of height (m) to compute the BMI (Quetelet's index). The BMI z-score was calculated and participants were classified into normal weight, overweight, and obese, according to the WHO sex- and age-related criterion-referenced standards (de Onis et al., 2007).

### 5.3.5. Maturity

Maturity offset was estimated based on sex-specific prediction equations suggested by Moore et al. (2015). The used equations were the following: boys' maturity offset = -7.999994+ (0.0036124*(age*height))); girls' maturity offset = -7.709133+ (0.0042232*(age*height))). Age at peak height velocity (PHV), age of maximum growth during puberty, was calculated as the difference between chronological age and maturity offset.

### 5.3.6. Sport participation

Sport participation was self-reported. Participants were asked whether they currently participate in organized sports outside of school, e.g. team sports, swimming, dance or fitness classes, independent of being involved in competition or performance settings. A dichotomous response option was provided, yes or no.

## 5.4. Data analysis

Different data analysis methodologies and statistical procedures were employed in each study. Study 1, a systematic review of the literature, followed the PRISMA guidelines (Moher et al., 2009; Moher et al., 2015) for data extraction and reporting, no statistical procedures were engaged in this study. For the other studies (study 2 to 4) a summary of the data used (including sample and measures) and statistical procedures applied is presented in Table 1. Data analysis was performed using Statistical Package for the Social Sciences ([SPSS] v.26, SPSS Inc., an IBM Company, Chicago, IL). Statistical significance was set at $p<0.05$.

Table 1. Summary of the data used (including sample and measures) and statistical procedures applied in studies 2 to 4.

| Study | Data source; participants | Measures | Statistical procedures |
|---|---|---|---|
| Study 2 | Primary data; 105 boys, 107 girls | Age; Age at PHV; BMI; Moderate and vigorous PA; PACER laps; Sex; SOFIT; Sport participation; $VO_{2peak}$ | Descriptive statistics; Independent samples t-test; Chi-square; McNemar test; Standardized and unstandardized multivariate linear regression |
| Study 3 | Primary data; 105 boys, 107 girls | Age; Age at PHV; BMI; Moderate and vigorous PA; PACER laps; Sex; SOFIT; Sport participation; $VO_{2peak}$ | Descriptive statistics; Independent samples t-test; Chi-square; Unstandardized multivariate linear regression |
| Study 4 | Secondary data from PESSOA; 218 boys, 222 girls | Age; Age at PHV; BMI; Moderate and vigorous PA; PACER laps; Sex; $VO_{2peak}$ | Descriptive statistics; Independent samples t-test; Chi-square; Repeated measures polynomial ANCOVA model |

Note: ANCOVA, analysis of covariance; PA, physical activity; PACER, Progressive Aerobic Cardiovascular Endurance Run; PESSOA, Physical Activity and Family-based Intervention in Paediatric Obesity Prevention in the School Setting; PHV, peak height velocity; SOFIT, System for Observing Fitness Instruction Time

Common statistical procedures to all studies include descriptive statistics calculated for all variables (means, standard deviation, and relative frequency), for the whole sample and stratified by sex. Differences between boys and girls were tested by the independent samples t-test, for continuous variables, and chi-square test, for nominal variables. Specific statistical techniques utilized in each study are described below.

In study 2, the prevalence of participants in the healthy CRF zone (fit), the number of PACER laps performed, and estimated peak oxygen uptake ($VO_{2peak}$) in the beginning and the end of the school-year was compared using the paired samples t-test and McNemar test, allowing to assess school-year differences. Afterwards, multivariate linear regression models were performed to examine which factors explained changes in PACER laps from the beginning to the end of the school-year, including sex, age, BMI, moderate and vigorous PA, sport participation, and percentage of PE time walking and being very active. Analyses for multicollinearity were conducted with the variance inflation factor and tolerance. Multicollinearity problems among variables were not observed. The models were conducted for the whole sample and stratified by sex and adjusted to age at PHV accelerometer wear time, PACER laps at baseline, and each of the explaining variables in the model. Both unstandardized coefficients (B) and standardized coefficients (β) were calculated to have indicators of measured unit estimates (absolute magnitude) and z-score estimates (relative magnitude).

For study 3, to examine the effect of the percentage of time spent in each of the SOFIT lesson context and teacher behaviour categories on the change in PACER laps from the beginning to the end of the school-year, multivariate linear regression models (B; 95% confidence interval [95%CI]) were performed. Models were stratified by sex and adjusted to age, age at PHV, BMI, moderate and vigorous PA, accelerometer wear time, PACER laps at baseline, and sport participation.

Study 4 specifically employed repeated measures general linear models to analyse differences and trends in $VO_{2peak}$ and being in the CRF healthy fitness zone (fit) at the beginning and the end of the school-years 1 and 2. Analysis were stratified by sex because of an existing interaction effect between sex and time. Polynomial analysis of covariance (ANCOVA) models, using the Huynh-Felt correction due to the lack of sphericity, with Bonferroni *post hoc* analysis for multiple comparisons were tested. The models were adjusted for baseline age, age at PHV, BMI, moderate and vigorous PA, and accelerometer wear time.

### 5.5. Ethics

The aim and overall aspects of the study were explained to the possible participants according to ethical references and informed consents were distributed. Only children and adolescents who returned the informed consent signed by their legal guardians were eligible to participate in the study. Before conducting the data collection, the study protocol was submitted to an ethics committee and schools were contacted. School directors and PE teachers in each school granted authorization to conduct the study and declare willingness to participate in the study. The studies that used primary source data had the protocol approved by the ethics committee of the Faculty of Human Kinetics, University of Lisbon (no. 19/2017) and by the Portuguese national commission for data protection (no. 9249/2017).

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# Chapter [3]

# 6. Results

To pursue this thesis' aim and specific aims four scientific studies were developed. In this section the results of the current thesis are presented in the form of those four studies.

Study 1, titled 'Promoting health-related CRF in PE: a systematic review', reviews the existing evidence regarding the contribution of PE classes for children and adolescents CRF. This study was devoted to attaining specific aim 1: to summarize literature findings on the contribution of PE classes for promoting health-related CRF in children and adolescents.

Study 2, that analysed the contribution of PE intensity and daily PA for children and adolescents' CRF, is titled 'Promoting health-related CRF in PE: the role of class intensity and habitual PA'. This study sought to accomplish specific aims 2: to analyse the relationship between PE class intensity and change in CRF over one school-year in children and adolescents.

Study 3 is titled 'Promoting health-related CRF in PE: the role of lesson context and teacher behaviour in an observational longitudinal study' and analysed the relationship between PE lesson context and PE teacher behaviour with children and adolescents' CRF. It pursued to achieve specific aims 3 and 4: to analyse the relationship between PE class contexts and change in CRF over one school-year in children and adolescents; and, to analyse the relationship between PE teacher behaviours and change in CRF over one school-year in children and adolescents.

Lastly, study 4 examined the trends in children and adolescents' CRF during two school-years and a summer break and is titled 'The effect of school-year and summer break in health-related cardiorespiratory fitness: a 2-year longitudinal analysis'. This study sought to attain specific aim 6: to analyse the trends of CRF during two school-years with a 3-month summer break in children and adolescents.

## 6.1. Study 1 – Promoting health-related cardiorespiratory fitness in physical education: a systematic review

### 6.1.1. Abstract

**Background:** This article aimed to systematically review the contribution of PE classes to improve CRF in children and adolescents; and to define potentially relevant factors for promoting CRF in PE classes.

**Methods:** Studies were identified from searches in ERIC, PubMed, SPORTDiscus, and Web of Science databases. Primary source articles, relating PE classes and CRF, published up to July 2019 in peer-reviewed journals were eligible for inclusion. Specific inclusion criteria were: (a) having cross-sectional or longitudinal and observational or interventional study designs; (b) targeting school-aged children or adolescents; (c) measuring CRF, heart rate or CRF test results as an outcome; (d) having statistical analyses of the CRF, heart rate or CRF test results outcomes reported; (e) focusing on PE classes or PE interventions that did not extended time or frequency of the classes; and (f) published in English, French, Portuguese, or Spanish.

**Results:** A total of 24 studies met the inclusion criteria. Overall, 10 studies have found a neutral effect of PE classes in students' CRF, eight studies found that PE indeed contributed to the improvement of CRF and six studies revealed mixed findings, when PE classes where controlled for others variables (e.g. BMI, intensity). Higher intensity PE classes consistently demonstrated contributions to improving students' CRF.

**Conclusion:** Review findings suggest that PE classes can contribute to the improvement of students' CRF. Intensity, age and weight status were identified as potentially relevant factors for promoting CRF in PE classes. To improve CRF, higher intensity classes should be provided.

### 6.1.2. Introduction

CRF mirrors the overall capacity of the cardiovascular and respiratory systems (Castro-Pinero et al., 2012). It is considered as an important health variable, which is associated with several risk factors for cardiovascular diseases independent of socio-demographic factors, diet, and PA (Andersen et al., 2006; Hurtig-Wennlof et al., 2007). Furthermore, CRF is suggested to be a significant risk factor to include in the assessment of the metabolic syndrome for children and adolescents (Andersen et al., 2015). Hereby, the study of this variable and its associations to health is widely recognized as essential both among adults and youth.

The school setting gives youth the opportunity to be physically active, mainly through PE classes (Bocarro et al., 2012). For this reason, the school system is viewed as an important means of promoting PA and health among children and adolescents. When performed appropriately and incorporated as one component of a broad and holistic health education programme, fitness monitoring in PE serve as a valuable part of the curriculum and play a role in supporting healthy lifestyles and PA (Harris & Cale, 2019).

It has been suggested that PE classes may play a significant role in CRF development (Chen et al., 2014; Coledam et al., 2018; IOM, 2013) and monitoring (Cale et al., 2014), as there are a number of field tests available that allow whole school classes to be assessed in one session (Andersen et al., 2008; Leger et al., 1988). Therefore, PE teachers have several quality tools to assess the students' CRF. Notwithstanding, evidence regarding the contribution of PE classes for the development of CRF in children and adolescents is inconsistent (Erfle & Gamble, 2015; Park et al., 2017) and most studies examine school-based PA intervention programs (Kriemler et al., 2011) instead of curricular PE.

Although the school setting and PE classes offer a platform that might help for improving (Coledam et al., 2018; IOM, 2013) and monitoring (Cale et al., 2014) of CRF, recent studies suggest that in the last decades CRF appears to have declined in children and adolescents worldwide (Catley & Tomkinson, 2013; Garber et al., 2014). Due to its importance, this evidence is of great concern. In order to begin reversing the decline in CRF, understanding how PE classes contribute to the improvement and maintenance of CRF in children and adolescents is vital. To the best of our knowledge, there is no study available that summarizes findings regarding the effect of PE classes on the CRF of students. Thus, the aims of this review were: (1) to summarize literature findings on the contribution of PE classes for improving CRF in children and adolescents; and (2) to define, based on this review, potentially relevant factors for promoting CRF in PE classes.

### 6.1.3. Methods

#### Study identification

Four relevant electronic databases (PubMed, ERIC, SPORTDiscus, and Web of Science) were comprehensively searched to identify peer-reviewed articles published up to July 2019. Definition of search terms was discussed among the authors. The identified search terms were: “physical education” AND (cardiorespiratory OR cardiopulmonary OR cardiovascular OR endurance OR aerobic OR fitness OR PACER OR FitnessGram OR $VO_2$ OR “physical condition” OR “physical aptitude”). Search terms were used in each database to identify potential articles with abstracts for review.

#### Study selection and selection criteria

Primary source articles, relating PE classes and CRF, published up to July 2019 in peer-reviewed journals were eligible for inclusion. Specific inclusion criteria were: (a) having cross-sectional or longitudinal and observational or interventional study designs; (b) targeting school-aged children or adolescents; (c) measuring CRF, heart rate or CRF test results as an outcome; (d) having statistical analyses of the CRF, heart rate or CRF test results outcomes reported; (e) focusing on PE classes or PE interventions that did not extended time or frequency of the classes; and (f) published in English, French, Portuguese, or Spanish. Articles that did not meet all the inclusion criteria were excluded. Duplicates from the electronic database search were deleted. Titles and abstracts of the retrieved articles were independently assessed for eligibility for inclusion by two authors (AM, MP). Full texts of all eligible articles were retrieved, and other possible relevant studies were searched in the references of those articles. Two authors (AM, MP) reviewed the text of potential studies, and decisions to include or exclude studies in the review were made by consensus.

#### Data extraction and harmonization

Based on the PRISMA statement (Moher et al., 2015) a data extraction form was applied. Relevant data was extracted from manuscripts by one author (MP); coding was verified by two other authors (AM, ERG). Divergences were discussed among authors and solved. Data extracted included study design, sample size, age, country, content of PE / intervention, outcome measure, method and main findings. Outcome measures were either a direct (e.g. maximal oxygen uptake [$VO_{2max}$]) or indirect measure (e.g. number of laps) of CRF, or heart rate during exercise. Main findings are presented as a description of the contribution of PE classes to the CRF.

#### Study quality and risk of bias

The Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (USDHHS, 2014) was used to appraise risk of bias (study quality). This tool comprises a 14 item checklist for longitudinal studies, while for cross-sectional studies only 11 items could be applied. According to the criteria, each longitudinal and cross-sectional study was rated either good (when meeting 10-14 and 8-11 criteria, respectively), fair (when meeting 5-9 and 4-7 criteria, respectively), or poor (when meeting 1-4 and 1-3 criteria, respectively). Study quality was assessed by two researchers (AM, MP) independently and discrepancies were discussed and solved by agreement.

### 6.1.4. Results

#### Literature search

Figure 4 presents the flow diagram of studies through the systematic review process. The systematic literature search identified a total of 582 studies. Additionally, one study was identified through a manual search and added to the review process. Out of these 583 studies, 225 were duplicated and thus removed, resulting in a total of 358 studies for title and abstract screening. After excluding studies at the title and abstract screening (n=268), 90 studies were eligible for full-text reading and 66 were excluded with reasons. Therefore, a total of 24 studies were identified as relevant and included in this review.

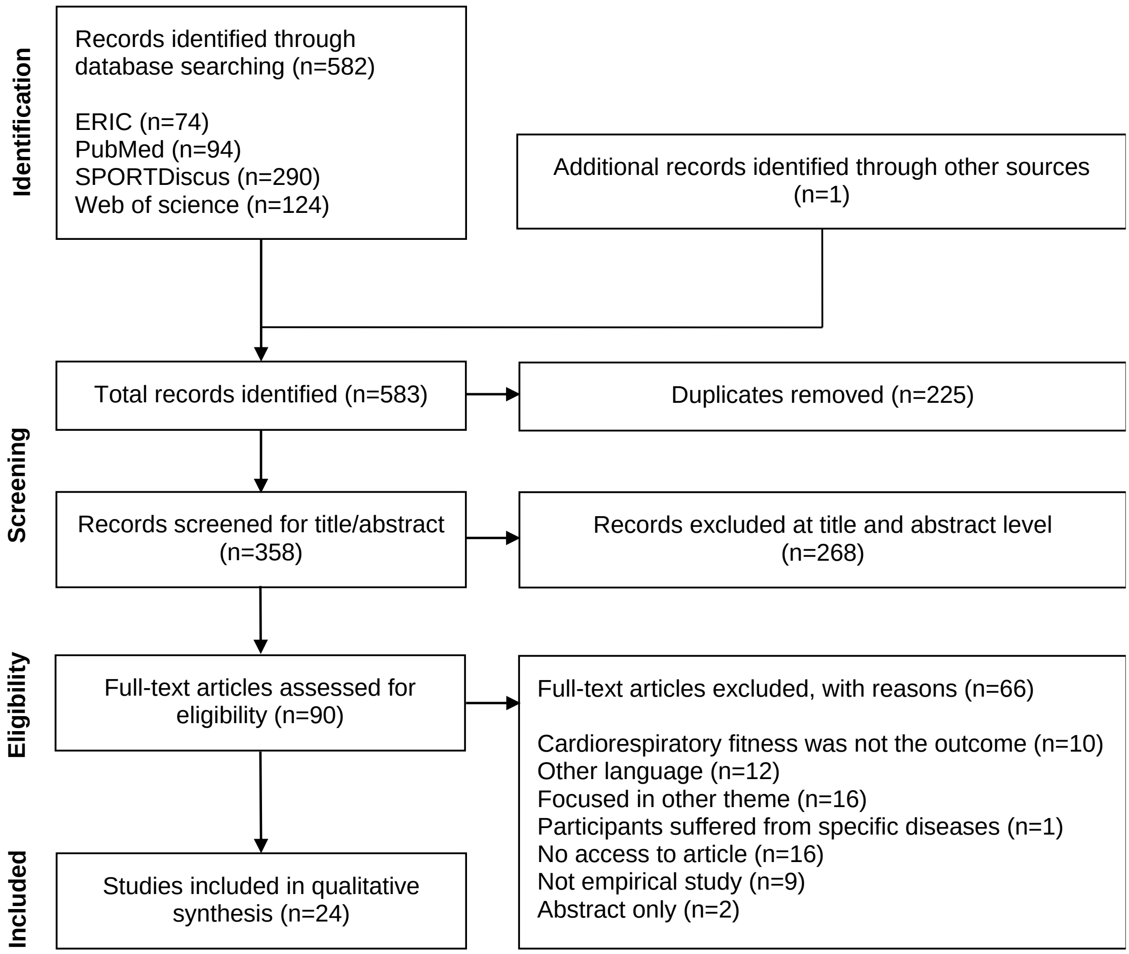


Figure 4. Flow diagram of studies.

### Risk of bias of included studies

Risk of bias of included studies was assessed by the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (USDHHS, 2014) and is presented in Table 2. Most studies (19 out of 24) were classified as 'fair', one study received a 'poor' classification, and the other four studies were considered 'good'.

Table 2. Risk of bias of included studies.

| **Author** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumming et al., 1969 | N | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Crowhurst et al., 1993 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Strand & Reeder, 1993 | Y | Y | CD | Y | N | Y | NA | CD | N | NA | Y | Y | NA | N | Fair |
| Baquet et al., 2001 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Baquet et al., 2002 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Koutedakis & Bouziotas, 2003 | Y | Y | N | Y | Y | Y | NA | Y | Y | NA | Y | N | NA | N | Good |
| Beets & Pitetti, 2005 | N | Y | CD | Y | N | Y | NA | N | Y | NA | Y | N | NA | N | Fair |
| Fairclough & Stratton, 2005 | Y | Y | N | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Fairclough & Stratton, 2006 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Laurson et al., 2008 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Pelclova et al., 2008 | Y | Y | CD | N | N | Y | NA | N | Y | NA | Y | N | NA | N | Fair |
| Gallotta et al., 2009 | Y | Y | N | Y | N | Y | Y | N | Y | N | Y | N | CD | N | Fair |
| Camhi et al., 2011 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Ramirez Lechunga et al., 2012 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Lucertini et al., 2013 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Reed et al., 2013 | Y | Y | N | Y | N | Y | Y | Y | Y | Y | Y | N | CD | Y | Good |
| Bendikson et al., 2014 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Rengasamy et al., 2014 | Y | Y | CD | Y | N | N | Y | N | N | N | Y | N | CD | N | Fair |
| Erfle & Gamble, 2015 | Y | Y | Y | Y | N | Y | Y | Y | Y | N | Y | N | N | Y | Good |
| Mayorga-Veiga & Viciana, 2015 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Jarani et al., 2016 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | Y | Y | Good |
| Mayora-Veiga et al., 2016 | Y | Y | CD | Y | N | Y | Y | N | Y | N | Y | N | CD | N | Fair |
| Andres, 2017 | Y | N | CD | CD | N | Y | Y | N | CD | N | N | N | CD | N | Poor |
| Park et al., 2017 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |

Y, yes; N, no; CD, cannot determine; NA, not available

### Study characteristics

Study characteristics are summarized in Table 3. Included studies presented several designs (intervention, observational cross-sectional and observational longitudinal), outcome measures ($VO_{2max}$, heart rate, test result), and methods to asses CRF. Studies from 14 countries were included, most of them with a mixed-sex sample.

Table 3. Characteristics of the included studies.

| Characteristics | Number of studies |
|---|---|
| Study design | |
| Cross-sectional | 7 |
| Longitudinal | 2 |
| Intervention | 15 |
| Outcome measured | |
| $VO_{2max}$ / predicted $VO_{2max}$ | 7 |
| Heart rate | 10 |
| Distance covered | 3 |
| Test duration | 6 |
| Number of laps | 1 |
| Methods used | |
| Cycle ergometer protocol | 2 |
| Monitoring heart rate | 10 |
| PACER test | 2 |
| Multistage 20-meter shuttle run test | 4 |
| Yo-Yo Intermittent Recovery Level 1 Children's test | 1 |
| Intermittent shuttle run test | 1 |
| 1-mile run/walk test | 2 |
| 1-km run/walk test | 2 |
| 12-Minute Cooper's Test | 1 |
| 7-minute running test | 1 |
| Gas analyser | 1 |
| Sample characteristics | |
| Country | |
| Albania | 1 |
| Canada | 1 |
| Czech Republic | 1 |
| Denmark | 1 |
| England | 2 |
| France | 2 |
| Greece | 1 |
| Italy | 2 |
| Malaysia | 1 |
| Poland | 1 |
| Spain | 3 |
| South Korea | 1 |
| Ukraine | 1 |
| United States of America | 7 |
| Sex | |
| Boys and girls | 19 |
| Boys | 2 |
| Girls | 3 |
| Age | |
| Younger ages (6-12 years old) | 6 |
| Older ages (11-19 years old) | 18 |
| Study quality | |
| Poor | 1 |
| Fair | 19 |
| Good | 4 |

PACER, Progressive Aerobic Cardiovascular Endurance Run; $VO_{2max}$, maximal oxygen uptake

### Main findings

Table 4 shows the main findings and characteristics of the studies included in this review. Included studies ranged from 1969 to 2017, demonstrating that scientific interest in the contribution of PE to promote CRF is close to 50 years old. Overall, 10 studies have found a neutral effect of PE classes in students' CRF, eight studies found that PE indeed contributed to the improvement of CRF and six studies revealed mixed findings, when PE classes where controlled for others variables (e.g. BMI, intensity). Although 24 studies were included in this review some presented more than one relevant finding, therefore, 33 findings regarding the contribution of PE to the promotion of students' CRF are presented. This resulted in 16 findings indicating that PE did contribute to the improvement of students' CRF, whereas 14 findings point to a neutral effect and 3 findings suggesting that students' CRF decreased during a given time period in a PE program. However, there was some heterogeneity in the study populations, as well as PE class characteristics included in this review that must be considered.

Findings from younger students (n=7) (Bendiksen et al., 2014; Gallotta et al., 2009; Jarani et al., 2016; Lucertini et al., 2013; Park et al., 2017; Reed et al., 2013), ranging from 6 to 12 years, showed mainly that participation in PE classes improved the students' CRF (Lucertini et al., 2013; Park et al., 2017; Reed et al., 2013), and in two of these studies the improvements were due to high intensity (whether fitness-oriented or game-oriented) PE classes (Bendiksen et al., 2014; Jarani et al., 2016). Notwithstanding, two other studies from this set concluded that PE had a neutral students' CRF (Bendiksen et al., 2014; Gallotta et al., 2009). On the other hand, findings from older students (n=26), with a wider age range (approximately 11 to 19 years), were mixed. A total of 15 findings from 14 studies showed that PE had a neutral effect on students' CRF (n=15) (Andres, 2017; Beets & Pitetti, 2005; Camhi et al., 2011; Crowhurst et al., 1993; Cumming et al., 1969; Erfle & Gamble, 2015; Fairclough & Stratton, 2005b, 2006; Koutedakis & Bouziotas, 2003; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012; Reed et al., 2013; Strand & Reeder, 1993). While, 11 findings from nine studies reported that PE had a positive effect in children's and adolescents' CRF (Baquet et al., 2001; Baquet et al., 2002; Camhi et al., 2011; Laurson et al., 2008; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Pelclová et al., 2008; Ramirez Lechuga et al., 2012; Rengasamy et al., 2014).

Studies concluding that PE classes had a neutral effect on students' CRF are supported by two main findings: (1) children and adolescents participating in PE classes did not improve or decreased their CRF during a given time period (n=7) (Andres, 2017; Cumming et al., 1969; Erfle & Gamble, 2015; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012; Reed et al., 2013); and (2) PE classes did not provide sufficient intensity for achieving an aerobic benefit (n=5) (Crowhurst et al., 1993; Fairclough & Stratton, 2005b, 2006; Mayorga-Vega et al., 2016; Strand & Reeder, 1993). Besides these findings, two other studies found that students participating only in PE classes had lower CRF levels than their peers participating in school-sponsored sports programs (Beets & Pitetti, 2005) and in extracurricular organized PA (Koutedakis & Bouziotas, 2003).

Almost all studies (n=10) with findings indicating that PE contributed to improving CRF in students are related with the intensity level of the classes. Six studies indicated that high intensity PE classes, involving fitness activities or aerobic training, improved the students' CRF in a given time period (Baquet et al., 2001; Baquet et al., 2002; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012; Rengasamy et al., 2014). Furthermore, three other studies showed that high intensity and fitness-oriented PE classes had more than 50% of time spent in moderate-to-vigorous PA (Laurson et al., 2008; Mayorga-Vega et al., 2016; Pelclová et al., 2008). Finally, one study identified fitness activities as the greatest provider of time in moderate-to-vigorous PA, compared with individual games and team games (Laurson et al., 2008).

One study (Camhi et al., 2011), in which the analysis was divided into three groups according to BMI classification, showed that: while normal-weight and overweight girls enrolled in PE showed improvements in fitness, as well as maintenance of these improvements; obese girls, enrolled in the same PE program, did not.

From the review of the results, three potential relevant factors for promoting CRF in PE classes were identified: students' age, PE classes' intensity, and students' weight status.

Table 4. Characteristics and main findings of the studies included in the systematic review.

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Cumming et al., 1969 | Longitudinal, n=89 (boys only), 6th and 10th graders | Canada | Fair | $VO_2$max | Submaximal cycle ergometer protocol | Not specified | (±) No changes in the $VO_2$max from September to June of the following year (nine months) |
| Crowhurst et al., 1993 | Cross-sectional, n=9 (girls only), $M_{age}$=14.6 years | USA | Fair | (1) $VO_2$max (2) Heart rate | (1) Incremental, maximal cycle ergometer protocol (2) Heart rate monitor during PE lessons | Basketball and floor hockey | (±) The intensity of PE classes (in minutes exercised at >50% of $VO_2$max) may not generally be sufficient for achieving an aerobic benefit |
| Strand & Reeder, 1993 | Cross-sectional, n=55, age range=12 to 13 years | USA | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. football, dodgeball), swimming and wrestling | (±) Students spend <50% of time in their assigned training zone (>60% of heart rate reserve) |
| Baquet et al., 2001 | Intervention, n=551 (52% boys), age range=11 to 16 years | France | Fair | Distance covered | 7-minute running test | Running | (+) High intensity PE (aerobic training) classes improves CRF |
| Baquet et al., 2002 | Intervention, n=345 (59% boys), age range=11 to 16 years | France | Fair | Heart rate | Heart rate monitor during PE classes | Running, jumping | (+) High intensity PE classes (in % time spent >50%, 60% and 75% of heart rate reserve) may improve CRF |
| Koutedakis & Bouziotas, 2003 | Intervention, n=84 (boys only), $M_{age}$=13.6 years | Greece | Good | $VO_2$max | Multistage 20-meter shuttle run test | Team games (e.g. football, handball), swimming, athletics, tennis | (±) Students participating only in PE classes have lower levels of $VO_2$max than students participating in PE classes and other extracurricular organized physical activities |
| Beets & Pitetti, 2005 | Cross-sectional, n=187(64% boys), age range=14 to 19 years | USA | Fair | $VO_2$max | PACER test | Team activities | (±) Students participating in PE classes have lower levels of $VO_2$max than students participating in school-sponsored sports programs |
| Fairclough & Stratton, 2005 | Cross-sectional, n=122 (50% boys), age range=11 to 14 years | England | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. football, softball), individual games (e.g. badminton, tennis), movement activities (e.g. dance, gymnastics) and individual activities (e.g. athletics, fitness) | (±) Students spent <50% of time in MVPA. Students participated in most MVPA during team games and the least during movement activities |
| Fairclough & Stratton, 2006 | Cross-sectional, n=68 (49% boys), age range=11 to 14 years | England | Fair | Heart rate | Heart rate monitor during PE classes | Team games, individual games, gymnastic, dance | (±) Students spent <50% of time in MVPA |

*(Continued)*

Table 4. (Continued).

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Laurson et al., 2008 | Cross-sectional, n=796 (53% boys), $M_{age}$=16 years | USA | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. volleyball, ultimate frisbee), individual games (e.g. golf, dance), fitness activities (e.g. aquatics, bleachers) | (+) 71% of class time was spent in MVPA (>50% of maximum heart rate)<br>(+) Fitness activities provided greater % of time above the lower heart rate threshold than individual and team games |
| Pelclová et al., 2008 | Cross-sectional, n=241 (girls only), $M_{age}$=16.0 years | Czech Republic and Poland | Fair | Heart rate | Heart rate monitor during PE classes | Dance and aerobic dance | (+) Girls spent more than 50% of class time (aerobic dance classes) in MVPA (>60% of maximum heart rate) |
| Gallotta et al., 2009 | Intervention, n=152, age range=11 to 12 years | Italy | Fair | Test duration | 1-mile run/walk test | Pre-tumbling, rhythmic gymnastics, ball mini-games, dexterity circuits | (±) There were no significant differences in the 1-mile run/walk test results five months apart, for both control (regular PE classes) and intervention groups |
| Camhi et al., 2011 | Longitudinal, n=131 (girls only), $M_{age}$=13.8 years | USA | Fair | Heart rate | Heart rate monitor during submaximal step test | Aerobic dance, football, walking/jogging, fitness activities (e.g. resistance training, circuit training), swimming, basketball, volleyball, recreational games | (+) Normal-weight and overweight girls enrolled in an eight months PE program showed improvement in fitness (decrease in stage 1 heart rate), as well as maintenance of these effects over the two next years<br>(±) Obese girls showed no fitness improvements in response to the same PE program. |
| Ramirez Lechuga et al., 2012 | Intervention, n=84 (61% boys), age range=15 to 18 years | Spain | Fair | $VO_2max$ | Portable gas analyser during multistage 20-meter shuttle run test | Running | (+) A eight weeks high intensity aerobic training program developed in PE classes improved students' $VO_2max$<br>(±) During the same 8-week period, regular PE classes did not improved students' $VO_2max$ |
| Lucertini et al., 2013 | Intervention, n=101, (50% boys), 3rd to 5th graders | Italy | Fair | $VO_2max$ | Multistage 20-meter shuttle run test | Basic motor skills, rhythm, coordination, endurance, strength, flexibility | (+) Specialist led and generalist teacher led PE classes increased primary school children's $VO_2max$ during a six months period |
| Reed et al., 2013 | Intervention, n=470 (50% boys), 2nd to 8th graders | USA | Good | Number of laps | PACER test | Fundamental skills, multiactivity sport theme curriculum | (+) CRF of elementary school students participating in regular PE increased in an eight months' period<br>(–) CRF of middle school students participating in regular PE decreased in an eight months period |
| Bendiksen et al., 2014 | Intervention, n=91 (55% boys), age range=8 to 9 years | Denmark | Fair | (1) Heart rate<br>(2) Distance covered | (1) Heart rate monitor during YYIR1C<br>(2) YYIR1C | Team games (e.g. football, unihockey), individual games (e.g. walking, parkour), Nintendo Wii Boxing, Nintendo Wii Tennis | (±) Students participating in regular PE classes did not improve CRF (distance covered and % of maximal heart rate) in a six weeks' period<br>(+) Students participating in high intensity PE classes improved CRF (distance covered and % of maximal heart rate) in a 6 weeks period |

*(Continued)*

Table 4. (Continued).

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Rengasamy et al., 2014 | Intervention, n=173 (50% boys), $M_{age}$=16 years | Malaysia | Fair | Distance covered | 12-Minute Cooper's Test | Circuit training | (+) A 10-week fitness program implemented within PE classes enhanced the students' CRF |
| Erfle & Gamble, 2015 | Intervention, n=10206 (50% boys), 6th to 8th graders | USA | Good | Test duration | 1-mile run/walk test | Not specified | (±) Students participating in regular PE classes did not improve CRF during one school year |
| Mayorga-Veiga & Viciana, 2015 | Intervention, n=178 (58% boys), elementary and middle school children | Spain | Fair | Test duration | Multistage 20-meter shuttle run test | Fitness activities (e.g. circuit training, multi-jumps), team games | (–) CRF of middle school students participating in regular PE decreased in eight weeks' period<br>(+) CRF of elementary and middle school students with low CRF participating in high intensity PE classes (fitness program) improved in an eight weeks period |
| Jarani et al., 2016 | Intervention, n=767 (52% boys), 1st and 4th graders | Albania | Good | $VO_2$max | Intermittent shuttle run test | Throwing/catching, rhythm activities (e.g. dance), fitness activities, tumbling / gymnastics | (+) Exercise (fitness) and game-oriented PE classes improved children's CRF and have greater effect in improving CRF than other PE classes |
| Mayorga-Veiga et al., 2016 | Intervention, n=111 (63% boys), $M_{age}$=12.5 years | Spain | Fair | (1) Test duration<br>(2) Heart rate | (1) Multistage 20-meter shuttle run test<br>(2) Heart rate monitor during PE classes | Fitness activities (circuit training, multi-jumps), team games | (+) Students participating in high intensity PE classes (fitness program) improved CRF in a nine weeks' period and maintained the improvements after four weeks detraining period<br>(+) High intensity PE classes had >50% of time in MVPA<br>(–) Students participating in regular PE classes decreased CRF in a nine weeks' period<br>(±) Regular PE classes had <50% of time in MVPA |
| Andres, 2017 | Intervention, n=100 | Ukraine | Poor | Test duration | 1-km run/walk test | Not specified | (±) No improvements in CRF from October to May of the following year (seven months) |
| Park et al., 2017 | Intervention, n=48 (50% boys), $M_{age}$≈12 years | South Korea | Fair | Test duration | 1-km run/walk test | Fitness activities (e.g. burpees, shuttle run) | (+) CRF of children participating in PE improved, while CRF of children not participating in PE decreased after an eight weeks period |

CRF, cardiorespiratory fitness; PE, physical education; PACER, progressive aerobic cardiovascular endurance run; YYIR1C, Yo-Yo Intermittent Recovery Level 1 Children's test; MVPA, moderate-to-vigorous physical activity; $M_{age}$, mean age; $VO_{2max}$, maximal oxygen uptake

(+) Found a positive effect of PE on students' CRF (positive changes in CRF or ≥50% of time in MVPA) (n=16)

(±) Found a neutral effect of PE on students' CRF (no changes in CRF or <50% of time in MVPA) (n=14)

(–) Students' CRF decreased during a given time period in a PE program (n=3)

### 6.1.5. Discussion

This review summarizes literature findings from studies published up to July 2019 on the contribution of PE classes for promoting CRF in children and adolescents. Twenty-four studies were included and systematically reviewed. Overall, this review revealed that findings regarding the contribution of PE classes to the promotion of CRF are mixed. Several findings suggested that PE has a neutral effect on students' CRF, while others reinforce its importance. However, higher intensity PE classes consistently demonstrated having a positive contribution in promoting students' CRF. Additionally, some other potentially relevant factors for promoting CRF in PE classes were identified, such as age and weight status. Review findings are discussed accordingly to these factors.

All studies were focused on school-aged children, however, due to the wide age range of the studies' populations, findings were organized into two age groups. This separation enabled some differences in findings between younger and older students to be found. While for older ages PE seems to be less effective in promoting students' CRF (Andres, 2017; Beets & Pitetti, 2005; Camhi et al., 2011; Crowhurst et al., 1993; Cumming et al., 1969; Erfle & Gamble, 2015; Fairclough & Stratton, 2005b, 2006; Koutedakis & Bouziotas, 2003; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012; Reed et al., 2013; Strand & Reeder, 1993), for younger ages almost all studies suggested that PE classes improved the students' CRF (Bendiksen et al., 2014; Jarani et al., 2016; Lucertini et al., 2013; Park et al., 2017; Reed et al., 2013). From a physiologic standpoint, CRF naturally increases as children grow-up. This increase is fairly linear in boys until later adolescence, whereas in girls it plateaus around age 13 (Eisenmann et al., 2011; Malina et al., 2004). Furthermore, during the early stages of adolescence, participation in PA and the corresponding physical fitness begins to show some decline (Duncan et al., 2007). Thus, increasing CRF, related to body growth, occurring at younger ages and decreasing participation in PA in older students may explain why improvements in CRF for a given period of time are more frequently found in younger children and adolescents. Another possible reason for the apparently less effective contribution of PE to the improvement of CRF in older students is motivation. Motivation to participate in PE seems to decline in the late elementary and high school years (Ntoumanis et al., 2009; Xiang et al., 2004), possibly resulting in decreasing PA both during PE and in leisure time. Considering these findings, PE may have a bigger role to play in promoting older students' CRF than it does in younger students, through providing moderate-to-vigorous PA opportunities.

Aerobic exercise has been shown to increase CRF by about 5-15% in youth (Malina et al., 2004; USDHHS, 2008). Additionally, improvements in CRF, involving structural and functional adaptations, as well as in the oxidative capacity of skeletal muscle occur with regular moderate-to-vigorous PA participation (Malina et al., 2004). In this review, five studies reported that PE classes did not provide sufficient intensity for achieving an aerobic benefit (Crowhurst et al., 1993; Fairclough & Stratton, 2005b, 2006; Mayorga-Vega et al., 2016; Strand & Reeder, 1993) and thus, did not contribute in a consistent manner to promote students' CRF. It is clear that CRF in youth increases with activity of sufficient intensity, leading to improvements in maximal stroke volume, blood volume, and oxidative enzymes after exercise (Rowland, 1996). Consequently, time spent in moderate-to-vigorous PA during PE classes should be monitored and adequate to promote health. Also, findings suggesting that PE has a positive contribution in improving CRF were mainly related to the intensity level of the classes. The majority of studies examined in this review involved intervention programs built to increase PE class intensity without increasing the number of classes or curricular time dedicated to PE (Baquet et al., 2001; Baquet et al., 2002; Bendiksen et al., 2014; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Pelclová et al., 2008; Ramirez Lechuga et al., 2012; Rengasamy et al., 2014). In fact, four of these studies reported that students participating in PE classes from the intervention programs increased their CRF levels, while students participating in regular PE classes, i.e. classes that were not part of the program, decreased or maintained their CRF levels (Bendiksen et al., 2014; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012). Considering the importance of CRF for health, the lack of intensity in PE classes is worrying. From a public health perspective, PE has the potential to provide the tools to face the current youth obesity and sedentary epidemic (Sallis et al., 2012). However, in order to effectively contribute to CRF and health, it is urgent to find strategies to increase the intensity of PE classes.

One study (Camhi et al., 2011), examining whether an eight months PE program improved students' CRF when considering BMI categories, suggested that although normal-weight and overweight girls showed improvement in fitness and maintenance of these effects over the next two years, their obese peers did not. PA and BMI are inversely correlated in children and adolescents (Lohman et al., 2006). Also, studies of usual PA in children suggest that the overweight and obese are less active (Hills et al., 2007; Strong et al., 2005) and have poorer fundamental movement skills than their normal-weight counterparts (Okely et al., 2004). Mastering of fundamental motor skills is strongly related to PA in children and adolescents and is critical to fostering PA since these skills are the foundation for advanced and sport-specific movement (Lubans et al., 2010). Furthermore, a recent meta-analysis found that overweight and obese students were, respectively, 27% and 54% more likely to have school absenteeism than their normal-weight peers (An et al., 2017). All these factors may contribute to a greater ineffectiveness of PE programs among obese students. Therefore, PE should not only provide sufficient intensity to promote health, but also be based on developmentally appropriate motor activities to nurture self-efficacy and enjoyment and encourage ongoing participation in PA.

High-quality PE together with appropriate approaches to fitness as part of health education programmes has been shown to promote fitness and healthy lifestyles (Harris & Cale, 2019). On the other hand, when applied inappropriately and without context fitness monitoring can have the opposite result (Cale & Harris, 2009). Therefore, mixed findings found in this systematic review may be due to the variations in the quality of PE. It is important that high-quality PE is provided and promoted in schools, as it benefits not only students' CRF, but also promotes future healthy lifestyles.

The present review has some limitations that should be acknowledged. Even though study bias was assessed according to their methodological quality (USDHHS, 2014), they were not weighted or ranked, thus, findings from studies with poorer quality and smaller sample sizes were given no less importance than other findings. Nonetheless, only one study was classified as ‘poor’ quality. Additionally, included studies had a wide publication date range, from 1969 to 2017, and were from different cultural and socioeconomic contexts, which could have implications on what PE classes represent as well as PE curricula. Also, 16 studies were not accessible to the authors. Grey literature research was not included. Despite the developed efforts for reducing publication bias by the authors, this should be taken into account.

Notwithstanding, to the best of our knowledge, this is the first systematic review focused on the contribution of PE classes or PE interventions that did not extend time or frequency of the classes to the improvement of students’ CRF. Furthermore, an extensive research strategy comprising four different databases and several keywords was used. Future research should continue to investigate the contribution of PE to the improvement of CRF and other fitness attributes, and examine which curricula offers the best opportunity to improve fitness, health and promote life-long PA behaviours.

### 6.1.6. Conclusion

Review findings from the 24 included studies suggest that PE classes can contribute to the promotion of students’ CRF. Some potentially relevant factors for promoting CRF in PE classes were identified, such as intensity, age and weight status. Exercise intensity is essential to promote CRF and other health outcomes in youth (Gutin, 2008; Malina et al., 2004; WHO, 2010), thus it is not surprising that higher intensity PE classes demonstrated improvements in CRF. Findings from studies of younger students more consistently reported improvements in CRF than findings from studies of older students. Therefore, as older students may be more vulnerable to decreasing PA levels (Duncan et al., 2007), PE should be keen in providing tools and opportunities to improve and maintain CRF levels in these ages. Regarding weight status, overweight and obese students should be a priority concern, as they may have more difficulty in improving CRF than normal-weight peers. Given that CRF is an independent health predictor and that decrease of CRF is a global trend, more efforts should be done to promote CRF in

PE classes. High-quality PE is needed as it can be a successful strategy in improving CRF levels.

## 6.2. Study 2 – Promoting health-related cardiorespiratory fitness in physical education: the role of class intensity and habitual physical activity

### 6.2.1. Abstract

**Background:** PE has the potential to promote health-related fitness, however its contribution is still not clear. The aim of this study was to assess whether students' health-related CRF improved from the beginning to the end of the school-year and to examine the role of PE class intensity and habitual PA in promoting students' CRF.

**Methods:** This observational study employed a longitudinal design. Participants were 212 7$^{th}$ and 8$^{th}$ grade students (105 boys), mean age 12.9 years old, followed during one school-year, from September 2017 to June 2018. The PACER was used to assess CRF at baseline and follow-up. PA was measured using accelerometers. PE class intensity was assessed using the SOFIT.

**Results:** Findings indicated that from the beginning to the end of the school-year a greater percentage of participants were in the CRF healthy fitness zone (73.1 % to 79.7 %, p=0.022). Among boys, participating in organized sports (B=4.61, 95%CI: 0.33, 8.88) and the percentage of PE time being very active (B=0.90, 95%CI: 0.44, 1.35) were positively associated with the change in PACER laps. Among girls, daily vigorous PA (B=0.38, 95%CI: 0.15, 0.60) and participating in organized sports (B=4.10, 95%CI: 0.93, 7.27) were also positively associated with PACER change, while being overweight or obese (B=-5.11, 95%CI: -8.28, -1.93) was negatively associated.

**Conclusion:** In conclusion, PE demonstrated to have a positive role in the promotion of CRF, especially among boys. While for girls, habitual PA seems to have a greater contribution. Nevertheless, results and conclusion should be considered carefully taking into account study limitations, such as the non-direct measures of PE class intensity, CRF and school setting.

### 6.2.2. Introduction

Promoting PA and healthy lifestyles has become a priority for public health authorities worldwide (WHO, 2019). When considering children and adolescents, school has been purposed as an important setting for achieving this priority. Especially through PE, the school provides an opportunity for youth to be physically active and promote healthy lifestyles (Bocarro et al., 2012).

An important health indicator related to PA is CRF. It is estimated that up to half of the CRF is hereditable (Bouchard et al., 1998). Nevertheless, habitual PA is still considered as the primary means of improving fitness (Lang et al., 2018). Systematized evidence revealed strong associations between CRF and youth cardiometabolic health, including blood pressure, cholesterol and triglyceride levels, and glucose tolerance (Raghuveer et al., 2020). Moreover, CRF in childhood is suggested to track into adulthood, giving a reasonable insight into future health (Ruiz et al., 2009).

There is a handful of field tests that allow for the assessment of CRF in the school setting. School and PE classes may play a significant role in both promoting and monitoring children and adolescents' CRF (Cale et al., 2014; Chen et al., 2014; IOM, 2013). However, among upper-middle- and high-income countries a substantial decline in CRF has been observed since 1981 (Tomkinson et al., 2019). Furthermore, evidence on the contribution of PE classes for promoting children and adolescents CRF is not consistent (Peralta, Henriques-Neto, et al., 2020). A recent systematic review showed that PE classes can promote child and adolescent CRF, and some factors that may explain the inconsistent findings were identified, including class intensity, age and weight status (Peralta, Henriques-Neto, et al., 2020).

In order to better understand the role of PE classes in promoting CRF more research is warranted. Previous investigations focusing on the promotion of CRF in PE had mostly implemented cross-sectional or intervention designs (Peralta, Henriques-Neto, et al., 2020). Cross-sectional design studies do not allow to establish the temporality and direction of the associations. On the other hand, intervention designs, by their nature, alter one or more components of PE classes, including content or intensity, which are important for the promotion of CRF. Taking that into account, there is a need for observational studies employing a longitudinal design. These type of studies allow to investigate the role of regular PE classes (i.e. not altered by an intervention) and to establish the direction of the associations.

Furthermore, precedent studies mainly examined students from a wide range of grades and ages. Students from different ages and grades may have different PE content, as well as different attitudes toward PE, which may affect the role of PE on promoting PA and CRF (Kjonniksen et al., 2009; Silverman, 2017). Focusing on a narrower range of grades is important to have more specific information. In that regard, the contribute of PE classes to improve CRF seems to be clearer among children and younger adolescents, until 12 years old, than onwards (Peralta, Henriques-Neto, et al., 2020). Also, early adolescence evidences a decline in PA (Dumith et al., 2011; Metcalf et al., 2015).

From a public health perspective, promoting and monitoring CRF provides a meaningful strategy to monitor and improve the present and future health status (Barrett-Williams et al., 2017; McKenzie & Lounsbery, 2014). Although PE may be an important platform for promoting children and adolescents' CRF, investigations on its role still present inconsistent results. Therefore, the aim of this study was to assess whether students' health-related CRF improved from the beginning to the end of the school-year. Also, the role of PE class intensity and habitual PA in promoting students' CRF was examined.

### 6.2.3. Methods

#### Study Design and Procedures

This was an observational study. It employed a longitudinal design, where 7$^{th}$ and 8$^{th}$ grade (middle school) students from two schools were followed during one school year, from October 2017 to June 2018. Individual data were collected at baseline, September and October 2017, and follow-up, May and June 2018. Data assessed in these periods included sociodemographic characteristics, PA (assessed only at baseline), and physical fitness. Data on PE classes were collected between January and April 2018.

The two participating public schools were located in Sintra, Portugal. Both schools are from urban areas and located in middle-to-low income neighbourhoods. These schools serve a population of approximately 800 students each, and have courses for students from the 5th to the 9th grades. School directors were approached by the research team, and authorization to conduct the study was granted. Afterwards, PE teachers were contacted and asked whether they were willing to participate in the study. Then, students, from the teachers who agreed to participate in the study, were recruited by the research team in a PE class, where the aim and overall aspects of the study were explained, and informed consents were distributed. Students who returned the informed consent signed by their legal guardians were eligible to participate in the study. Before initiating this process, the study protocol was approved by the ethics committee of the Faculty of Human Kinetics, University of Lisbon (no. 19/2017) and by the Portuguese National Data Protection Commission (no. 9249/2017).

**Participants**

A total of 294 students, from 21 different classes, enrolled in the study. From the 294 students, five were lost to follow-up (1.7%). Additionally, 24 participants did not have data on CRF, and 53 participants had invalid accelerometer data. Therefore, a total of 212 students (105 boys, 107 girls), mean age 12.9 years old, were included in the analysis. The flow diagram of the study sample is presented in Figure 5.

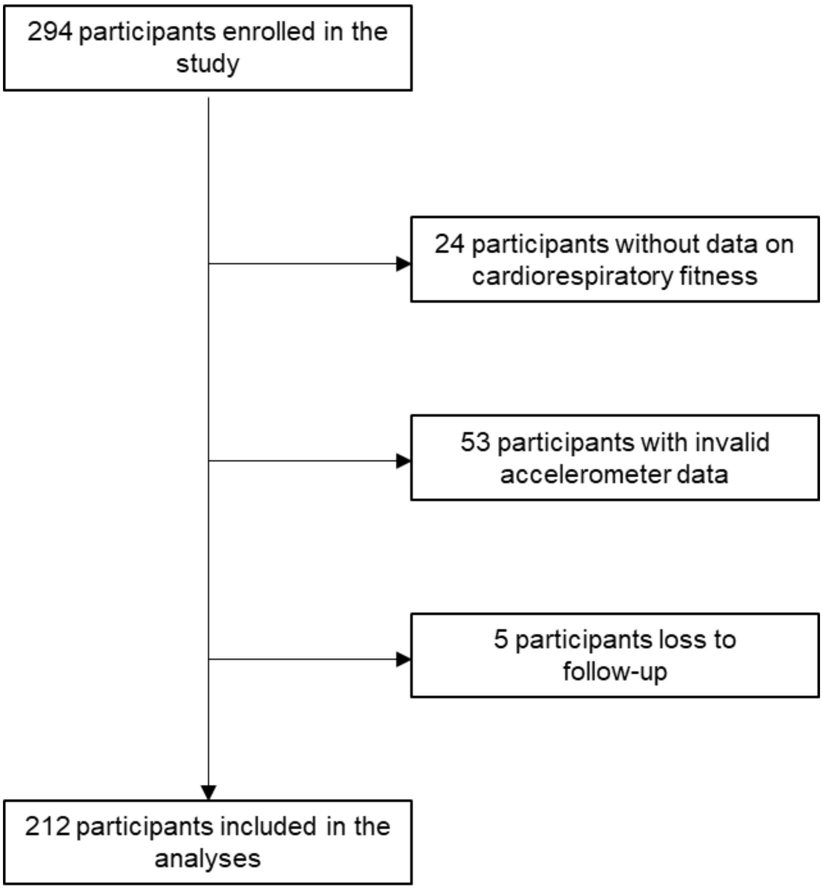


Figure 5. Flow diagram of the study sample.

**Measures**

*Cardiorespiratory fitness*

CRF was assessed using the PACER, also known as the 20-meter shuttle run, as part of the FITescola battery, which is widely used by PE teachers in Portugal (Henriques-Neto et al., 2020). The main aim of this test was to perform the maximum number of laps with a defined cadence. An audio signal was used to help the participants manage running speed during the test. The test starts with a cadence of 8.5 km per hour and increases progressively 0.5 km per hour every minute. The PACER was performed twice by each participant, at the beginning of the school-year (baseline) and at the end of the school-year (follow-up). Results from the PACER were recorded in number of laps and $VO_{2peak}$. (mL/kg/min). For estimating $VO_{2peak}$ the equations of Saint-Maurice et al. (2015) were used and afterwards participants were classified into being in or out of the CRF healthy fitness zone according to existing standards (Welk et al., 2011).

*Physical activity*

PA was assessed using accelerometers (ActiGraph, GT3X model, Fort Walton Beach, FL), between September and October 2017. The accelerometers used in this research ignored high-frequency vibrations associated with mechanical equipment. All participants were asked to wear the accelerometer on the right side, near the iliac crest, for seven consecutive days and instructed to remove the devices only when performing water activities (e.g. bathing or swimming) and during sleep. To increase compliance, study staff instructed children how to wear the accelerometer during the initial in-school assessment. Accelerometers were activated on the morning of the first wear day. Individual data as recorded and downloaded into 15 seconds epochs that were reintegrated into 60 seconds epochs. This technique is consistent with previously published research (Judice et al., 2017). Periods of at least 60 consecutive minutes of zero counts were considered as non-wear time. Only when in a single day at least 600 minutes (10 hours) of wear time was recorded, it was considered valid. Participants had to present at least three valid days (including at least 1 weekend day and 2 weekdays) in order to have valid accelerometer data.

The cut-points capture the sporadic nature of children's activity and provide the best classification accuracy among the currently available cut-points for PA in children. Activity levels were expressed in terms of counts per minute, and intensity thresholds were defined according to Evenson et al. criteria (Evenson et al., 2008; Trost et al., 2011). Accelerometer counts ≥100 counts/min were identified as active time, and posteriorly separated as moderate PA (2296 to 4011 counts/min) and vigorous PA (≥4012 counts/min).

*Physical education class intensity*

PE class intensity was assessed using the SOFIT, by a member of the research team. SOFIT is a visual observation instrument previously validated as a measure of PA during PE classes (McKenzie et al., 1991). SOFIT scores activity using a 5-point Likert scale (1 lying down; 2 sitting; 3 standing; 4 walking; 5 very active). A total of 63 PE classes, three PE classes from each student class, were observed. Both schools had three spaces where PE classes were performed (a big outdoor space; a big indoor space; and a small indoor space). One observation was scheduled for each space per student class. For each student class, mean values from the three PE classes were calculated. Intensity values were transformed to percentages of PE time because class length was not equal for every class. In one school three PE classes of 50 minutes were performed per week. While, in the other school two PE classes, one of 50 minutes and one of 100 minutes were performed per week.

*Covariates*

Covariates included sex, age, height, weight, BMI, age of PHV, and organized sports participation, at baseline. All participants were weighed to the nearest 0.01 kg on an electronic scale (model 799 SECA, Seca GmbH, Hamburg, Germany) while wearing minimal clothes (t-shirt and shorts) and without shoes. Height was measured to the nearest 0.1 cm with a flexible anthropometric tape on the wall, without shoes. BMI was calculated as body mass (kg)/height$^2$ (m). The BMI z-score was calculated and BMI categories were defined based on the WHO classification. Age at PHV was estimated as suggested by Moore et al. (2015). Participants were asked whether they participated in organized sports outside of school (yes / no).

**Statistical analysis**

Descriptive statistics were calculated for all variables (means, standard deviation, and percentages), for the entire sample and separated by sex. Differences between boys and girls were tested by the independent samples t-test, for continuous variables, and chi-square test, for nominal variables. Paired samples t-test and McNemar test were performed to compare the PACER laps, $VO_{2peak}$ and being or not in the healthy fitness zone between the beginning and the end of the school-year. Multivariate linear regression models were conducted to assess which factors explained changes in PACER laps from the beginning to the end of the school-year, including sex, age, BMI categories, PA (moderate and vigorous), organized sports participation, and percentage of PE time walking and being very active. Models were run for the total sample and by sex, and adjusted to age at peak height velocity, accelerometer wear time, PACER laps at baseline and each explaining variable. Unstandardized coefficients (B) and standardized coefficients (β) were calculated to have indicators of both measured unit estimates (absolute magnitude) and z-score estimates (relative magnitude). Data analysis was performed using IBM SPSS Statistics version 26.0 (IBM, Armonk, NY). Statistical significance was set at $p<0.05$.

**6.2.4. Results**

Sample baseline characteristics for the entire sample and by sex are presented in Table 5. The majority of participants were normal-weight (66.5%), while 22.2% were overweight, and 8.5% obese. Boys spent more time in moderate PA (34.2 min versus 25.9 min, $p<0.001$) and vigorous PA (22.0 min versus 10.5 min, $p<0.001$) than girls. Also, a greater percentage of boys than girls participated in organized sports outside of school (55.2% vs. 37.4%, $p=0.013$). Boys performed more laps in PACER (49.1 versus 30.2, $p<0.001$), and had a greater estimated $VO_{2peak}$ (48.4 mL/kg/min versus 41.9 mL/kg/min, $p<0.001$). Most participants, 73.1%, were in the CRF healthy fitness zone; however, a greater percentage of boys was at the CRF healthy fitness zone than girls (83.8% versus 62.6%, $p=0.001$). On average, participants spent 29.8% of the observed PE time walking, and 24.8% being very active.

Table 6 presents the comparison between aerobic capacity and healthy fitness zone at the beginning and the end of the school year. When considering the total sample from the beginning to the end of the school year, participants improved the number of PACER laps (39.6 to 45.0, $p<0.001$), and the estimated $VO_{2peak}$ (45.1 mL/kg/min to 46.5 mL/kg/min, $p<0.001$). Furthermore, the percentage of students in the CRF healthy fitness zone increased (73.1% to 79.7%, $p=0.022$) from the beginning to the end of the school year.

However, when analyses were stratified by sex, significant changes for all these variables were only found for boys. For girls, differences in estimated $VO_{2peak}$ and percentage in the CRF healthy fitness zone were not significant.

Table 5. Sample baseline characteristics.

| Variables | M (SD) or % Total (n=212) | Boys (n=105) | Girls (n=107) | *p* |
|---|---|---|---|---|
| Age (years) | 12.9 (1.0) | 13.0 (1.0) | 12.8 (1.1) | 0.201 |
| Height (m) | 1.59 (0.08) | 1.61 (0.10) | 1.57 (0.07) | 0.011 |
| Weight (kg) | 52.5 (12.8) | 51.6 (12.4) | 52.5 (13.2) | 0.582 |
| BMI (kg/m$^2$) | 20.4 (4.1) | 19.9 (3.4) | 21.0 (4.6) | 0.026 |
| BMI (categories) | | | | 0.224 |
| Underweight | 2.8 | 2.9 | 2.8 | |
| Normal-weight | 66.5 | 71.4 | 61.7 | |
| Overweight | 22.2 | 16.2 | 28.0 | |
| Obese | 8.5 | 9.5 | 7.5 | |
| Age at PHV (years) | 12.9 (0.9) | 13.6 (0.5) | 12.1 (0.5) | <0.001 |
| Daily MPA (min) | 30.0 (11.8) | 34.2 (12.5) | 25.9 (9.4) | <0.001 |
| Daily VPA (min) | 16.2 (12.7) | 22.0 (13.6) | 10.5 (8.4) | <0.001 |
| Sport participation | | | | 0.013 |
| No | 53.8 | 44.8 | 62.6 | |
| Yes | 46.2 | 55.2 | 37.4 | |
| PACER (laps) | 39.6 (19.4) | 49.1 (20.0) | 30.2 (13.4) | <0.001 |
| $VO_{2peak}$ (mL/kg/min) | 45.1 (6.8) | 48.4 (6.9) | 41.9 (5.0) | <0.001 |
| CRF healthy fitness zone | | | | 0.001 |
| No | 26.9 | 16.2 | 37.4 | |
| Yes | 73.1 | 83.8 | 62.6 | |
| % of PE time walking | 29.8 (5.3) | 30.1 (5.1) | 29.5 (5.4) | 0.422 |
| % of PE time very active | 24.8 (4.8) | 25.0 (4.7) | 24.5 (4.9) | 0.475 |

Note: M: mean; SD: standard deviation; BMI: body mass index; PHV: peak height velocity; VPA: vigorous physical activity; PACER: Progressive Aerobic Cardiovascular Endurance Run; $VO_{2peak}$: peak oxygen uptake; CRF: cardiorespiratory fitness; PE: physical education. Differences between sexes were tested by independent samples t-test for continuous variables, and by chi-square test for nominal variables.

Table 6. Aerobic capacity and healthy fitness zone at the beginning and at the end of the school year.

| | M (SD) or % Beginning of the school-year | End of the school-year | *p* |
|---|---|---|---|
| **Total** | | | |
| PACER (laps) [a] | 39.6 (19.4) | 45.0 (20.7) | <0.001 |
| $VO_{2peak}$ (mL/kg/min) [a] | 45.1 (6.8) | 46.5 (7.2) | <0.001 |
| CRF healthy fitness zone (%) [b] | | | 0.022 |
| No | 26.9 | 20.3 | |
| Yes | 73.1 | 79.7 | |
| **Boys** | | | |
| PACER (laps) [a] | 49.1 (20.0) | 57.3 (20.3) | <0.001 |
| $VO_{2peak}$ (mL/kg/min) [a] | 48.4 (6.9) | 50.8 (7.1) | <0.001 |
| CRF healthy fitness zone (%) [b] | | | 0.039 |
| No | 16.2 | 9.5 | |
| Yes | 83.8 | 90.5 | |
| **Girls** | | | |
| PACER (laps) [a] | 30.2 (13.4) | 32.9 (12.3) | 0.007 |
| $VO_{2peak}$ (mL/kg/min) [a] | 41.9 (5.0) | 42.3 (4.4) | 0.210 |
| CRF healthy fitness zone (%) [b] | | | 0.210 |
| No | 37.4 | 30.8 | |
| Yes | 62.6 | 69.2 | |

Note: M: mean; SD: standard deviation; PACER: Progressive Aerobic Cardiovascular Endurance Run; $VO_{2peak}$: peak oxygen uptake; CRF: cardiorespiratory fitness.
[a] Tested by paired samples t-test.
[b] Tested by McNemar test.

Linear regression models, to explain the change in PACER laps from the beginning to the end of the school year, are presented in Table 7. Considering the entire sample, change in PACER laps was positively associated with being a boy (B=13.21, 95%CI: 7.64, 18.72), having daily vigorous PA (B=0.25, 95%CI: 0.10, 0.41), participating in organized sports (B=4.60, 95%CI: 1.92, 7.28), and the percentage of PE time being very active (B=0.41, 95%CI: 0.14, 0.68). On the other hand, being overweight or obese (B=−3.01, 95%CI: −5.98, −0.05) was negatively associated with change in PACER laps. It was observed that sex (β = 0.60), followed by daily vigorous PA (β=0.29), organized sports participation (β=0.21), and percentage of PE time being very active (β=0.19) presented the greatest magnitude of association to PACER change.

Table 7. Linear regression to explain the change in PACER laps from the beginning to the end of the school-year.

| | **Change in PACER from the beginning to the end of the school-year** | | | | | |
|---|---|---|---|---|---|---|
| | **Total** | | **Boys** | | **Girls** | |
| | **B (95%CI)** | **β** | **B (95%CI)** | **β** | **B (95%CI)** | **β** |
| Sex | | | | | | |
| Girl | 0.00 (ref) | | NA | NA | NA | NA |
| Boy | **13.21 (7.64, 18.72)** | **0.60** | | | | |
| Age (years) | 0.59 (-0.80, 1.98) | 0.06 | -1.00 (-3.36, 1.37) | -0.08 | 0.95 (-0.60, 2.50) | 0.10 |
| BMI categories | | | | | | |
| Not overweight or obese | 0.00 (ref) | | 0.00 (ref) | | 0.00 (ref) | |
| Overweight or obese | **-3.01 (-5.98, -0.05)** | **-0.13** | 0.82 (-4.22, 5.85) | 0.03 | **-5.11 (-8.28, -1.93)** | **-0.25** |
| Daily MPA (min) | -0.09 (-0.23, 0.06) | -0.09 | -0.09 (-0.31, 0.13) | -0.09 | -0.10 (-0.30, 0.09) | -0.10 |
| Daily VPA (min) | **0.25 (0.10, 0.41)** | **0.29** | 0.16 (-0.05, 0.36) | 0.19 | **0.38 (0.15, 0.60)** | **0.32** |
| Sport participation | | | | | | |
| No | 0.00 (ref) | | 0.00 (ref) | | 0.00 (ref) | |
| Yes | **4.60 (1.92, 7.28)** | **0.21** | **4.61 (0.33, 8.88)** | **0.20** | **4.10 (0.93, 7.27)** | **0.21** |
| % of PE time walking | -0.11 (-0.36, 0.14) | -0.05 | -0.36 (-0.77, 0.05) | -0.16 | 0.02 (-0.28, 0.33) | 0.15 |
| % of PE time very active | **0.41 (0.14, 0.68)** | **0.19** | **0.90 (0.44, 1.35)** | **0.37** | 0.02 (-0.29, 0.32) | 0.15 |

Note. PACER: Progressive Aerobic Cardiovascular Endurance Run; CI: confidence interval; BMI: body mass index; MPA: moderate physical activity; VPA: vigorous physical activity; PE: physical education; NA: not applicable. B coefficients show the unstandardized values, and β coefficients show the standardized values. The model was adjusted for age at peak height velocity, accelerometer wear time, PACER laps at baseline, and each presented variable. Significant values are in bold.

Interestingly, stratified analysis revealed some sex differences in the variables explaining the change in PACER laps from the beginning to the end of the school year. For boys, participating in organized sports (B=4.61, 95%CI: 0.33, 8.88) and the percentage of PE time being very active (B=0.90, 95%CI: 0.44, 1.35) were positively associated with the change in PACER laps. The percentage of PE time being very active had the greatest magnitude of association to PACER change (β=0.37). For girls, daily vigorous PA (B=0.38, 95%CI: 0.15, 0.60) and participating in organized sports (B=4.10, 95%CI: 0.93, 7.27) were also positively associated, while being overweight or obese (B=−5.11, 95%CI: −8.28, −1.93) was negatively associated with PACER change. Minutes of daily vigorous PA had the greatest magnitude of association with PACER change (β=0.32).

### 6.2.5. Discussion

With the aim of examining the promotion of CRF in PE class, these findings demonstrated that from the beginning to the end of the school-year a greater percentage of participants were in the CRF healthy fitness zone. Also, sex, being overweight or obese, minutes of daily vigorous PA, organized sports participation and the percentage of PE classes being very active were associated with the change in PACER laps from the beginning to the end of the school-year.

Boys are known to have higher CRF than girls from late childhood onwards and the difference increases throughout the years reaching approximately 40% in late adolescence (Armstrong & Welsman, 1994). Thus, as expected, in this study, boys performed more PACER laps and had higher estimated $VO_{2peak}$ than girls. Notwithstanding, a greater percentage of boys were in the CRF healthy fitness zone than girls, at both baseline and follow-up. Also, even though findings have demonstrated that from the beginning to the end of the school-year a greater percentage of participants were in the CRF healthy fitness zone, sex differences were found. At the beginning of the school-year 83.8% of boys were in the CRF healthy fitness zone, and this percentage increased to 90.5% at the end. On the other hand, 62.6% of girls were in the CRF healthy fitness zone at the beginning of the school-year and 69.2% at the end, however, this difference was not significant. The healthy fitness zone uses health criterion-referenced standards for each sex and age, therefore differences in the percentage of boys and girls in the CRF healthy fitness zone may reveal health disparities. The healthy fitness zone difference between boys and girls is in accordance with previous studies in the Portuguese population (Santos et al., 2014). These differences may also be a reflection of the lower levels of PA that girls present when compared to boys (Marques et al., 2020), which was also observed in this study, as habitual PA is still considered a crucial factor in improving fitness (Lang et al., 2018).

According to a recent systematic review, age, weight status and PE classes intensity are relevant factors for promoting students' CRF (Peralta, Henriques-Neto, et al., 2020). In this study, sex, weight status, habitual vigorous PA, participation in organized sports and the percentage of PE classes being very active were associated with the change in PACER laps from the beginning to the end of the school-year. For both boys and girls, age was not associated with changes in CRF, suggesting that both younger and older students can improve. Although this is not in accordance with other studies (Peralta, Henriques-Neto, et al., 2020), it should be taken into consideration that 88.7% (n=188) of participants were aged 12 to 14 years old, and thus, age differences may not be identifiable.

Participating in organized sports was associated with a positive change in PACER from the beginning to the end of the school-year. Also, sports participation was the only common variable to be associated with changes in PACER in both boys and girls. Previous studies have demonstrated that children and adolescents participating in organized sports have better CRF than their non-participating peers and that appropriate exercise training is known to increase CRF levels in youth, irrespective of sex, age or maturity (Armstrong & Barker, 2011; Silva et al., 2013). This evidence reinforces that planned and structured exercise programs with adequate frequency, duration and intensity induces changes in fitness. Considering the school setting, it is possible to plan for activities that fulfil these requirements, especially in PE programs and therefore promote health-related CRF in PE. However, evidence has demonstrated that most students spend less than 50% of PE time in moderate-to-vigorous PA (Hollis et al., 2017) and that PE time is not associated with students CRF (Cheung et al., 2019).

Habitual PA is associated with children and adolescents' fitness (Lang et al., 2018). In this study, moderate PA was not associated with a change in PACER, while vigorous PA was only related to a positive CRF change in girls and when considering the entire sample. Nonetheless, vigorous PA presented the greatest magnitude of association to PACER change among girls. In fact, engaging in regular vigorous PA is most beneficial for improving CRF (Collings et al., 2017), and is often achieved for those who participated in adequately planned and structured organized sports (Armstrong & Barker, 2011; Silva et al., 2013). Surprisingly, in this study, vigorous PA was not associated with PACER change in boys, but only in girls. This may be the result of consistent higher levels of PA (moderate and vigorous) in boys, that made impossible to distinguish levels of vigorous PA between those with positive and negative changes in PACER. Notwithstanding, once again PE classes have the opportunity to contribute to youth PA levels, including vigorous PA, and thus promoting CRF. However, few students spend more than 50% of PE time in moderate-to-vigorous PA (Hollis et al., 2017).

Percentage of PE time walking was not associated with positive changes in CRF. However, percentage of PE time being very active was, although only among boys. Furthermore, among boys, the percentage of PE time being very active was found to have the greatest magnitude of association to PACER change. These are relevant findings for PE, as they demonstrate that PE classes may have an important role in promoting health-related CRF. This is in agreement with a recent systematic review that has identified PE class intensity as a key factor for promoting students' CRF (Peralta, Henriques-Neto, et al., 2020). However, as reported earlier, most of the students spent less than 50% of PE time in moderate-to-vigorous PA (Hollis et al., 2017). In this study, this was not the case, as more than 50% of PE time was estimated to be in moderate-to-vigorous PA (walking plus being very active). As it is for habitual PA and training, in PE sufficient intensity together with adequate frequency and duration are key for promoting fitness.

Other aspects of PE besides intensity, such as frequency and duration, can also have an important role in promoting CRF. This study's participants had 150 weekly minutes of PE. In one school those minutes were distributed in three classes of 50 minutes, while in the other school they were divided in two classes of 50 and 100 minutes. Several investigations have proposed that daily PE provides better opportunities for enhancing PA and fitness (Lahti et al., 2018; Loprinzi et al., 2018; Mooses et al., 2017; Reed et al., 2013). Also, the content of PE is of importance. Contents that provide greater chances for engaging in moderate-to-vigorous PA (e.g., fitness activities and team games), may help promoting CRF in PE (Peralta, Henriques-Neto, et al., 2020). Therefore, high-quality PE, considering time, frequency and intensity, can be a successful strategy to promote children and adolescents' CRF levels.

Finally, only for girls, being overweight or obese was negatively associated with the change in PACER laps from the beginning to the end of the school-year. A previous longitudinal study showed that although normal-weight girls enrolled in an eight-months PE program improved fitness, their obese peers showed no improvements in response to the same PE program (Camhi et al., 2011). Overweight and obese youth engage in less habitual PA (Hills et al., 2007) and are estimated to be 27% and 54% more likely to have school absenteeism, respectively, than their normal-weight peers (An et al., 2017). These two factors, associated with the fact that PACER is a weight-bearing test, and may explain why overweight and obese students have more difficulties in improving CRF.

This study has some limitations that must be acknowledged. The percentage of PE time walking and being very active were estimated through a visual observation instrument (SOFIT), instead of objectively measured (as habitual PA was), which can overestimate PA levels in PE. Nonetheless, SOFIT is validated as a measure of PA intensity during PE classes (McKenzie et al., 1991). Similarly, CRF was assessed using a field-test, giving an estimation and not a direct measure (Mayorga-Vega et al., 2015). The two schools participating in the study are both from urban areas and middle-to-low income neighbourhoods, which does not take into account participants from other settings. Despite these limitations, the study presents some strengths. Habitual PA was objectively measured using accelerometers. Furthermore, the study employed a longitudinal design, following participants for a whole school-year, allowing to infer temporal directions in the associations assessed.

### 6.2.6. Conclusion

From the beginning to the end of the school year, a greater percentage of participants were in the CRF healthy fitness zone; however, differences were only significant for boys. Additionally, being overweight or obese, daily vigorous PA, and participating in organized sports for girls, and organized sports participation and the percentage of PE classes being very active for boys, were associated with the change in PACER laps from the beginning to the end of the school year. Thus, findings suggest that PE has a positive and significant role in the promotion of CRF, especially among boys. Among girls, habitual PA seems to have a greater contribution to the promotion of CRF. From a public health perspective, PE classes can play a significant role in the promotion of health-related fitness, and thus, in improving children's and adolescents' health.

## 6.3. Study 3 – Promoting health-related cardiorespiratory fitness in physical education: the role of lesson context and teacher behaviour in an observational longitudinal study

### 6.3.1. Abstract

**Background:** PE lesson context and teacher behaviour may have an important role in promoting CRF, however research on this topic is scarce. Therefore, the goal of this study was to assess whether students' CRF improvement in a school-year was explained by PE lesson context and teacher behaviour

**Methods:** An observational longitudinal study, including 212 7th and 8th grade students (105 boys), mean age 12.9 years, was conducted throughout one school-year. The PACER was used to assess CRF at baseline and follow-up. PE lesson context and teacher behaviour were assessed using the SOFIT.

**Results:** The mean percentage of lesson time spent in gameplay (boys: B=-0.24, 95%CI: -0.45, -0.02; girls: B=-0.17, 95%CI: -0.29, -0.04), time spent by teachers in instruction tasks (boys: B=0.38, 95%CI: 0.17, 0.60; girls: B=0.33, 95%CI: 0.17, 0.48) and promoting fitness (girls: B=1.40, 95%CI: 0.60, 2.20) were positively associated to PACER improvement. On the other hand, lesson time spent in general content (boys: B=-0.24, 95%CI: -0.45, -0.02; girls: B=-0.17, 95%CI: -0.29, -0.04), fitness (boys: B=-0.56, 95%CI: -1.04, -0.07) and time spent by teachers in management tasks (boys: B=-0.42, 95%CI: -0.70, -0.15; girls: B=-0.46, 95%CI: -0.63, -0.28) were negatively associated to PACER.

**Conclusion:** PE lesson context and teacher behaviour are important modifiable factors controlled by the teacher that can improve students' CRF. Promoting CRF in PE can be achieved by providing active class contexts, such as gameplay, reducing management time and promoting in-class and out-of-class fitness.

### 6.3.2. Introduction

Schools provide opportunities for children and adolescents to engage in PA during discrete periods of the day (Bocarro et al., 2012; Kelly et al., 2019; Stratton et al., 2008). PE predominantly, which is part of the school curriculum in most countries, allows children and adolescents to engage in structured and appropriate PA (Mersh & Fairclough, 2010). Furthermore, many children and adolescents spend most hours of their day at school. For these reasons school, and particularly PE, is considered an important setting for the promotion of health-enhancing PA among young people (WHO Regional Office for Europe, 2018). In line with promoting health-enhancing PA, schools and PE are also important for promoting physical fitness (IOM, 2013).

Among the physical fitness components, CRF is the most studied, as it is an important health indicator associated with cardiometabolic health, including blood pressure, cholesterol and triglyceride levels, and glucose tolerance, in children and adolescents (Raghuveer et al., 2020). Because of its importance to health and for sustaining an active and healthy lifestyle, promoting physical fitness in general, and CRF in particular, is part of many PE goals (IOM, 2013; Sallis et al., 2012).

Physical fitness, including CRF, is mainly improved through engaging in moderate-to-vigorous PA and thus previous studies have shown that PE can promote students CRF given that the classes have enough intensity (Peralta, Henriques-Neto, et al., 2020; Peralta, Santos, et al., 2020). Notwithstanding, achieving appropriate levels of moderate-to-vigorous PA is influenced by a range of environmental (e.g. equipment and space), social (e.g. student interactions), and pedagogical factors (e.g. teaching dynamic), being the later one modifiable by teachers (Fairclough & Stratton, 2005a; Mersh & Fairclough, 2010). Therefore, besides PA intensity in PE classes, other aspects, such as lesson context and teacher behaviour, may be relevant for the promotion of students' CRF.

To the best of our knowledge no previous research has examined the role of PE lesson context and teacher behaviour in promoting the CRF of children and adolescents. As a result, the main purpose of this study was to assess whether students' CRF improvement from the baseline to post-test was explained by PE lesson context and teacher behaviour. Investigating these teacher-dependent modifiable factors can bring further insight into effective strategies for promoting CRF in PE and clearer indications to teachers and health-promoting authorities, rather than just PA intensity.

### 6.3.3. Methods

#### Study design and procedures

An observational longitudinal study was conducted throughout the school-year in two schools from Sintra, Portugal. Individual student's data were collected at the beginning of the school-year, September and October 2017 (at baseline), and at the end of the school-year, June and July 2018 (post-test). Data on PE lessons were collected between January and April 2018.

Before conducting the data collection, the study protocol was submitted to an ethics committee and schools were contacted. The study protocol was approved by the Faculty of Human Kinetics, University of Lisbon's ethics committee (no. 19/2017), and by the Portuguese National Commission for Data Protection (no. 9249/2017). School directors and PE teachers in each school were contacted to grant authorization and declare willingness to participate in the study. Then, the students who agreed to participate in the study were contacted during a PE lesson, where the aim and overall aspects of the study were explained, and informed consents were distributed. After returning the informed consent signed by their legal tutors, students were eligible to participate in the study.

#### Participants

A total of 294 students from the 7$^{th}$ and 8$^{th}$ grades (middle school) were eligible to participate in the study and thus performed the baseline assessments. From the initial 294 students, 212 were included in the final sample. Reasons for participants' exclusion were the following: five participants were lost to follow-up (1.7%), 24 participants did not have data on CRF and 53 participants had invalid accelerometer data. The final sample, included in the analysis, was composed of 105 boys and 107 girls, mean age 12.9 years old. The teacher sample was composed of 11 PE teachers (6 men, 5 women).

### Measures

*Cardiorespiratory fitness*

The 20-meter PACER was used to access students' CRF. This test is widely used by PE teachers in Portugal (Henriques-Neto et al., 2020) and the test protocol can be found elsewhere (Peralta, Santos, et al., 2020). Results from the PACER were recorded in number of laps. To analyse the change in PACER laps the school-year the performance in the PACER test at the beginning of the school-year was subtracted to the performance in the PACER test at the end of the school-year.

*Physical education lesson content and teacher behaviour*

Lesson content and teacher behaviour were assessed using the SOFIT (McKenzie, 2015; McKenzie et al., 1991). SOFIT showed moderately strong correlations ranging from 0.50 to 0.54 with ActiGraph accelerometers for PA levels during PE classes (Sharma et al., 2011). The SOFIT was performed in a total of 63 PE lessons, three lessons for each student class, and mean values from the three PE lessons were calculated. For the lesson content dimension, three main categories were observed: general content, knowledge content, and motor content. General content includes the lesson situations that students spent in transition, management, and break times. Knowledge content refers to situations where the primary focus is on student acquisition of knowledge related to PE, while not being physically active. Lastly, motor content includes the time when students are in motor engagement, this category is further divided into fitness, skill practice, gameplay, and free play. Regarding teacher behaviour six main categories were observed: promotes fitness, demonstrates fitness, instructs generally, manages, observes, and other tasks. More information on the SOFIT protocol can be found in the procedures manual (McKenzie, 2015).

*Covariates*

Sex, age, BMI, age of PHV, daily minutes of moderate and vigorous PA, and organized sports participation, at baseline, were included in the study as covariates. BMI was calculated by dividing body mass (kg) for the square of height (m) and BMI categories were defined based on the WHO classification. Participants were weighed on an electronic scale (model 799 SECA, Seca GmbH, Hamburg, Germany), wearing minimal clothes, to the nearest 0.01 kg, and height was measured with a flexible anthropometric tape on the wall, to the nearest 0.1 cm. Age at PHV was estimated as suggested by Moore et al. (2015). Daily moderate and vigorous PA was assessed using accelerometers (ActiGraph, GT3X model, Fort Walton Beach, FL), as described elsewhere (Peralta, Santos, et al., 2020). Finally, participation in organized sports was self-reported.

**Statistical analysis**

Descriptive statistics, for the whole sample and stratified by sex, were calculated for all individual variables and SOFIT lesson content and teacher behaviour categories, including means, standard deviation, and percentages. The independent samples t-test, for continuous variables, and chi-square test, for nominal variables, were used to assess sex differences. To examine the effect of time spent in each of the SOFIT lesson content and teacher behaviour categories on the change PACER laps from the beginning to the end of the school-year multivariate linear regression models (B; 95%CI) were performed. Models were stratified by sex and adjusted to age, age at PHV, daily moderate and vigorous PA, accelerometer wear time, PACER laps at baseline, and participation in organized sports. Data analysis was conducted using IBM SPSS Statistics version 26.0 (IBM, Armonk, NY). Statistical significance was set at $p<0.05$.

### 6.3.4. Results

Participants' characteristics are presented in Table 8 for the whole sample and by sex. Although, girls presented a slightly higher BMI than boys (19.9 versus 21.0, $p=0.026$), no differences were found for the distribution of boys and girls by BMI categories. Regarding PA and sports, boys showed higher levels of daily moderate and vigorous PA intensities than girls (moderate PA: 34.2 min versus 25.9 min, $p<0.001$; vigorous PA: 22.0 min versus 10.5 min, $p<0.001$). Additionally, 55.2% of boys participated in organized sports outside of school and only 37.4% of girls did ($p=0.013$). Lastly, boys performed more laps in PACER than girls in both assessment moments ($p<0.001$), and the mean number of PACER laps performed increased from the beginning of the school-year to the end of the school-year for both, boys and girls.

Table 8. Participants' characteristics.

| | **M (SD) or %** | | | ***p*** |
|---|---|---|---|---|
| | **Total (n=212)** | **Boys (n=105)** | **Girls (n=107)** | |
| Age (years) | 12.9 (1.0) | 13.0 (1.0) | 12.8 (1.1) | 0.201 |
| Height (m) | 1.59 (0.08) | 1.61 (0.10) | 1.57 (0.07) | 0.011 |
| Weight (kg) | 52.5 (12.8) | 51.6 (12.4) | 52.5 (13.2) | 0.582 |
| BMI (kg/m$^2$) | 20.4 (4.1) | 19.9 (3.4) | 21.0 (4.6) | 0.026 |
| BMI (categories) | | | | 0.224 |
| Underweight | 2.8 | 2.9 | 2.8 | |
| Normal-weight | 66.5 | 71.4 | 61.7 | |
| Overweight | 22.2 | 16.2 | 28.0 | |
| Obese | 8.5 | 9.5 | 7.5 | |
| Age at PHV (years) | 12.9 (0.9) | 13.6 (0.5) | 12.1 (0.5) | <0.001 |
| Daily MPA (min) | 30.0 (11.8) | 34.2 (12.5) | 25.9 (9.4) | <0.001 |
| Daily VPA (min) | 16.2 (12.7) | 22.0 (13.6) | 10.5 (8.4) | <0.001 |
| Sport participation | | | | 0.013 |
| No | 53.8 | 44.8 | 62.6 | |
| Yes | 46.2 | 55.2 | 37.4 | |
| PACER at baseline (laps) | 39.6 (19.4) | 49.1 (20.0) | 30.2 (13.4) | <0.001 |
| PACER at post-test (laps) | 44.9 (20.7) | 57.3 (20.3) | 32.9 (12.3) | <0.001 |

Abbreviations: M, mean; SD, standard deviation; BMI, body mass index; PHV, peak height velocity; MPA, moderate physical activity; VPA, vigorous physical activity; PACER, Progressive Aerobic Cardiovascular Endurance Run.
Differences between sexes were tested by independent samples t-test, for continuous variables, and by chi-square test, for nominal variables.

The SOFIT analysis (mean percentage of time spent) for the lesson content and teacher behaviour dimensions are shown in Table 9. Regarding lesson content, PE lessons time was mainly spent in gameplay situations (37.8%), followed by general content (25.2%) and skill (20.8%) situations. On the other hand, fitness (12.0%) and knowledge content (4.2%) situations obtained relatively less time spent on PE lessons. Regarding teacher behaviour, PE teachers spent, in mean, most of PE lessons time performing instruction (39.1%) and management tasks (39.7%), followed by observation (12.6%). A few percentage of PE lessons time was dedicated to promoting (3.8%) and demonstrating (2.3%) fitness.

Table 9. Mean percentage of physical education lessons spent in each lesson content and teacher behaviour categories from SOFIT.

| | **Mean (SD) percentage of time spent** |
|---|---|
| **SOFIT lesson content categories** | |
| General content | 25.2 (11.21) |
| Knowledge content | 4.2 (2.5) |
| Motor content | |
| Fitness | 12.0 (4.7) |
| Skill practice | 20.8 (7.0) |
| Gameplay | 37.8 (11.6) |
| **SOFIT teacher behaviour categories** | |
| Promotes fitness | 3.8 (2.3) |
| Demonstrates fitness | 2.3 (2.6) |
| Instructs | 39.1 (11.0) |
| Manages | 39.7 (9.3) |
| Observes | 12.6 (4.3) |
| Other | 2.5 (2.9) |

Abbreviations: SOFIT, System for Observing Fitness Instruction Time; SD, standard deviation.

Table 10 presents the linear regression models for PACER change according to SOFIT lesson content categories stratified by sex. Slight differences in the associations were found for boys and girls. Time spent in general content was negatively associated with PACER change in both sexes, however the association was stronger for boys (B=-0.24, 95%CI: -0.45, -0.02) than for girls (B=-0.17, 95%CI: -0.29, -0.04). Contrary, time spent in gameplay situations was positively associated with PACER change in both sexes. Once again, this association was stronger for boys (B=0.41, 95%CI: 0.22, 0.59) than for girls (B=0.14, 95%CI: 0.02, 0.26). Lastly, only for boys, time spent in fitness situations was negatively associated with PACER change (B=-0.56, 95%CI: -1.04, -0.07).

Table 10. Linear regression to explain the change in PACER laps from baseline to post-test using SOFIT lesson content categories as predictors.

| SOFIT Lesson content categories | Change in PACER from baseline to post-test | | | |
|---|---|---|---|---|
| | Boys | | Girls | |
| | B (95% CI) | *p* | B (95% CI) | *p* |
| General content | -0.24 (-0.45, -0.02) | 0.034 | -0.17 (-0.29, -0.04) | 0.010 |
| Knowledge content | -0.62 (-1.55, 0.31) | 0.189 | 0.08 (-0.55, 0.71) | 0.801 |
| Motor content | | | | |
| Fitness | -0.56 (-1.04, -0.07) | 0.025 | -0.29 (-0.60, 0.01) | 0.486 |
| Skill practice | -0.25 (-0.58, 0.07) | 0.125 | 0.17 (-0.04, 0.37) | 0.116 |
| Gameplay | 0.41 (0.22, 0.59) | <0.001 | 0.14 (0.02, 0.26) | 0.022 |

Abbreviations: SOFIT, System for Observing Fitness Instruction Time; PACER, Progressive Aerobic Cardiovascular Endurance Run; CI, confidence interval.
The model was adjusted for age, age at peak height velocity, body mass index, moderate physical activity, vigorous physical activity, accelerometer wear time, organized sport participation and PACER laps at baseline.

Linear regression models for PACER change by the SOFIT teacher behaviour categories stratified by sex are presented in Table 11. For boys and girls, the time spent by the teacher in instruction tasks was positively associated with PACER change (boys: B=0.38, 95%CI: 0.17, 0.60; girls: B=0.33, 95%CI: 0.17, 0.48), while time spent by the teacher in management tasks was negatively associated with PACER change (boys: B=-0.42, 95%CI: -0.70, -0.15; girls: B=-0.46, 95%CI: -0.63, -0.28). Regarding time spent by the teacher in fitness tasks, only for girls, time spent promoting fitness was positively related to PACER change (B=1.40, 95%CI: 0.60, 2.20).

Table 11. Linear regression to explain the change in PACER laps from baseline to post-test using SOFIT teacher behaviour categories as predictors.

| SOFIT Teacher behaviour categories | Change in PACER from baseline to post-test | | | |
|---|---|---|---|---|
| | Boys | | Girls | |
| | B (95% CI) | *p* | B (95% CI) | *p* |
| Promotes fitness | 0.15 (-0.93, 1.22) | 0.790 | 1.40 (0.60, 2.20) | 0.001 |
| Demonstrates fitness | 0.23 (-0.69, 1.15) | 0.619 | 0.35 (-0.42, 1.13) | 0.364 |
| Instructs generally | 0.38 (0.17, 0.60) | 0.001 | 0.33 (0.17, 0.48) | <0.001 |
| Manages | -0.42 (-0.70, -0.15) | 0.003 | -0.46 (-0.63,-0.28) | <0.001 |
| Observes | -0.26 (-0.83, 0.32) | 0.382 | -0.40 (-0.82, 0.02) | 0.059 |

Abbreviations: SOFIT, System for Observing Fitness Instruction Time; PACER, Progressive Aerobic Cardiovascular Endurance Run; CI, confidence interval.
The model was adjusted for age, age at peak height velocity, body mass index, moderate physical activity, vigorous physical activity, accelerometer wear time, organized sport participation and PACER laps at baseline.

### 6.3.5. Discussion

The present study aimed to explore the role of PE lesson context and teacher behaviour on promoting students' CRF, using the SOFIT direct observation tool. Overall, the mean percentage of time spent in gameplay, general content and fitness, as well as time spent by teachers performing instruction, management and fitness promoting tasks were found to be associated with changes in students' CRF from the baseline to post-test, nevertheless, sex differences in the pattern and strength of the associations were observed.

Although to the best of our knowledge, no studies have investigated the associations between PE lesson context and teacher behaviour with CRF, previous research has already explored its associations to moderate-to-vigorous PA in PE. Engaging in moderate-to-vigorous PA is essential for improving fitness (Lang et al., 2018), consequently, time spent in moderate-to-vigorous PA plays an important role in promoting CRF in PE (Peralta, Henriques-Neto, et al., 2020). PE classes of invasion games and sports have been proposed to engage students in the highest intensities of PA (Fairclough & Stratton, 2005a; McKenzie et al., 2000; Molina-Garcia et al., 2016). Furthermore, it was reported that small-sided games in football at schools can improve children's physical fitness (Krustrup et al., 2016). Similarly, in this study, it was observed that PE lesson time spent in gameplay was associated with improvements in CRF for both boys and girls. Besides promoting PA and fitness, invasion games and sports seem to be the most appropriate context to promote equal involvement between boys and girls (Molina-Garcia et al., 2016). To sum up, it appears that gameplay situations in PE classes can simultaneously promote PA levels and CRF while opportunities for all, and should therefore be encouraged in PE teaching practice guidelines.

Besides invasion games and sports, it has been reported that fitness activities contexts in PE also present the greatest amount of time spent in moderate-to-vigorous PA by students (Fairclough & Stratton, 2005a; McKenzie et al., 2000; Molina-Garcia et al., 2016). Controversially, in the present study, PE lesson time spent in fitness was not associated with CRF in girls and was negatively associated with CRF in boys. One possible explanation is that the SOFIT coding of fitness motor content includes the warm-up and cool-down periods.

Possibly, most of the time coded as fitness was spent in warm-up and cool-down activities, during which students were less engaged in higher intensity levels of PA. Nevertheless, when looking at teacher behaviour during PE lessons, promoting fitness presented the strongest association with CRF improvement in girls. This finding is of great significance, especially considering that in the vast majority of cases, due to PE lessons' limited frequency and duration, teachers are unable to provide students with the recommend 60 minutes of moderate-to-vigorous PA for health and fitness promotion (McKenzie & Lounsbery, 2013). Therefore, promoting fitness during and outside of class may be a smart strategy for teachers to engage their students in PA and improve CRF, especially for girls.

Contrary to the motor activity contexts, including gameplay, fitness, and skill practice, in the management and knowledge contexts students typically present lower levels of PA (McKenzie et al., 2006; McKenzie & Lounsbery, 2013; McKenzie et al., 2000; Mersh & Fairclough, 2010). Accordingly, in this study it was observed that both lesson time spent in general content, mainly management and transition situations, and the time teachers were engaged in management tasks were inversely associated with CRF change in boys and girls. Through deliberated planning that optimizes moderate-to-vigorous PA time while still delivering educationally and psychologically beneficial PE lessons and effective communication and delivery, teachers can promote appropriate PA levels within purposeful learning environments (Mersh & Fairclough, 2010). Lesson planning to specifically increase moderate-to-vigorous PA time and improved teacher management skills are considered to be the most effective strategies to increase both PA minutes and intensity in PE (McKenzie & Lounsbery, 2013). Transferring to fitness, and considering PA as a key determinant for improving fitness, it seems that teachers' effectiveness in their management tasks, planning and delivering skills are important factors for promoting students' CRF. This is further supported by the fact that PE delivered by well-trained specialists increases PA during school hours in youth (IOM, 2013).

The percentage of time teachers spent in instruction tasks, including feedback, was associated with improvements in CRF from the baseline to the post-test. Positive feedback is known to be associated with competence satisfaction, which in turn predicts greater intentions to participate (Mouratidis et al., 2008). Furthermore, expectancy-related beliefs, i.e. students' beliefs of how good they are in PE was previously found to be associated with performance on the PACER test (Gao et al., 2008). Thus, it is possible that teachers that give more feedback to students can improve their perceived competence and expectancy-related beliefs, encouraging them to be more active.

There are several strengths and limitations that should be taken into account when interpreting the findings of the present study. As for strengths, this study employed a longitudinal design, following participants for a whole school year, used a well-established and validated observational system (SOFIT), and controlled the analysis for important confounding variables, such as daily PA through objective measurements using accelerometers. Also, to the best of our knowledge, this is the first study examining the associations between PE lesson context and teacher behaviour with change in CRF, being novel research. Regarding limitations, CRF was assessed by an indirect measure, namely the PACER field test, which gives an estimation of CRF (Mayorga-Vega et al., 2015). Additionally, the schools included in the study are both from middle-to-low-income neighbourhoods in urban areas, which makes generalizing the findings to other settings difficult. Finally, limitations associated with using SOFIT to characterize some dimensions, for example, PE lesson time spent on fitness, may introduce some bias.

### 6.3.6. Conclusion

PE lesson context and teacher behaviour are important predictors to explain the variance in CRF change throughout the school-year. Specifically, time spent in gameplay situations and teacher behaviours of instructing and promoting fitness (particularly for girls) were associated with improvements in students' CRF; while time spent in general content and fitness situations (particularly for boys) and, by teachers, in management tasks was inversely associated with students' CRF. These are important modifiable factors controlled by the teacher that can improve students' CRF. Promoting CRF in PE can be achieved by providing active class contexts, such as gameplay, reducing management time, and promoting in-class and out-of-class fitness.

## 6.4. Study 4 – The effect of school-year and summer break in health-related cardiorespiratory fitness: a 2-year longitudinal analysis

### 6.4.1. Abstract

**Background:** Some studies have suggested that summer break has a negative impact on children and adolescent's CRF, however evidence is still scarce. Therefore, this study aimed to assess the trends of health-related CRF during two school-years with a 3-month summer break in children and adolescents.

**Methods:** A 2-year longitudinal study, including 440 6$^{th}$ to 8$^{th}$ graders (218 boys), mean age 12.3 years, was conducted. The PACER was used to assess CRF at the beginning and end of each school-year. Physical activity was measured using accelerometers. Repeated measures general linear models were used to analyses differences and trends in $VO_{2peak}$ and health-related CRF.

**Results:** Overall differences between time-point $VO_{2peak}$ were significant for both boys ($p<0.001$) and girls ($p=0.003$). Pairwise comparisons showed that $VO_{2peak}$ improved from the beginning of each school-year to the end of the same school-year for boys (49.1 to 50.6 ml/kg/min, $p<0.001$; 51.0 to 52.8 ml/kg/min, $p<0.001$) and girls (41.7 to 42.5 ml/kg/min, $p<0.001$; 42.2 to 43.3 ml/kg/min, $p<0.001$). However, differences in CRF between the end of school-year 1 and the beginning of school-year 2, i.e. during summer break, were not significant (boys: $p=0.543$; girls: $p=0.343$).

**Conclusion:** Improvements in CRF were only observed during each school-year and remained unchanged during summer break. These findings provide relevant information for the health education community, suggesting the need for additional efforts to counteract the summer break effects on CRF.

### 6.4.2. Introduction

CRF is a well-known indicator of children's current (Ruiz et al., 2015) and future health (Henriksson et al., 2021; Raghuveer et al., 2020). CRF is associated with a clustering of cardiometabolic risk factors (Anderssen et al., 2007; Klasson-Heggebo et al., 2006) and this association has been found to be even independent of PA (Ekelund et al., 2007). Furthermore, CRF has been found to be associated with mental health in youth (Janssen et al., 2020; Ruggero et al., 2015), which can be partly explained by its relationship with greater global grey and white matter, brain volume and anterior hippocampal functional connectivity (Cadenas-Sanchez et al., 2020; Esteban-Cornejo et al., 2021). This is of importance and may explain why, among adolescents, CRF is related to academic performance (Marques et al., 2018), either cross-sectionally (Sardinha et al., 2014) or prospectively (Garcia-Hermoso et al., 2021; Sardinha et al., 2016). Despite its importance, a concerning secular decline in young people's CRF has been observed (Masanovic et al., 2020; Tomkinson et al., 2019).

Participation in PA is a cornerstone for improving CRF (Lang et al., 2018). Among young people, several strategies for improving PA and fitness are focused on the school-setting, as schools provide opportunities for regular PA, such as PE and recess, and children and adolescents spend a great part of their days in this context (Bocarro et al., 2012; Brazendale et al., 2017). However, the inability to continue school-based PA programs aimed to enhance PA levels in youth over the summer has recently raised concerns (Brusseau & Burns, 2018; Fu et al., 2017). In fact, there is evidence that weight gain accelerates during the school summer break in children of paediatric ages (Baranowski et al., 2014; von Hippel & Workman, 2016).

Evidence regarding CRF is more limited. Nevertheless, some investigations, predominantly from North America, have indicated that CRF improvements made during the school-year are negatively impacted by the summer break (Brusseau & Burns, 2018; Carrel et al., 2007; Fu et al., 2017). A proxy of how summer break can impact young people's behaviour, is the observed differences in PA on weekdays and weekend days. It is often reported that children and adolescents are more active during weekdays compared to weekend days, which may be attributed to the daily structured and unstructured PA opportunities provided in the school setting (Brusseau, 2015).

Given these findings, the school summer break has been suggested as a particularly high-risk period for unfavourable changes in fitness (e.g. body composition, CRF) (Watson et al., 2019). However, more evidence is needed on this issue in European countries with different summer break periods, to ascertain the summer break effect on young people's CRF. Therefore, this investigation aimed to assess the trends of health-related CRF during two school-years with a 3-month summer break in children and adolescents.

### 6.4.3. Methods

#### Study design and procedures

This study uses data from the PESSOA program. The PESSOA program aimed to develop a school-based intervention to promote healthy lifestyles knowledge and skills. More information about the PESSOA program can be found elsewhere (Sardinha et al., 2014).

For this investigation, a longitudinal design was employed where students from the 6$^{th}$, 7$^{th}$ and 8$^{th}$ grades (middle school) were followed for two school-years with assessment moments at the beginning (October and November of school-year 1 and 2) and at the end (May and June of school-year 1 and 2) of each school-year. Thirteen schools, from the Oeiras municipality in the Lisbon metropolitan area, were invited to participate in the PESSOA program, with all of them agreeing to participate. Participants and their legal guardians were informed about the objectives of the study and invited to participate. Informed written consent was obtained from children who wanted to participate and their legal guardians. The investigation received approval from the Scientific Committee of the Faculty of the Human Kinetics of the University of Lisbon, the Portuguese Minister of Education, and the principals from each of the surveyed schools.

**Participants**

Only participants with valid CRF data on the four assessment moments (beginning of school-year 1 and 2 and end of school-year 1 and 2) and valid baseline data on covariates were included in the study. Therefore, this study sample comprised 440 participants (218 boys, 222 girls), mean age 12.3 (standard deviation=1.2) years old. Figure 6 presents the flow diagram of the included sample.

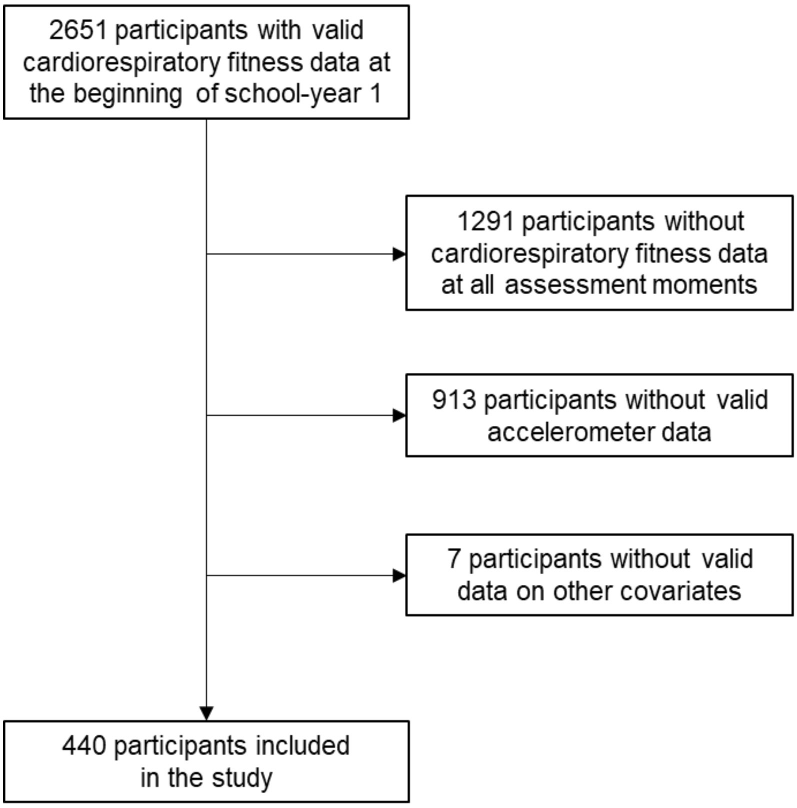


Figure 6. Flow diagram of the included sample.

**Measures**

*Cardiorespiratory fitness*

Participant's CRF was assessed using the 20-meter PACER, a valid and reliable test for measuring cardiovascular fitness in children (Welk & Meredith, 2010). The test protocol can be found elsewhere (Leger et al., 1988). The PACER test was performed during a PE lesson supervised by a trained PE teacher and a member of the PESSOA research team. The results of the PACER test, which were recorded in laps were transformed using the equations of Saint-Maurice et al. (2015) for estimating $VO_{2peak}$ (ml/kg/min). Afterwards, participants were classified as being in or out of the CRF healthy fitness zone according to existing standards (Welk et al., 2011).

*Physical activity*

Baseline daily PA was objectively measured using accelerometers (ActiGraph, GT1M model, Fort Walton Beach, FL) between November and June of school-year 1. Prior to initiating data collection, each participant was instructed on how and when to wear the accelerometer, placing it on the hip's right side (midaxillary line at the level of the iliac crest) with an elastic belt, and only removing it when performing water activities (e.g. bathing or swimming) and during sleep. Accelerometer data was considered valid if participants had a minimum of three valid days (including at least 1 weekend day and 2 weekdays). Days were valid when participants reached at least 600 minutes (10 hours) of wear time (60 consecutive minutes of zero counts were considered as non-wear time). Intensity thresholds were identified according to Evenson et al. criteria (Evenson et al., 2008; Trost et al., 2011).

*Anthropometry*

Anthropometric measures included baseline height, weight, BMI and age of PHV. Participants' height was measured using a portable stadiometer, without shoes, to the nearest 0.1 cm; weight was measured on an electronic scale while wearing minimal clothes (t-shirt and shorts) and without shoes to the nearest 0.01 kg. Body mass (kg) was divided by the square of height (m) to compute the BMI, BMI z-score and BMI categories according to the WHO criteria (de Onis et al., 2007). Age at PHV was estimated as suggested by Moore et al. (2015).

**Statistical analysis**

Descriptive statistics for the total sample and stratified by sex were calculated for all variables (means, standard deviation, and percentages). Sex differences were assessed by the independent samples t-test for continuous variables and chi-square test for nominal variables. Repeated measures general linear models were used to analyse differences and trends in CRF (measured in $VO_{2peak}$) and being in the CRF healthy fitness zone at the beginning and at the end of school-years 1 and 2 for the total sample and by sex. All analyses were stratified by sex, given the interaction effect between sex and time in the repeated measures ANCOVA model for the whole sample. Polynomial ANCOVA models, using the Huynh-Felt correction, with Bonferroni *post hoc* analysis for multiple comparisons were computed. These models were adjusted for baseline measures of age, age at peak height velocity, body mass index, moderate and vigorous PA and accelerometer wear time. Data analysis was performed using IBM SPSS Statistics version 26.0 (IBM, Armonk, NY). Statistical significance was set at $p<0.05$.

### 6.4.4. Results

Participants' baseline characteristics and PACER laps at the beginning and at the end of school-years 1 and 2 are presented in Table 12.

Table 12. Participants' baseline characteristics and PACER laps at the beginning and end of school-years 1 and 2.

| | M (SD) or % | | | *p* |
|---|---|---|---|---|
| | **Total (n=440)** | **Boys (n=218)** | **Girls (n=222)** | |
| Age (years) | 12.3 (1.2) | 12.3 (1.2) | 12.2 (1.2) | 0.774 |
| Height (m) | 1.56 (0.09) | 1.56 (0.11) | 1.55 (0.08) | 0.083 |
| Weight (kg) | 49.4 (11.6) | 50.1 (11.9) | 48.7 (11.2) | 0.222 |
| BMI ($kg/m^2$) | 20.2 (3.5) | 20.3 (3.5) | 20.2 (3.6) | 0.738 |
| BMI (categories) | | | | 0.203 |
| Normal weight | 71.6 | 67.9 | 75.2 | |
| Overweight | 21.8 | 25.2 | 18.5 | |
| Obese | 6.6 | 6.9 | 6.3 | |
| Age at PHV (years) | 12.6 (0.8) | 13.3 (0.4) | 11.9 (0.4) | <0.001 |
| Daily MPA (min) | 40.4 (17.4) | 46.7 (18.8) | 34.3 (13.5) | <0.001 |
| Daily VPA (min) | 6.6 (5.8) | 8.2 (6.2) | 5.0 (4.9) | <0.001 |
| PACER at beginning of school-year 1 (laps) | 39.9 (19.7) | 47.9 (21.4) | 32.2 (14.1) | <0.001 |
| PACER at end of school-year 1 (laps) | 44.3 (20.8) | 53.5 (22.0) | 35.3 (14.9) | <0.001 |
| PACER at beginning of school-year 2 (laps) | 44.4 (21.4) | 54.8 (22.6) | 34.1 (13.9) | <0.001 |
| PACER at end of school-year 2 (laps) | 49.6 (22.3) | 61.5 (22.4) | 37.9 (14.6) | <0.001 |

Abbreviations: M, mean; SD, standard deviation; BMI, body mass index; PHV, peak height velocity; MPA, moderate physical activity; VPA, vigorous physical activity; PACER, Progressive Aerobic Cardiovascular Endurance Run.
Differences between sexes were tested by independent samples t-test, for continuous variables, and by chi-square test, for nominal variables.

Most participants (71.6%) were categorized as normal weight, 21.8% as overweight, and 6.6% as obese, with no differences being observed between boys and girls ($p=0.203$). Boys engaged in more daily time of moderate PA (46.7 min versus 34.3 min, $p<0.001$) and vigorous PA (8.2 min versus 5.0 min, $p<0.001$) than girls, and performed more laps in PACER in every assessment moment ($p<0.001$).

Differences and trends in $VO_{2peak}$ for boys and girls assessed with repeated measures general linear models are shown in Figure 7. Overall differences between time-point $VO_{2peak}$ were significant for both boys ($p<0.001$) and girls ($p=0.003$). Pairwise comparisons showed that $VO_{2peak}$ improved from the to the end of each school-year for boys (49.1 to 50.6 ml/kg/min, $p<0.001$; 51.0 to 52.8 ml/kg/min, $p<0.001$) and girls (41.7 to 42.5 ml/kg/min, $p<0.001$; 42.2 to 43.3 ml/kg/min, $p<0.001$). However, differences in CRF between the end of school-year 1 and the beginning of school-year 2, i.e. during summer break, were not significant (boys: $p=0.543$; girls: $p=0.343$). Boys presented a linear trend for the change of $VO_{2peak}$ over time ($p=0.029$), while girls presented a cubic trend ($p<0.001$).

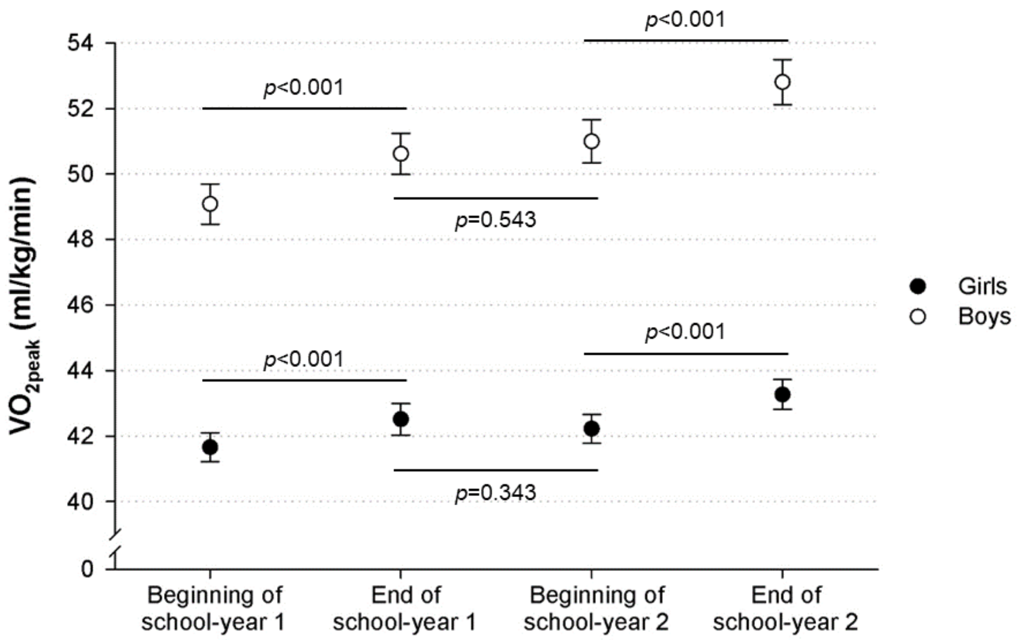


Figure 7. General linear model estimates for the repeated measures of $VO_{2peak}$ at the beginning and end of school-years 1 and 2 for boys and girls.

After analysing trends in $VO_{2peak}$, the trends in the percentage of participants falling in the CRF healthy fitness zone were assessed (Table 13). A cubic trend was found (p=0.001) in the percentage of participants being in the CRF healthy fitness zone for the total sample. Overall differences between time-points were significant (p<0.001), and posterior *post hoc* analysis showed that the percentage of participants in the CRF healthy fitness zone increased during the school-years (77.7% to 84.8%, p<0.001;84.1% to 90.2%, p<0.001) and remained unchanged during the summer break. When splitting the analyses by sex, the same cubic trend (p=0.001) and overall time-point differences (p<0.001) were found for girls, while for boys no significant differences were observed (p=0.370), suggesting that the percentage of boys in the CRF healthy fitness zone remained stable. Furthermore, pairwise comparisons revealed that the percentage of girls in the CRF healthy fitness zone increased during the school-years (60.8% to 73.4%, p<0.001; 73.0% to 83.3%, p<0.001) and did not change during the summer break.

Table 13. General linear model estimates for the repeated measures of cardiorespiratory fitness healthy fitness zone at the beginning and end of school-years 1 and 2.

| | % in CRF healthy fitness zone (95% CI) | | | | |
|---|---|---|---|---|---|
| | **Beginning of school-year 1** | **End of school-year 1** | **Beginning of school-year 2** | **End of school-year 2** | ***p*** |
| Total (n=440) | 77.7 (73.8, 81.4) | 84.8 (81.6, 88.1) | 84.1 (80.7, 87.4) | 90.2 (87.5, 93.0) | <0.001 |
| Boys (n=218) | 95.0 (92.0, 97.9) | 96.3 (93.8, 98.8) | 95.4 (92.6, 98.2) | 97.2 (95.1, 99.4) | 0.370 |
| Girls (n=222) | 60.8 (54.3, 67.3) | 73.4 (67.6, 79.3) | 73.0 (67.1, 78.4) | 83.3 (78.9, 88.3) | <0.001 |

Abbreviations: CRF, cardiorespiratory fitness; CI, confidence interval.
Analysis was adjusted for baseline measures of age, age at peak height velocity, body mass index, moderate and vigorous physical activity and accelerometer wear time.

### 6.4.5. Discussion

This 2-year longitudinal investigation following 6th to 8th graders' CRF trends during the school-year showed that CRF increased from the beginning to the end of each school-year, but remained unchanged during summer break. This highlights a possible adverse effect of summer break on CRF, given the lack of continued CRF improvement observed during the summer break period.

The detrimental effect of summer break in young people's weight status has been widely studied, with evidence showing accelerated weight gain during the summer period (Baranowski et al., 2014; von Hippel & Workman, 2016). Although evidence is much scarcer for CRF, a similar influence of summer has been proposed (Brusseau & Burns, 2018; Carrel et al., 2007; Fu et al., 2017). Brusseau and Burns (2018) and Fu et al. (2017) examined the impact of a single and multiple 12-week summer breaks on both BMI and CRF in children participating in a multi-year school-based PA intervention. Their findings suggested that improvements in CRF seen during the school-year were partially or completely negated with the summer break. Carrel et al. (2007) obtained similar results showing that improvements seen in the 9-month school-year fitness program intervention in body fat, CRF, and insulin levels in overweight children were lost during the 3-month summer break.

The findings from the current investigation are in line with previous research (Brusseau & Burns, 2018; Carrel et al., 2007; Fu et al., 2017), contributing to the relatively small body of knowledge on this topic. For both boys and girls, CRF remained unchanged during the summer, contradicting the improvement trend found during each of the two school-years. Furthermore, for girls, when examining health-related CRF (i.e. having a high enough CRF to be within the healthy fitness zone), improvements were observed during the school-year, but not during the summer break. However, the same trend was not observed in boys, which may be related to the already very high percentage of boys in the healthy CRF zone at baseline. Notwithstanding, a pattern of improvement during school-year and stall during summer were clear. This is an important finding that reinforces the role of school in promoting children and adolescents' CRF. Also, it highlights summer break as a possible high-risk period that may be an overlooked critical window for intervention (Watson et al., 2019).

Some hypotheses that may explain why the summer break seems to have an impact on CRF and other health indicators, have been proposed. Of these hypothesis, the 'Structured Days Hypothesis' stands out, providing logical and data-based evidence supporting the idea that children are more exposed to obesogenic behaviours during days that are unstructured (Brazendale et al., 2017). This hypothesis states that the presence of routine, and/or regulation in structured days, such as a school weekday, positively shapes the healthy behaviours of young people, with one of these behaviours being PA. On the one hand, it has been suggested that children and adolescents are more physically active during structured days (e.g. in-school period, weekdays) than on unstructured days (e.g. school summer break, weekend days) (Brazendale et al., 2021; Olds et al., 2019). On the other hand, some studies report higher levels of PA during the summer break compared with school time (Staiano et al., 2015; Wang et al., 2015). Although there is not a clear consensus regarding PA levels during the school-year versus summer break, it is plausible that scheduled PA opportunities, such as PE and recess included in structured days limit opportunities for unhealthy weight gain and declines in fitness (Brazendale et al., 2017). Additionally, recent research has shown that school, and more specifically PE, may contribute to student's CRF improvement (Peralta, Henriques-Neto, et al., 2020; Peralta, Santos, et al., 2020). Therefore, the several PA opportunities presented throughout structured days (e.g. PE, recess, free play time before or after school hours, active transport to and from school) may positively influence young peoples' CRF (Brazendale et al., 2017; Watson et al., 2019).

The present investigation presents a set of limitations that must be considered before any generalizations can be made. The sample was from one city, Oeiras, in Portugal and, thus, caution must be taken when generalizing our results to other populations. CRF was assessed using a field-test instead of a direct measure. Notwithstanding, the PACER test been shown to be a reliable and valid tool to assess CRF in children and adolescents (Morrow et al., 2010). Also, PA opportunities of the children during the summer were not tracked. Besides the limitations, the investigation also presents some strengths that are worth mentioning. To the best of our knowledge, this is the first study examining the trends of CRF in the school-year and summer break in a sample composed predominantly of middle-school students (previous studies have been focused on elementary-school children). Analyses were adjusted to an important set of confounding variables such as maturity, objectively measured PA and weight status. Lastly, the investigation followed participants for two consecutive school-years, allowing for the analysis of the CRF trend during the school-years immediately before and after the summer break.

### 6.4.6. Conclusion

Improvements in CRF were observed during the school-years and remained unchanged during summer break in middle-school boys and girls. This finding provides relevant information for the health education community, suggesting the need for additional efforts to reverse the adverse effect of summer break on continued improvements in CRF. Also, this finding reinforces the identification of summer break as a potentially high-risk period for young peoples' health that may be an overlooked critical window for intervention. Future studies should investigate how summer PA levels may mediate this trend and how a summer break- or unstructured days-based PA intervention could prevent/counter this trend.

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# Chapter [4]

# 7. Discussion

This thesis investigated the promotion of CRF in the school context, especially in PE. Several specific aims were pursued, related to PA in PE, teacher behaviour, lesson context and trends in CRF during the school-year and summer break. In this section a summary of the findings and a general discussion of those findings are provided.

## 7.1. Summary of the main findings

The summary of the main findings is presented below according to each specific aim.

**Specific aim 1: to summarize literature findings on the contribution of PE classes for promoting health-related CRF in children and adolescents**

A systematic review, Study 1, was conducted, including 24 studies ranging from 1969 and 2017. Taking into account the reviewed studies results it was not possible to reach a conclusive understanding of PE contribution to students' CRF, as several findings suggested that PE has a neutral effect on students' CRF, while others reinforce its importance. However, higher intensity PE classes consistently demonstrated having a positive contribution in promoting students' CRF. Additionally, some other potentially relevant factors for promoting CRF in PE classes were identified, such as age and weight status.

**Specific aim 2: to analyse the relationship between PE class intensity and change in CRF over one school-year in children and adolescents**

Study 2, a school-year long longitudinal study, showed that from the beginning to the end of the school-year a greater percentage of participants were in the CRF healthy fitness zone. Several factors associated with the change in CRF were identified, including sex, being overweight or obese, minutes of daily vigorous PA, organized sports participation and PE intensity. Regarding PE, the percentage of PE time being very active was associated with positive changes in CRF, although only among boys. Furthermore, among boys, the percentage of PE time being very active was found to have the greatest magnitude of association to PACER change.

**Specific aim 3: to analyse the relationship between PE class contexts and change in CRF over one school-year in children and adolescents**

Study 3, which used the same design as Study 2, explored the role of PE lesson context on promoting students' CRF. Time spent in general content was found to be negatively associated with PACER change in both sexes. However, time spent in gameplay situations was associated with positive changes in CRF. Only for boys, time spent in fitness situations was negatively associated with PACER change.

**Specific aim 4: to analyse the relationship between PE teacher behaviours and change in CRF over one school-year in children and adolescents**

Also in Study 3, the role of PE teacher behaviour on promoting students' CRF was examined. For both boys and girls, time spent by the teacher in instruction tasks was positively associated with PACER change and time spent by the teacher in management tasks was associated with negative changes in CRF. Additionally, in girls, time spent by the teacher promoting fitness was positively related to CRF improvements.

**Specific aim 5: to analyse the trends of CRF during two school-years with a 3-month summer break in children and adolescents**

A 2-year longitudinal investigation was performed, Study 4, following students' CRF trends during the school-year. Findings showed that CRF increased from the beginning to the end of each school-year, but remained unchanged during summer break. This highlights a possible adverse effect of summer break on CRF, given the lack of continued CRF improvement observed during the summer break period.

## 7.2. Promoting cardiorespiratory fitness in physical education

Research interest on the contributing role of PE in promoting CRF among children and adolescents is not new, however findings are still inconclusive and investigations have mainly focused on intervention programs within PE, which often increased frequency or duration of offered PE (Peralta et al., 2020). Therefore, research focused on curricular PE is scarce. This was noted by the systematic review performed within the scope of this thesis. Many of the included studies were from intervention programs (although not increasing frequency or duration of offered PE, these intervention programs altered intensity of the classes) or studying moderate-to-vigorous PA during PE. Notwithstanding, this systematic review allowed to identify relevant factors for promoting CRF in PE that should be taken into account. Besides the systematic review, the original studies performed within the scope of this thesis also revealed several factors associated with promoting CRF in young people. Findings from this thesis are important to characterize the contribution of PE for promoting CRF in young people, as well as health promotion in PE.

One of the main factors associated with promoting CRF in PE is PA intensity during lessons and the percentage of time spent in higher intensity PA. Study 2 showed that, while the percentage of PE time walking (which can be comparable to moderate PA) was not associated with positive changes in CRF, the percentage of PE time being very active (which can be comparable to vigorous PA) was, although only among boys. Furthermore, among boys, the percentage of PE time being very active was found to have the greatest magnitude of association to PACER change. This finding is in agreement with Study 1, the systematic review, that has identified PE class intensity as a key factor for promoting students' CRF (Peralta et al., 2020). In this review, findings suggesting that PE has a positive contribution in improving CRF were mainly related to the intensity level of the classes. However, most studies reflecting this association examined intervention programs built to increase PE class intensity without increasing the number of classes or curricular time dedicated to PE. For example, four studies reported that students participating in PE classes from the intervention programs increased their CRF levels, while students participating in regular PE classes, i.e. classes that were not part of the program, decreased or maintained their CRF levels (Bendiksen et al., 2014; Mayorga-Vega et al., 2016; Mayorga-Vega & Viciana, 2015; Ramirez Lechuga et al., 2012). Findings from Studies 1 and 2 are relevant for PE, as they demonstrate that PE classes may have an important role in promoting health-related CRF if PA of sufficient intensity is provided. Despite this, several investigations have shown that most students spent less than the recommended 50% of PE time in moderate-to-vigorous PA (Hollis et al., 2017; Lonsdale et al., 2013). Interestingly, in this thesis' original investigations this was not the case, as more than 50% of PE time was estimated to be in moderate-to-vigorous PA (walking plus being very active). To promote CRF in PE it is crucial that moderate-to-vigorous PA is provided, especially vigorous PA, in sufficient quantity. Thus, actions to increase the percentage of time spent in moderate-to-vigorous PA in PE should be performed in order to promote health.

Besides time spent in PA during PE classes, teacher behaviour and class context were also investigated in this thesis. From the systematic review, it was evident that contexts that provide greater chances for engaging in moderate-to-vigorous PA (e.g., fitness activities and team games), helped to promote CRF in PE (Peralta et al., 2020). This was partially confirmed by Study 3. On the one hand, it was observed that PE lesson time spent in gameplay was associated with improvements in CRF for both boys and girls. It is known that PE classes of invasion games and sports can engage students in moderate-to-vigorous PA (Fairclough & Stratton, 2005; McKenzie et al., 2000; Molina-Garcia et al., 2016). Furthermore, small-sided games in football at schools can improve children's physical fitness (Krustrup et al., 2016). This is corroborated with investigations from out-of-school contexts, such as sports training. Previous studies have demonstrated that children and adolescents participating in organized sports have better CRF than their non-participating peers and that appropriate exercise training is known to increase CRF levels in youth, irrespective of sex, age or maturity (Armstrong & Barker, 2011; Silva et al., 2013). Also, Study 2 revealed that participation in organized sports was associated with a positive change in PACER from the beginning to the end of the school-year, being this the only common variable associated with changes in PACER for both boys and girls in this study. Thus, invasion games and sports seem to be the most appropriate context to promote equal involvement between boys and girls (Molina-Garcia et al., 2016). This evidence reinforces that planned and structured exercise programs with adequate frequency, duration, and intensity induce changes in CRF. Considering the school setting, it is possible to plan for activities that fulfil these requirements, especially in PE programs and therefore promote health-related CRF in PE.

On the other hand, PE lesson time spent in fitness was not associated with CRF in girls and was negatively associated with CRF in boys, which is in contrast with both Study 1 and previous research. Previous investigations have shown that invasion games and fitness activities in PE also present the greatest amount of time spent in moderate-to-vigorous PA by students (Fairclough & Stratton, 2005; McKenzie et al., 2000; Molina-Garcia et al., 2016). It is possible that results obtained in Study 2 may be due to the SOFIT coding of fitness motor content including the warm-up and cool-down periods. The majority of the time coded as fitness was most likely spent in warm-up and cool-down activities, during which students were less engaged in higher intensity levels of PA, therefore these results should be interpreted with caution. Additionally, when looking at teacher behaviour during PE lessons, promoting fitness presented the strongest association with CRF improvement in girls. This finding is of great significance, especially considering that in the vast majority of cases, due to PE lessons' limited frequency and duration, teachers are unable to provide students with the recommend 60 minutes of moderate-to-vigorous PA for health and fitness promotion (McKenzie & Lounsbery, 2013). Therefore, promoting fitness during and outside of class may be a smart strategy for teachers to engage their students in PA and improve CRF, especially for girls.

Also, Study 3 revealed that the percentage of time teachers spent in instruction tasks, including feedback, was associated with improvements in CRF from the beginning to the end of the school-year. Competence satisfaction, which predicts greater intentions to participate in PA, is associated with positive feedback (Mouratidis et al., 2008). Furthermore, expectancy-related beliefs in PE were previously found to be associated with performance on the PACER test (Gao et al., 2008). Therefore, it is possible that providing more feedback to students might improve their expectancy-related beliefs and encourage them to be more active, which in turn may help to promote their CRF.

In opposition to the previous factors, some PE contexts hinder the potential of PE for promoting CRF. Previous investigations have demonstrated that students typically present lower levels of PA during PE time in management context (McKenzie et al., 2006; McKenzie & Lounsbery, 2013; McKenzie et al., 2000; Mersh & Fairclough, 2010). In conformity, Study 3 showed that lesson time spent in general content, mainly management and transition situations, and the time teachers were engaged in management tasks were inversely associated with CRF change in boys and girls. Reducing managing time in PE is crucial, especially considering the limited time devoted to PE lessons. Planning to specifically increase moderate-to-vigorous PA time and improved teacher management skills are considered to be the most effective strategies to increase both PA minutes and intensity in PE (McKenzie & Lounsbery, 2013). Considering PA as a key determinant for improving fitness, lesson planning and deliberated planning that optimizes moderate-to-vigorous PA time assumes a crucial role in promoting CRF in PE. This is further supported by the fact that PE delivered by well-trained specialists increases PA during school hours in young people (IOM, 2013).

Another factor associated with promoting CRF in PE was age. For older ages PE seemed to be less effective in promoting students' CRF (Erfle & Gamble, 2015; Mayorga-Vega et al., 2016; Ramirez Lechuga et al., 2012; Reed et al., 2013), whereas for younger ages almost all studies suggested that PE classes improved the students' CRF (Bendiksen et al., 2014; Jarani et al., 2016; Lucertini et al., 2013; Reed et al., 2013). This finding may be linked to several factors regarding the associations between age and CRF and age and PA participation. It is known that CRF naturally increases as children grow-up, mainly because of body growth. Growth occurring with greater emphasis at younger ages potentiates increases in CRF independently of PA and PE. This increase is fairly linear in boys until later adolescence, whereas in girls it plateaus around age 13 (Eisenmann et al., 2011; Malina et al., 2004). Furthermore, age and PA participation are inversely associated (Duncan et al., 2007; Marques et al., 2020), which is of importance considering that PA is the primary means of promoting CRF (Lang et al., 2018). Lastly, motivation to participate in PE declines in the late elementary, middle and high school years (Ntoumanis et al., 2009; Xiang et al., 2004) possibly resulting in decreasing PA during PE. Therefore, increasing CRF, related to body growth, occurring at younger ages and decreasing participation in PA, including during PE, among older students may explain why improvements in CRF for a given period are more frequently found in younger children and adolescents. In contrast with the systematic review (Peralta et al., 2020), findings from Study 2 did not find age to be associated with the change in CRF from the beginning to the end of the school-year. Notwithstanding, it should be taken into consideration that 88.7% of participants were aged 12 to 14 years old, and thus, age differences may not be identifiable.

Weight status was also identified as a factor influencing the promotion of CRF in PE. Study 2 revealed that being overweight or obese was negatively associated with the change in PACER laps from the beginning to the end of the school-year, although only in girls. Also, in the systematic review, Study 1, one of the included studies showed that an eight months PE program was unable to improve CRF and maintenance of these effects over the next two years in obese girls (Camhi et al., 2011). Several factors may explain the effect of weight status in CRF. Firstly, the PACER is a weight-bearing test, thus overweight and obese students have more difficulties in performing better in this test. Secondly, young people who are overweight and obese have lower levels of moderate-to-vigorous PA (Hills et al., 2007; Strong et al., 2005), which might compromise improvements in CRF. Thirdly, overweight and obese students were, respectively, 27% and 54% more likely to have school absenteeism than their normal-weight peers (An et al., 2017). Given that PE is for many students the only opportunity to engage in structured and appropriate PA, especially among those that have low levels of habitual PA, overweight and obese students might be penalized by school absenteeism. Lastly, overweight and obese children have poorer fundamental movement skills than their normal-weight counterparts (Okely et al., 2004). Mastering fundamental motor skills is strongly related to PA in children and adolescents and is critical to fostering PA since these skills are the foundation for advanced and sport-specific movement (Lubans et al., 2010). All these factors may contribute to a greater ineffectiveness of PE programs among overweight and obese students. Therefore, PE should not only provide sufficient intensity PA to promote health but also be based on developmentally appropriate motor activities to nurture self-efficacy and enjoyment and encourage ongoing participation in PA.

In summary, findings from Studies 1, 2, and 3 suggest that PE contributes to the promotion of health-related CRF mainly through providing high-intensity PA opportunities, but also through the action of PE teachers. Promoting CRF in PE can be achieved by providing active class contexts, such as gameplay, reducing management time, and promoting in-class and out-of-class fitness. These are important modifiable factors controlled by the teacher that can improve students' CRF. Despite these findings, differences between boys and girls were observed and must be acknowledged. Specifically, for girls encouraging fitness and daily vigorous PA were associated with a positive change in CRF, while PA in PE was not. To improve CRF in girls, it is important that PE teachers reduce management time, provide more opportunities for them to engage in structured and appropriate PA, such as invasion games and sports, and encourage fitness and PA outside of school.

## 7.3. The effect of the school-year and summer break on cardiorespiratory fitness

The school setting is an important context for health promotion, mainly because schools provide opportunities for healthy behaviours such as regular PA, and young people spend a great part of their days in this context (Bocarro et al., 2012; Brazendale et al., 2017). Conversely, a recent concern regarding school-based health promotion strategies has emerged, founded by the inability to continue school programs aimed over the summer (Brusseau & Burns, 2018; Fu et al., 2017). Therefore, recently it has been proposed that summer break may have a negative impact on young people's health, including CRF (Watson et al., 2019).

Previous investigations, predominantly from North America, have indicated that weight gain accelerates during the summer break (Baranowski et al., 2014; von Hippel & Workman, 2016) and that CRF improvements made during the school-year are adversely impacted by the summer break (Brusseau & Burns, 2018; Carrel et al., 2007; Fu et al., 2017). In line with previous studies, findings from Study 4 showed that CRF increased from the beginning of each school-year to its end but remained unchanged during summer break, highlighting a possible adverse effect of summer break on CRF, given the lack of continued CRF improvement observed during the summer break period.

A proxy of how summer break can impact children and adolescents' behaviour, is the observed differences in PA on weekdays and weekend days. It is often reported that young people are more active during weekdays, which may be attributed to the daily structured and unstructured PA opportunities provided in the school setting (Brazendale et al., 2021; Olds et al., 2019). The 'Structured Days Hypothesis' states that the presence of routine, and/or regulation in structured days, such as a school weekday, positively shapes the obesogenic behaviours of young people, being one of these behaviours PA (Brazendale et al., 2017). Therefore, this hypothesis provides logical and data-based evidence supporting the idea that children are more exposed to obesogenic behaviours during unstructured days. Nevertheless, some investigations have evidence suggesting the opposite, i.e. reporting higher levels of PA during the summer break compared with school time (Staiano et al., 2015; Wang et al., 2015).

Although there is not a clear consensus regarding PA levels during the school-year versus summer break, it is plausible that scheduled PA opportunities, such as PE and recess, included in structured days limit opportunities for unhealthy weight gain and declines in fitness (Brazendale et al., 2017). This is consistent with evidence from Study 1, 2, and 3 that have shown that PE classes may contribute to improving young peoples' CRF. Furthermore, the several PA opportunities presented throughout structured days (e.g. PE, recess, free play time before or after school hours, active transport to and from school) may positively influence young peoples' CRF (Brazendale et al., 2017; Watson et al., 2019). The trends in CRF observed in Study 4, more precisely improvements during school time and stall during the summer break, reinforce the role of school in promoting children and adolescents' CRF. Also, it highlights summer break as a possible high-risk period that may be an overlooked critical window for intervention (Watson et al., 2019).

## 8. Strengths and limitations

This thesis has several strengths and limitations that should be taken into account when interpreting the findings of the present thesis.

Regarding the original investigations' limitations, CRF was assessed using a field-test, namely the PACER, which gives an estimation of CRF instead of a direct measure (Mayorga-Vega et al., 2015). Nonetheless, the PACER test is a reliable and valid tool to assess CRF in children and adolescents (Morrow et al., 2010). Also, specific to Study 4, young people's PA opportunities during the summer were not tracked, which may be an important confounding variable for trends of CRF during this period. The samples included in this thesis were from Sintra, in Study 2 and 3, and Oeiras, in Study 4, therefore, caution must be taken when generalizing our results to other populations. Additionally, the schools included in Study 2 and 3 are both from middle-to-low-income neighbourhoods in urban areas, which makes generalizing the findings to other settings difficult. Finally, limitations associated with the use of SOFIT were presented in Studies 2 and 3. The percentage of PE time walking and being very active were estimated through a visual observation instrument (SOFIT) instead of objectively measured which can overestimate PA levels in PE. Nonetheless, SOFIT is validated as a measure of PA intensity during PE classes (McKenzie et al., 1991).

Limitations specific to the systematic review (Study 1) are the following. First, included studies had a wide publication date range, from 1969 to 2017, and were from different cultural and socioeconomic contexts, which could have implications on what PE classes represent as well as PE curricula. Secondly, 16 studies were not accessible to the authors. Lastly, even though study bias was assessed according to their methodological quality (USDHHS, 2014), they were not weighted or ranked, thus, findings from studies with poorer quality and smaller sample sizes were given no less importance than other findings.

Despite these limitations, this thesis' studies also present several strengths. All the original investigations, Study 2, 3, and 4, employed a longitudinal study design, following participants for one or two school-years. The longitudinal design allows inferring temporal directions in the associations assessed and to determine the CRF trend during the school-years immediately before and after the summer break. Furthermore, habitual PA was objectively measured using accelerometers. Also, analyses were adjusted to an important set of confounding variables such as maturity, objectively measured PA, sports participation and weight status. As for the systematic review, Study 1, an extensive research strategy comprising four different databases and several keywords was used. Lastly, to the best of our knowledge, the investigations performed for this thesis present novel research, specifically regarding the contribution of PE classes in promoting students' CRF and the trends of CRF in the school-year and summer break in a sample composed predominantly of middle-school students.

# 9. Perspectives and future research

This thesis findings have shown that PE and the action of the PE teacher are important for the improvement in CRF and thus for the promotion of health-related CRF particularly and health in general. It was noted that classes with lower management time and greater active time (whether it was gameplay or percentage of time being very active) contributed to a positive change in CRF from the beginning to the end of the school-year, independently of daily moderate and vigorous PA, weight status, age and sport participation. Also, the time spent by the PE teacher in instruction, including feedback, and promoting fitness was associated with an improvement in CRF. Therefore, PE is a valuable health promotion setting capable of providing adequate PA opportunities and impact young peoples' health and can be a successful context to promote children and adolescents' CRF levels that should be invested in.

Notwithstanding, for this to happen high-quality PE classes must be provided. The key aspects related to this high-quality PE are the time spent in moderate-to-vigorous PA and being thought by skilled specialist PE teachers. In fact, for Study 2 and 3, where students increased CRF over the school-year and PA in PE was found to be associated with positive changes in CRF, PE classes provided in mean more than the recommended 50% of the time in moderate-to-vigorous PA. This is encouraging and shows that PE classes can achieve this recommendation and whit it impacts students' health. However, this was only significant for boys. Other aspects of PE besides intensity, such as frequency and duration, can also have an important role in promoting CRF. Several investigations have proposed that daily PE provides better opportunities for enhancing PA and fitness (Lahti et al., 2018; Loprinzi et al., 2018; Mooses et al., 2017; Reed et al., 2013). It is possible that girls, because of their lower daily PA levels need more PE classes per week to achieve health benefits. Furthermore, the content of PE is of importance. Contents that provide greater chances for engaging in moderate-to-vigorous PA (e.g., fitness activities and team games), may help to promote CRF in PE. It appears that gameplay situations in PE classes can simultaneously promote PA levels and CRF while opportunities for all, and should therefore be encouraged in PE teaching practice guidelines.

Given these findings, the low levels of PA and decreasing levels of CRF and the fact that PE can have a greater impact on CRF and health if performed more frequently within the week, health and education authorities in Portugal, and worldwide, should improve the implementation conditions for PE. More precisely by increasing the frequency of classes, improving adequate PA opportunities for all children and adolescents, and recognizing the critical role of specialists PE teachers by investing in the initial and during service training.

Future research on the role of school and PE in promoting CRF should continue to investigate the contribution of PE to the improvement of CRF and other fitness attributes, and examine which curricula offers the best opportunity to improve fitness, health and promote life-long PA behaviours. Also, the identification of the summer break as a period where improvements in CRF seen during the school-year are hindered requires that future investigations examine how summer PA levels may mediate this trend and how a summer break- or unstructured days-based PA intervention could prevent/counter this trend.

## 10. Conclusion

Health and education authorities have considered the school setting as an important context for promoting PA and fitness. Within the school context, PE stands out as the privileged means to achieve this goal. However, few investigations have examined the contribution of PE classes to promoting CRF in children and adolescents. This thesis adds relevant information to the literature in this field by demonstrating that PA in PE, PE class contexts and the PE teacher action contribute to changes in CRF throughout the school-year.

Regarding the role of school, Study 4 indicated that improvements in CRF were observed during the school-years and remained unchanged during summer break in middle-school boys and girls. This finding provides relevant information for the health education community, suggesting the need for additional efforts to reverse the adverse effect of summer break on continued improvements in CRF. Also, this finding reinforces the identification of summer break as a potentially high-risk period for young peoples' health that may be an overlooked critical window for intervention.

Regarding the role of PE, Study 2 findings suggest that the percentage of time being very active in PE has a positive and significant role in the promotion of CRF, especially among boys. Complementing, Study 3 shows that time spent in gameplay situations and teacher behaviours of instructing and promoting fitness (particularly for girls) were associated with improvements in students' CRF; whereas time spent in general content and fitness situations (particularly for boys) and, by teachers, in management tasks was inversely associated with students' CRF. These are important modifiable factors controlled by the teacher that can improve students' CRF. Promoting CRF in PE can be achieved by providing active class contexts, such as gameplay, reducing management time, and promoting in-class and out-of-class fitness. From a health promotion perspective, PE classes can play a significant role in the promotion of health-related CRF, and thus, in improving young peoples' health. For that, high-quality PE, considering class context, teacher behaviour, and PA intensity should be provided.

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# Appendices

## Appendix 1. Ethical approval by the ethics committee of the Faculty of Human Kinetics, University of Lisbon

FACULDADE DE MOTRICIDADE HUMANA

Conselho de Ética



**Para:**

Dr. Miguel Peralta
Faculdade de Motricidade Humana

**Data**: 26 de junho de 2017

**Projeto**: "O papel da escola e das aulas de educação física no desenvolvimento da aptidão cardiorrespiratória"

**Estado CEFMH**: Positivo

**Parecer CEFMH N.º**: 19/2017

Este Conselho analisou o projeto em epígrafe. Confirma-se que o mesmo está em conformidade com as diretrizes nacionais e internacionais para a investigação científica que envolve seres humanos, incluindo a Declaração de Helsínquia sobre os Princípios Éticos para a Investigação Médica em Seres Humanos (2013) e a Convenção sobre os Direitos do Homem e a Biomedicina ("Convenção de Oviedo", 1997).

*O Vice-Presidente do Conselho de Ética da FMH*

Paulo A. S. Armada da Silva

Conselho de Ética da Faculdade de Motricidade Humana, Universidade de Lisboa
Faculdade de Motricidade Humana
Estrada da Costa, 1495-688 Cruz Quebrada - Portugal
etica@fmh.ulisboa.pt

## Appendix 2. Ethical approval by the Portuguese national commission for data protection

# Autorização n.º 9259/ 2017

Miguel Pedro Fernandes de Almeida Fragoso Peralta notificou à Comissão Nacional de Protecção de Dados (CNPD) um tratamento de dados pessoais com a finalidade de realizar um Estudo Clínico sem Intervenção, denominado O papel da escola e das aulas de educação física no desenvolvimento da aptidão cardiorrespiratória .

O participante é identificado por um código especificamente criado para este estudo, constituído de modo a não permitir a imediata identificação do titular dos dados; designadamente, não são utilizados códigos que coincidam com os números de identificação, iniciais do nome, data de nascimento, número de telefone, ou resultem de uma composição simples desse tipo de dados. A chave da codificação só é conhecida do(s) investigador(es).

É recolhido o consentimento expresso do participante ou do seu representante legal.

A informação é recolhida diretamente do titular.

As eventuais transmissões de informação são efetuadas por referência ao código do participante, sendo, nessa medida, anónimas para o destinatário.

A CNPD já se pronunciou na Deliberação n.º 1704/2015 sobre o enquadramento legal, os fundamentos de legitimidade, os princípios aplicáveis para o correto cumprimento da Lei n.º 67/98, de 26 de outubro, alterada pela Lei n.º 103/2015, de 24 de agosto, doravante LPD, bem como sobre as condições e limites aplicáveis ao tratamento de dados efetuados para a finalidade de investigação clínica.

No caso em apreço, o tratamento objeto da notificação enquadra-se no âmbito daquela deliberação e o responsável declara expressamente que cumpre os limites e condições aplicáveis por força da LPD e da Lei n.º 21/2014, de 16 de abril, alterada pela Lei n.º 73/2015, de 27 de junho – Lei da Investigação Clínica –, explicitados na Deliberação n.º 1704/2015.

O fundamento de legitimidade é o consentimento do titular.

A informação tratada é recolhida de forma lícita, para finalidade determinada, explícita e legitima e não é excessiva – cf. alíneas a), b) e c) do n.º 1 do artigo 5.º da LPD.

Assim, nos termos das disposições conjugadas do n.º 2 do artigo 7.º, da alínea a) do n.º 1 do artigo 28.º e do artigo 30.º da LPD, bem como do n.º 3 do artigo 1.º e do n.º 9 do artigo 16.º ambos da Lei de Investigação Clínica, com as condições e limites explicitados na Deliberação da CNPD n.º 1704/2015, que aqui se dão por reproduzidos, autoriza-se o presente tratamento de dados pessoais nos seguintes termos:

**Responsável –** Miguel Pedro Fernandes de Almeida Fragoso Peralta

**Finalidade –** Estudo Clínico sem Intervenção, denominado O papel da escola e das aulas de educação física no desenvolvimento da aptidão cardiorrespiratória

**Categoria de dados pessoais tratados –** Código do participante; idade/data de nascimento; género; dados antropométricos; composição do agregado familiar sem identificação dos membros; dados da história clínica; dados dados de exame físico; dados de qualidade de vida/efeitos psicológicos

**Exercício do direito de acesso –** Através dos investigadores, por escrito

**Comunicações, interconexões e fluxos transfronteiriços de dados pessoais identificáveis no destinatário –** Não existem

**Prazo máximo de conservação dos dados –** A chave que produziu o código que permite a identificação indireta do titular dos dados deve ser eliminada 5 anos após o fim do estudo.

Da LPD e da Lei de Investigação Clínica, nos termos e condições fixados na presente Autorização e desenvolvidos na Deliberação da CNPD n.º 1704/2015, resultam obrigações que o responsável tem de cumprir. Destas deve dar conhecimento a todos os que intervenham no tratamento de dados pessoais.

Lisboa, 10-08-2017

A Presidente

**Appendix 3. Copy of the published version of Study 1**

PLOS ONE

RESEARCH ARTICLE

# Promoting health-related cardiorespiratory fitness in physical education: A systematic review

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**Competing interests:** The authors have declared that no competing interests exist.

## Abstract

### Background

This article aimed to systematically review the contribution of physical education (PE) classes to improve cardiorespiratory fitness (CRF) in children and adolescents; and to define potentially relevant factors for promoting CRF in PE classes.

### Methods

Studies were identified from searches in ERIC, PubMed, SPORTDiscus, and Web of Science databases. Primary source articles, relating PE classes and CRF, published up to July 2019 in peer-reviewed journals were eligible for inclusion. Specific inclusion criteria were: (a) having cross-sectional or longitudinal and observational or interventional study designs; (b) targeting school-aged children or adolescents; (c) measuring CRF, heart rate or CRF test results as an outcome; (d) having statistical analyses of the CRF, heart rate or CRF test results outcomes reported; (e) focusing on PE classes or PE interventions that did not extended time or frequency of the classes; and (f) published in English, French, Portuguese, or Spanish.

### Results

A total of 24 studies met the inclusion criteria. Overall, 10 studies have found a neutral effect of PE classes in students' CRF, eight studies found that PE indeed contributed to the improvement of CRF and six studies revealed mixed findings, when PE classes where controlled for others variables (e.g. body mass index, intensity). Higher intensity PE classes consistently demonstrated contributions to improving students' CRF.

### Conclusion

Review findings suggest that PE classes can contribute to the improvement of students' CRF. Intensity, age and weight status were identified as potentially relevant factors for promoting CRF in PE classes. To improve CRF, higher intensity classes should be provided.

## Introduction

Cardiorespiratory fitness (CRF) mirrors the overall capacity of the cardiovascular and respiratory systems [1]. It is considered as an important health variable, which is associated with several risk factors for cardiovascular diseases independent of socio-demographic factors, diet, and physical activity [2, 3]. Furthermore, CRF is suggested to be a significant risk factor to include in the assessment of the metabolic syndrome for children and adolescents [4]. Hereby, the study of this variable and its associations to health is widely recognized as essential both among adults and youth.

The school setting gives youth the opportunity to be physically active, mainly through physical education (PE) classes [5]. For this reason, the school system is viewed as an important means of promoting physical activity and health among children and adolescents. When performed appropriately and incorporated as one component of a broad and holistic health education programme, fitness monitoring in PE serve as a valuable part of the curriculum and play a role in supporting healthy lifestyles and physical activity [6].

It has been suggested that PE classes may play a significant role in CRF development [7–9] and monitoring [10], as there are a number of field tests available that allow whole school classes to be assessed in one session [11, 12]. Therefore, PE teachers have several quality tools to assess the students' CRF. Notwithstanding, evidence regarding the contribution of PE classes for the development of CRF in children and adolescents is inconsistent [13, 14] and most studies examine school-based physical activity intervention programs [15] instead of curricular PE.

Although the school setting and PE classes offer a platform that might help for improving [7, 8] and monitoring [10] of CRF, recent studies suggest that in the last decades CRF appears to have declined in children and adolescents worldwide [16, 17]. Due to its importance, this evidence is of great concern. In order to begin reversing the decline in CRF, understanding how PE classes contribute to the improvement and maintenance of CRF in children and adolescents is vital. To the best of our knowledge, there is no study available that summarizes findings regarding the effect of PE classes on the CRF of students. Thus, the aims of this review were: (1) to summarize literature findings on the contribution of PE classes for improving CRF in children and adolescents; and (2) to define, based on this review, potentially relevant factors for promoting CRF in PE classes.

## Methods

### Study identification

Four relevant electronic databases (PubMed, ERIC, SPORTDiscus, and Web of Science) were comprehensively searched to identify peer-reviewed articles published up to July 2019. Definition of search terms was discussed among the authors. The identified search terms were: "physical education" AND cardiorespiratory OR cardiopulmonary OR cardiovascular OR endurance OR aerobic OR fitness OR PACER OR FitnessGram OR $VO_2$ OR "physical condition" OR "physical aptitude". Search terms were used in each database to identify potential articles with abstracts for review.

### Study selection and selection criteria

Primary source articles, relating PE classes and CRF, published up to July 2019 in peer-reviewed journals were eligible for inclusion. Specific inclusion criteria were: (a) having cross-sectional or longitudinal and observational or interventional study designs; (b) targeting school-aged children or adolescents; (c) measuring CRF, heart rate or CRF test results as an outcome; (d) having statistical analyses of the CRF, heart rate or CRF test results outcomes reported; (e) focusing on PE classes or PE interventions that did not extended time or frequency of the classes; and (f) published in English, French, Portuguese, or Spanish. Articles that did not meet all the inclusion criteria were excluded. Titles and abstracts of the retrieved articles were independently assessed for eligibility for inclusion by two authors (AM, MP). Duplicates from the electronic database search were deleted. Full texts of all eligible articles were retrieved, and other possible relevant studies were searched in the references of those articles. Two authors (AM, MP) reviewed the text of potential studies, and decisions to include or exclude studies in the review were made by consensus.

### Data extraction and harmonization

Based on the PRISMA statement [18] a data extraction form was applied. Relevant data was extracted from manuscripts by one author (MP); coding was verified by two other authors (AM, ERG). Divergences were discussed among authors and solved. Data extracted included study design, sample size, age, country, content of PE / intervention, outcome measure, method and main findings. Outcome measures were either a direct (e.g. $VO_2$max) or indirect measure (e.g. number of laps) of CRF, or heart rate during exercise. Main findings are presented as a description of the contribution of PE classes to the CRF.

### Study quality and risk of bias

The Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [19] was used to appraise risk of bias (study quality). This tool comprises a 14 item checklist for longitudinal studies, while for cross-sectional studies only 11 items could be applied. According to the criteria, each longitudinal and cross-sectional study was rated either good (when meeting 10–14 and 8–11 criteria, respectively), fair (when meeting 5–9 and 4–7 criteria, respectively), or poor (when meeting 1–4 and 1–3 criteria, respectively). Study quality was assessed by two researchers (AM, MP) independently and discrepancies were discussed and solved by agreement.

## Results

### Literature search

Fig 1 presents the flow diagram of studies through the systematic review process. The systematic literature search identified a total of 582 studies. Additionally, one study was identified through a manual search and added to the review process. Out of these 583 studies, 225 were duplicated and thus removed, resulting in a total of 358 studies for title and abstract screening. After excluding studies at the title and abstract screening (n = 268), 90 studies were eligible for full-text reading and 66 were excluded with reasons. Therefore, a total of 24 studies were identified as relevant and included in this review.

### Risk of bias of included studies

Risk of bias of included studies was assessed by the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [19] and is presented in Table 1. Most studies (19 out of 24) were classified as 'fair', one study received a 'poor' classification, and the other four studies were considered 'good'.

### Study characteristics

Study characteristics are summarized in Table 2. Included studies presented several designs (intervention, observational cross-sectional and observational longitudinal), outcome

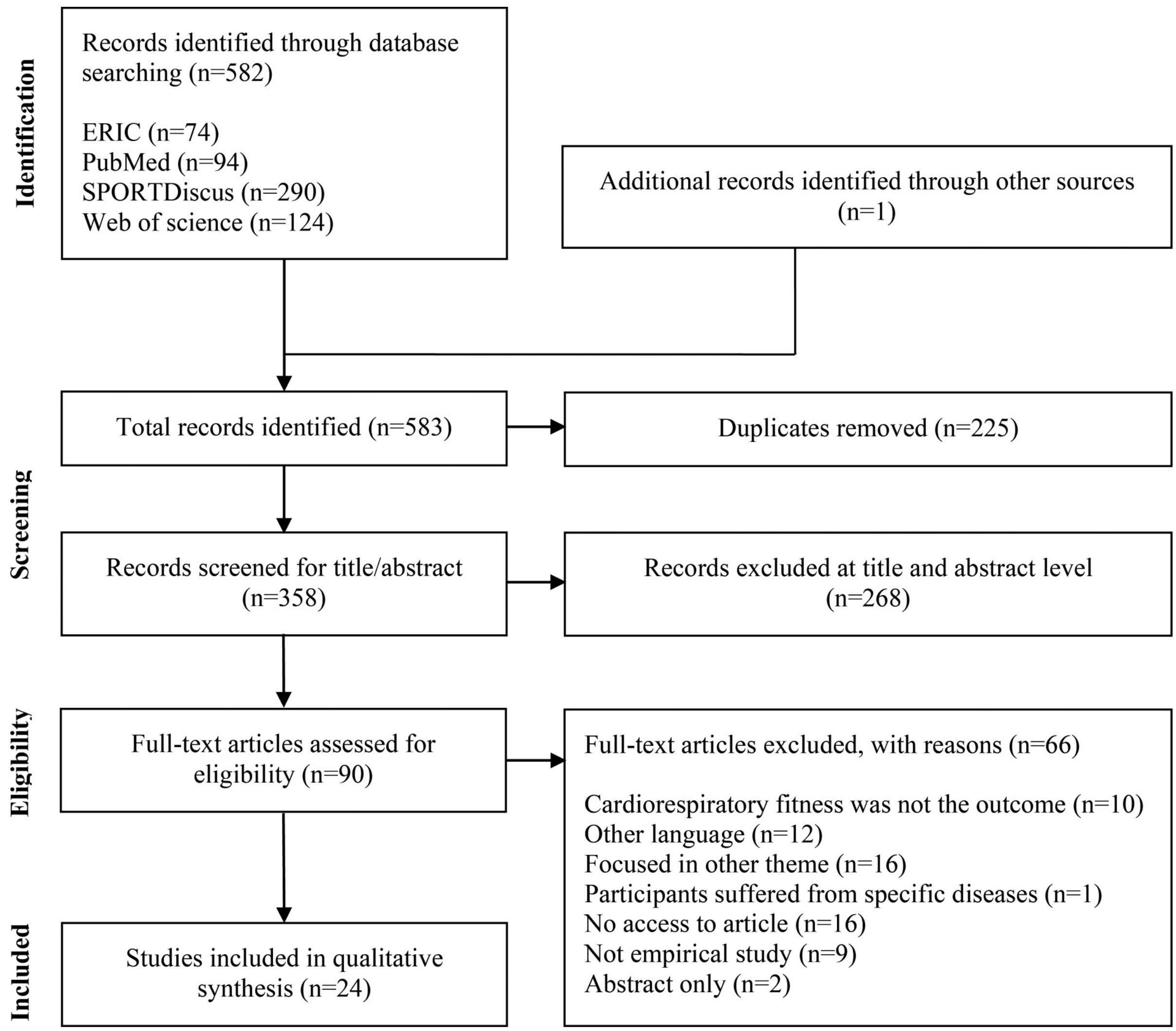


**Fig 1. Flow diagram of studies.**

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measures ($VO_2$max, heart rate, test result), and methods to asses CRF. Studies from 14 countries were included, most of them with a mixed sex sample.

## Main findings

Table 3 shows the main findings and characteristics of the studies included in this review. Included studies ranged from 1969 to 2017, demonstrating that scientific interest in the contribution of PE to promote CRF is close to 50 years old. Overall, 10 studies have found a neutral effect of PE classes in students' CRF, eight studies found that PE indeed contributed to the improvement of CRF and six studies revealed mixed findings, when PE classes where controlled for others variables (e.g. body mass index, intensity). Although 24 studies were included in this review some presented more than one relevant finding, therefore, 33 findings regarding the contribution of PE to the promotion of students' CRF are presented. This resulted in 16 findings indicating that PE did contribute to the improvement of students' CRF, whereas 14 findings point to a neutral effect and 3 findings suggesting that students' CRF decreased during

**Table 1. Risk of bias of included studies.**

| Author | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumming et al., 1969 | N | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Crowhurst et al., 1993 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Strand & Reeder, 1993 | Y | Y | CD | Y | N | Y | NA | CD | N | NA | Y | Y | NA | N | Fair |
| Baquet et al., 2001 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Baquet et al., 2002 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Koutedakis & Bouziotas, 2003 | Y | Y | N | Y | Y | Y | NA | Y | Y | NA | Y | N | NA | N | Good |
| Beets & Pitetti, 2005 | N | Y | CD | Y | N | Y | NA | N | Y | NA | Y | N | NA | N | Fair |
| Fairclough & Stratton, 2005 | Y | Y | N | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Fairclough & Stratton, 2006 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Laurson et al., 2008 | Y | Y | CD | Y | N | Y | NA | Y | Y | NA | Y | N | NA | N | Fair |
| Pelclova et al., 2008 | Y | Y | CD | N | N | Y | NA | N | Y | NA | Y | N | NA | N | Fair |
| Gallotta et al., 2009 | Y | Y | N | Y | N | Y | Y | N | Y | N | Y | N | CD | N | Fair |
| Camhi et al., 2011 | Y | Y | CD | Y | N | Y | Y | Y | Y | Y | Y | N | CD | N | Fair |
| Ramirez Lechunga et al., 2012 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Lucertini et al., 2013 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Reed et al., 2013 | Y | Y | N | Y | N | Y | Y | Y | Y | Y | Y | N | CD | Y | Good |
| Bendikson et al., 2014 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Rengasamy et al., 2014 | Y | Y | CD | Y | N | N | Y | N | N | N | Y | N | CD | N | Fair |
| Erfle & Gamble, 2015 | Y | Y | Y | Y | N | Y | Y | Y | Y | N | Y | N | N | Y | Good |
| Mayorga-Veiga & Viciana, 2015 | Y | Y | CD | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |
| Jarani et al., 2016 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | Y | Y | Good |
| Mayora-Veiga et al., 2016 | Y | Y | CD | Y | N | Y | Y | N | Y | N | Y | N | CD | N | Fair |
| Andres, 2017 | Y | N | CD | CD | N | Y | Y | N | CD | N | N | N | CD | N | Poor |
| Park et al., 2017 | Y | Y | N | Y | N | Y | Y | Y | Y | N | Y | N | CD | N | Fair |

Y, yes; N, no; CD, cannot determine; NA, not available.

https://doi.org/10.1371/journal.pone.0237019.t001

**Table 2. Characteristics of the included studies.**

| Characteristics | Number of studies |
|---|---|
| **Study design** | |
| Cross-sectional | 7 |
| Longitudinal | 2 |
| Intervention | 15 |
| **Outcome measured** | |
| $VO_2max$ / predicted $VO_2max$ | 7 |
| Heart rate | 10 |
| Distance covered | 3 |
| Test duration | 6 |
| Number of laps | 1 |
| **Methods used** | |
| Cycle ergometer protocol | 2 |
| Monitoring heart rate | 10 |
| PACER test | 2 |
| Multistage 20-meter shuttle run test | 4 |
| Yo-Yo Intermittent Recovery Level 1 Children's test | 1 |

(*Continued*)

**Table 2.** (Continued)

| Characteristics | Number of studies |
|---|---|
| Intermittent shuttle run test | 1 |
| 1-mile run/walk test | 2 |
| 1-km run/walk test | 2 |
| 12-Minute Cooper's Test | 1 |
| 7-minute running test | 1 |
| Gas analyser | 1 |
| **Sample characteristics** | |
| **Country** | |
| Albania | 1 |
| Canada | 1 |
| Czech Republic | 1 |
| Denmark | 1 |
| England | 2 |
| France | 2 |
| Greece | 1 |
| Italy | 2 |
| Malaysia | 1 |
| Poland | 1 |
| Spain | 3 |
| South Korea | 1 |
| Ukraine | 1 |
| United States of America | 7 |
| **Sex** | |
| Boys and girls | 19 |
| Boys | 2 |
| Girls | 3 |
| **Age** | |
| Younger ages (6–12 years old) | 6 |
| Older ages (11–19 years old) | 18 |
| **Study quality** | |
| Poor | 1 |
| Fair | 19 |
| Good | 4 |

PACER, progressive aerobic cardiovascular endurance run.

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a given time period in a PE program. However, there was some heterogeneity in the study populations, as well as PE class characteristics included in this review that must be considered.

Findings from younger students (n = 7) [13, 20–24], ranging from 6 to 12 years, showed mainly that participation in PE classes improved the students' CRF [13, 21, 22], and in two of these studies the improvements were due to high intensity (whether fitness oriented or game oriented) PE classes [23, 24]. Notwithstanding, two other studies from this set concluded that PE had a neutral students' CRF [20, 23]. On the other hand, findings from older students (n = 26), with a wider age range (approximately 11 to 19 years), were mixed. A total of 15 findings from 14 studies showed that PE had a neutral effect on students' CRF (n = 15) [14, 22, 25–36]. While, 11 findings from nine studies reported that PE had a positive effect in children's and adolescents' CRF [26–28, 36–41].

**Table 3. Characteristics and main findings of the studies included in the systematic review.**

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Cumming et al., 1969 | Longitudinal, n = 89 (boys only), 6th and 10th graders | Canada | Fair | $VO_2$max | Submaximal cycle ergometer protocol | Not specified | (±) No changes in the $VO_2$max from September to June of the following year (nine months) |
| Crowhurst et al., 1993 | Cross-sectional, n = 9 (girls only), $M_{age}$ = 14.6 years | USA | Fair | (1) $VO_2$max<br>(2) Heart rate | (1) Incremental, maximal cycle ergometer protocol<br>(2) Heart rate monitor during PE lessons | Basketball and floor hockey | (±) The intensity of PE classes (in minutes exercised at >50% of $VO_2$max) may not generally be sufficient for achieving an aerobic benefit |
| Strand & Reeder, 1993 | Cross-sectional, n = 55, age range = 12 to 13 years | USA | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. football, dodgeball), swimming and wrestling | (±) Students spend <50% of time in their assigned training zone (>60% of heart rate reserve) |
| Baquet et al., 2001 | Intervention, n = 551 (52% boys), age range = 11 to 16 years | France | Fair | Distance covered | 7-minute running test | Running | (+) High intensity PE (aerobic training) classes improves CRF |
| Baquet et al., 2002 | Intervention, n = 345 (59% boys), age range = 11 to 16 years | France | Fair | Heart rate | Heart rate monitor during PE classes | Running, jumping | (+) High intensity PE classes (in % time spent >50%, 60% and 75% of heart rate reserve) may improve CRF |
| Koutedakis & Bouziotas, 2003 | Intervention, n = 84 (boys only), $M_{age}$ = 13.6 years | Greece | Good | $VO_2$max | Multistage 20-meter shuttle run test | Team games (e.g. football, handball), swimming, athletics, tennis | (±) Students participating only in PE classes have lower levels of $VO_2$max than students participating in PE classes and other extracurricular organised physical activities |
| Beets & Pitetti, 2005 | Cross-sectional, n = 187(64% boys), age range = 14 to 19 years | USA | Fair | $VO_2$max | PACER test | Team activities | (±) Students participating in PE classes have lower levels of $VO_2$max than students participating in school-sponsored sports programs |
| Fairclough & Stratton, 2005 | Cross-sectional, n = 122 (50% boys), age range = 11 to 14 years | England | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. football, softball), individual games (e.g. badminton, tennis), movement activities (e.g. dance, gymnastics) and individual activities (e.g. athletics, fitness) | (±) Students spent <50% of time in MVPA. Students participated in most MVPA during team games and the least during movement activities |
| Fairclough & Stratton, 2006 | Cross-sectional, n = 68 (49% boys), age range = 11 to 14 years | England | Fair | Heart rate | Heart rate monitor during PE classes | Team games, individual games, gymnastic, dance | (±) Students spent <50% of time in MVPA |
| Laurson et al., 2008 | Cross-sectional, n = 796 (53% boys), $M_{age}$ = 16 years | USA | Fair | Heart rate | Heart rate monitor during PE classes | Team games (e.g. volleyball, ultimate frisbee), individual games (e.g. golf, dance), fitness activities (e.g. aquatics, bleachers) | (+) 71% of class time was spent in MVPA (>50% of maximum heart rate)<br>(+) Fitness activities provided greater % of time above the lower heart rate threshold than individual and team games |
| Pelclová et al., 2008 | Cross-sectional, n = 241 (girls only), $M_{age}$ = 16.0 years | Czech Republic and Poland | Fair | Heart rate | Heart rate monitor during PE classes | Dance and aerobic dance | (+) Girls spent more than 50% of class time (aerobic dance classes) in MVPA (>60% of maximum heart rate) |

(*Continued*)

**Table 3.** (Continued)

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Gallotta et al., 2009 | Intervention, n = 152, age range = 11 to 12 years | Italy | Fair | Test duration | 1-mile run/walk test | Pre-tumbling, rhythmic gymnastics, ball mini-games, dexterity circuits | (±) There were no significant differences in the 1-mile run/walk test results five months apart, for both control (regular PE classes) and intervention groups |
| Camhi et al., 2011 | Longitudinal, n = 131 (girls only), $M_{age}$ = 13.8 years | USA | Fair | Heart rate | Heart rate monitor during submaximal step test | Aerobic dance, football, walking/jogging, fitness activities (e.g. resistance training, circuit training), swimming, basketball, volleyball, recreational games | (+) Normal-weight and overweight girls enrolled in an eight months PE program showed improvement in fitness (decrease in stage 1 heart rate), as well as maintenance of these effects over the two next years |
| | | | | | | | (±) Obese girls showed no fitness improvements in response to the same PE program. |
| Ramirez Lechuga et al., 2012 | Intervention, n = 84 (61% boys), age range = 15 to 18 years | Spain | Fair | $VO_2$max | Portable gas analyser during multistage 20-meter shuttle run test | Running | (+) A eight weeks high intensity aerobic training program developed in PE classes improved students' $VO_2$max |
| | | | | | | | (±) During the same 8-week period, regular PE classes did not improved students' $VO_2$max |
| Lucertini et al., 2013 | Intervention, n = 101, (50% boys), 3rd to 5th graders | Italy | Fair | $VO_2$max | Multistage 20-meter shuttle run test | Basic motor skills, rhythm, coordination, endurance, strength, flexibility | (+) Specialist led and generalist teacher led PE classes increased primary school children's $VO_2$max during a six months period |
| Reed et al., 2013 | Intervention, n = 470 (50% boys), 2nd to 8th graders | USA | Good | Number of laps | PACER test | Fundamental skills, multiactivity sport theme curriculum | (+) CRF of elementary school students participating in regular PE increased in an eight months period |
| | | | | | | | (–) CRF of middle school students participating in regular PE decreased in an eight months period |
| Bendiksen et al., 2014 | Intervention, n = 91 (55% boys), age range = 8 to 9 years | Denmark | Fair | (1) Heart rate | (1) Heart rate monitor during YYIR1C | Team games (e.g. football, unihockey), individual games (e.g. walking, parkour), Nintendo Wii Boxing, Nintendo Wii Tennis | (±) Students participating in regular PE classes did not improve CRF (distance covered and % of maximal heart rate) in a six weeks period |
| | | | | (2) Distance covered | (2) YYIR1C | | (+) Students participating in high intensity PE classes improved CRF (distance covered and % of maximal heart rate) in a 6 weeks period |
| Rengasamy et al., 2014 | Intervention, n = 173 (50% boys), $M_{age}$ = 16 years | Malaysia | Fair | Distance covered | 12-Minute Cooper's Test | Circuit training | (+) A 10-week fitness program implemented within PE classes enhanced the students' CRF |
| Erfle & Gamble, 2015 | Intervention, n = 10206 (50% boys), 6th to 8th graders | USA | Good | Test duration | 1-mile run/walk test | Not specified | (±) Students participating in regular PE classes did not improve CRF during one school year |

(*Continued*)

**Table 3.** (Continued)

| Source | Study design, sample size, age | Country | Study quality | Outcome measure(s) | Method(s) | Content of PE / intervention | Main finding(s) |
|---|---|---|---|---|---|---|---|
| Mayorga-Veiga & Viciana, 2015 | Intervention, n = 178 (58% boys), elementary and middle school children | Spain | Fair | Test duration | Multistage 20-meter shuttle run test | Fitness activities (e.g. circuit training, multi-jumps), team games | (–) CRF of middle school students participating in regular PE decreased in eight weeks period<br>(+) CRF of elementary and middle school students with low CRF participating in high intensity PE classes (fitness program) improved in an eight weeks period |
| Jarani et al., 2016 | Intervention, n = 767 (52% boys), 1st and 4th graders | Albania | Good | $VO_2$max | Intermittent shuttle run test | Throwing/catching, rhythm activities (e.g. dance), fitness activities, tumbling / gymnastics | (+) Exercise (fitness) and game-oriented PE classes improved children's CRF and have greater effect in improving CRF than other PE classes |
| Mayorga-Veiga et al., 2016 | Intervention, n = 111 (63% boys), $M_{age}$ = 12.5 years | Spain | Fair | (1) Test duration<br>(2) Heart rate | (1) Multistage 20-meter shuttle run test<br>(2) Heart rate monitor during PE classes | Fitness activities (circuit training, multi-jumps), team games | (+) Students participating in high intensity PE classes (fitness program) improved CRF in a nine weeks period and maintained the improvements after four weeks detraining period<br>(+) High intensity PE classes had >50% of time in MVPA<br>(–) Students participating in regular PE classes decreased CRF in a nine weeks period<br>(±) Regular PE classes had <50% of time in MVPA |
| Andres, 2017 | Intervention, n = 100 | Ukraine | Poor | Test duration | 1-km run/walk test | Not specified | (±) No improvements in CRF from October to May of the following year (seven months) |
| Park et al., 2017 | Intervention, n = 48 (50% boys), $M_{age}\approx12$ years | South Korea | Fair | Test duration | 1-km run/walk test | Fitness activities (e.g. burpees, shuttle run) | (+) CRF of children participating in PE improved, while CRF of children not participating in PE decreased after an eight weeks period |

CRF, cardiorespiratory fitness; PE, physical education; PACER, progressive aerobic cardiovascular endurance run; YYIR1C, Yo-Yo Intermittent Recovery Level 1 Children's test; MVPA, moderate-to-vigorous physical activity; $M_{age}$, mean age.

(+) Found a positive effect of PE on students' CRF (positive changes in CRF or ≥50% of time in MVPA) (n = 16).

(±) Found a neutral effect of PE on students' CRF (no changes in CRF or <50% of time in MVPA) (n = 14).

(–) Students' CRF decreased during a given time period in a PE program (n = 3).

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Studies concluding that PE classes had a neutral effect on students' CRF are supported by two main findings: (1) children and adolescents participating in PE classes did not improve or decreased their CRF during a given time period (n = 7) [14, 22, 26–29, 35]; and (2) PE classes did not provide sufficient intensity for achieving an aerobic benefit (n = 5) [28, 30, 31, 33, 34]. Besides these findings, two other studies found that students participating only in PE classes had lower CRF levels than their peers participating in school-sponsored sports programs [32] and in extracurricular organized physical activities [25].

Almost all studies (n = 10) with findings indicating that PE contributed to improving CRF in students are related with the intensity level of the classes. Six studies indicated that high intensity PE classes, involving fitness activities or aerobic training, improved the students'

CRF in a given time period [26–28, 37–39]. Furthermore, three other studies showed that high intensity and fitness oriented PE classes had more than 50% of time spent in moderate-to-vigorous physical activity (MVPA) [28, 40, 41]. Finally, one study identified fitness activities as the greatest provider of time in MVPA, compared with individuals games and team games [40].

One study [36], in which the analysis was divided into three groups according to body mass index classification, showed that: while normal-weight and overweight girls enrolled in PE showed improvements in fitness, as well as maintenance of these improvements; obese girls, enrolled in the same PE program, did not.

From the review of these results, three potential relevant factors for promoting CRF in PE classes were identified: students' age, PE classes' intensity, and students' weight status.

## Discussion

This review summarizes literature findings from studies published up to July 2019 on the contribution of PE classes for promoting CRF in children and adolescents. Twenty-four studies were included and systematically reviewed. Overall, this review revealed that findings regarding the contribution of PE classes to the promotion of CRF are mixed. Several findings suggested that PE has a neutral effect on students' CRF, while others reinforce its importance. However, higher intensity PE classes consistently demonstrated having a positive contribution in promoting students' CRF. Additionally, some other potentially relevant factors for promoting CRF in PE classes were identified, such as age and weight status. Review findings are discussed accordingly to these factors.

All studies were focused on school-aged children, however, due to the wide age range of the studies' populations, findings were organized in two age groups. This separation enabled some differences in findings between younger and older students to be found. While for older ages PE seems to be less effective in promoting students' CRF [14, 22, 25–36], for younger ages almost all studies suggested that PE classes improved the students' CRF [13, 21–24]. From a physiologic standpoint, CRF naturally increases as children grow-up. This increase is fairly linear in boys until later adolescence, whereas in girls it plateaus around age 13 [42, 43]. Furthermore, during the early stages of adolescence, participation in physical activity and the corresponding physical fitness begins to show some decline [44]. Thus, increasing CRF, related to body growth, occurring at younger ages and decreasing participation in physical activity in older students may explain why improvements in CRF for a given period of time are more frequently found in younger children and adolescents. Another possible reason for the apparently less effective contribution of PE to the improvement of CRF in older students is motivation. Motivation to participate in PE seems to decline in the late elementary and high school years [45, 46], possibly resulting in decreasing physical activity both during PE and in leisure time. Considering these findings, PE may have a bigger role to play in promoting older students' CRF than it does in younger students, through providing MVPA opportunities.

Aerobic exercise has been shown to increase CRF by about 5–15% in youth [42, 47]. Additionally, improvements in CRF, involving structural and functional adaptations, as well as in the oxidative capacity of skeletal muscle occur with regular MVPA participation [42]. In this review, five studies reported that PE classes did not provide sufficient intensity for achieving an aerobic benefit [28, 30, 31, 33, 34] and thus, did not contribute in a consistent manner to promote students' CRF. It is clear that CRF in youth increases with activity of sufficient intensity, leading to improvements in maximal stroke volume, blood volume, and oxidative enzymes after exercise [48]. Consequently, time spent in MVPA during PE classes should be monitored and adequate to promote health. Also, findings suggesting that PE has a positive contribution in improving CRF were mainly related to the intensity level of the classes. The majority of studies examined in this review involved intervention programs built to increase PE class intensity without increasing the number of classes or curricular time dedicated to PE [23, 26–28, 37–39, 41]. In fact, four of these studies reported that students participating in PE classes from the intervention programs increased their CRF levels, while students participating in regular PE classes, i.e. classes that were not part of the program, decreased or maintained their CRF levels [23, 26–28]. Considering the importance of CRF for health, the lack of intensity in PE classes is worrying. From a public health perspective, PE has the potential to provide the tools to face the current youth obesity and sedentary epidemic [49]. However, in order to effectively contribute to CRF and health, it is urgent to find strategies to increase the intensity of PE classes.

One study [36], examining whether an eight months PE program improved students' CRF when considering body mass index categories, suggested that although normal-weight and overweight girls showed improvement in fitness and maintenance of these effects over the next two years, their obese peers did not. Physical activity and body mass index are inversely correlated in children and adolescents [50]. Also, studies of usual physical activity in children suggest that the overweight and obese are less active [51, 52] and have poorer fundamental movement skills than their normal-weight counterparts [53]. Mastering of fundamental motor skills is strongly related to physical activity in children and adolescents and is critical to fostering physical activity since these skills are the foundation for advanced and sport-specific movement [54]. Furthermore, a recent meta-analysis found that overweight and obese students were, respectively, 27% and 54% more likely to have school absenteeism than their normal weight peers [55]. All these factors may contribute to a greater ineffectiveness of PE programs among obese students. Therefore, PE should not only provide sufficient intensity to promote health, but also be based on developmentally appropriate motor activities to nurture self-efficacy and enjoyment and encourage ongoing participation in physical activity.

High quality PE together with appropriate approaches to fitness as part of health education programmes has been shown to promote fitness and healthy lifestyles [6]. On the other hand, when applied inappropriately and without context fitness monitoring can have the opposite result [56]. Therefore, mixed findings found in this systematic review may be due to the variations in the quality of PE. It is important that high quality PE is provided and promoted in schools, as it benefits not only students' CRF, but also promotes future healthy lifestyles.

The present review has some limitations that should be acknowledged. Even though study bias was assessed according to their methodological quality [19], they were not weighted or ranked, thus, findings from studies with poorer quality and smaller sample sizes were given no less importance than other findings. Nonetheless, only one study was classified as 'poor' quality. Additionally, included studies had a wide publication date range, from 1969 to 2017, and were from different cultural and socioeconomic contexts, which could have implications on what PE classes represent as well as PE curricula. Also, 16 studies were not accessible to the authors. Grey literature research was not included. Despite the developed efforts for reducing publication bias by the authors, this should be taken into account.

Notwithstanding, to the best of our knowledge, this is the first systematic review focused on the contribution of PE classes or PE interventions that did not extend time or frequency of the classes to the improvement of students' CRF. Furthermore, an extensive research strategy comprising four different databases and several keywords was used. Future research should continue to investigate the contribution of PE to the improvement of CRF and other fitness attributes, and examine which curricula offers the best opportunity to improve fitness, health and promote life-long physical activity behaviours.

## Conclusions

Review findings from the 24 included studies suggest that PE classes can contribute to the promotion of students' CRF. Some potentially relevant factors for promoting CRF in PE classes were identified, such as intensity, age and weight status. Exercise intensity is essential to promote CRF and other health outcomes in youth [42, 57, 58], thus it is not surprising that higher intensity PE classes demonstrated improvements in CRF. Findings from studies of younger students more consistently reported improvements in CRF than findings from studies of older students. Therefore, as older students may be more vulnerable to decreasing physical activity levels [44], PE should be keen in providing tools and opportunities to improve and maintain CRF levels in these ages. Regarding weight status, overweight and obese students should be a priority concern, as they may have more difficulty in improving CRF than normal-weight peers. Given that CRF is an independent health predictor and that decrease of CRF is a global trend, more efforts should be done to promote CRF in PE classes. High quality PE is needed as it can be a successful strategy in improving CRF levels.

## Supporting information

**S1 File.**
(DOC)

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**Appendix 4. Copy of the published version of Study 2**

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MDPI

*Article*

# Promoting Health-Related Cardiorespiratory Fitness in Physical Education: The Role of Class Intensity and Habitual Physical Activity

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**Abstract:** Physical education (PE) has the potential to promote health-related fitness, however, its contribution is still not clear. The aim of this study was to assess whether students' health-related cardiorespiratory fitness (CRF) improved from the beginning to the end of the school year, and to examine the role of PE class intensity and habitual physical activity (PA) in promoting students' CRF. This observational study employed a longitudinal design. Participants were 212 7th and 8th grade students (105 boys), mean age 12.9 years old, followed during one school year, from September 2017 to June 2018. The Progressive Aerobic Cardiovascular Endurance Run (PACER) was used to assess CRF at baseline and follow-up. PA was measured using accelerometers. PE class intensity was assessed using the System for Observing Fitness Instruction Time. Findings indicated that from the beginning to the end of the school year, a greater percentage of participants were in the CRF healthy fitness zone (73.1% to 79.7%, $p = 0.022$). Among boys, participating in organized sports (B = 4.61, 95% confidence interval [CI]: 0.33, 8.88) and the percentage of PE time being very active (B = 0.90, 95% CI: 0.44, 1.35) were positively associated with the change in PACER laps. Among girls, daily vigorous PA (B = 0.38, 95% CI: 0.15, 0.60) and participating in organized sports (B = 4.10, 95% CI: 0.93, 7.27) were also positively associated with PACER change, while being overweight or obese (B = −5.11, 95% CI: −8.28, −1.93) was negatively associated. In conclusion, PE was demonstrated to have a positive role in the promotion of CRF, especially among boys, while for girls, habitual PA seems to have a greater contribution. Nevertheless, results and conclusions should be considered carefully, taking into account study limitations, such as the non-direct measures of PE class intensity, CRF, and school setting.

**Keywords:** aerobic fitness; children; PACER; school; 20-m shuttle run

## 1. Introduction

Promoting physical activity (PA) and healthy lifestyles has become a priority for public health authorities worldwide [1]. When considering children and adolescents, school has been purposed as an important setting for achieving this priority. Especially through physical education (PE), the school provides an opportunity for youth to be physically active and promote healthy lifestyles [2].

An important health indicator related to PA is cardiorespiratory fitness (CRF). It is estimated that up to half of the CRF is hereditable [3]. Nevertheless, habitual PA is still considered as the primary means of improving fitness [4]. Systematized evidence revealed strong associations between CRF and youth cardiometabolic health, including blood pressure, cholesterol and triglyceride levels, and glucose tolerance [5]. Moreover, CRF in childhood is suggested to track into adulthood, giving a reasonable insight into future health [6].

There are a handful of field tests that allow for the assessment of CRF in the school setting. School and PE classes may play a significant role in both promoting and monitoring children's and adolescents' CRF [7–9]. However, among upper-middle- and high-income countries, a substantial decline in CRF has been observed since 1981 [10]. Furthermore, evidence on the contribution of PE classes for promoting children's and adolescents' CRF is not consistent [11]. A recent systematic review showed that PE classes can promote child and adolescent CRF, and some factors that may explain the inconsistent findings were identified, including class intensity, age, and weight status [11].

In order to better understand the role of PE classes in promoting CRF, more research is warranted. Previous investigations focusing on the promotion of CRF in PE had mostly implemented cross-sectional or intervention designs [11]. Cross-sectional design studies do not allow us to establish the temporality and direction of the associations. On the other hand, intervention designs, by their nature, alter one or more components of PE classes, including content or intensity, which are important for the promotion of CRF. Taking that into account, there is a need for observational studies employing a longitudinal design. These types of studies allow us to investigate the role of regular PE classes (i.e., not altered by an intervention), and to establish the direction of the associations.

Furthermore, precedent studies mainly examined students from a wide range of grades and ages. Students from different ages and grades may have different PE content, as well as different attitudes toward PE, which may affect the role of PE on promoting PA and CRF [12,13]. Focusing on a narrower range of grades is important to have more specific information. In that regard, the contribution of PE classes to improve CRF seems to be clearer among children and younger adolescents, until 12 years old, than onwards [11]. Also, early adolescence evidences a decline in PA [14,15].

From a public health perspective, promoting and monitoring CRF provides a meaningful strategy to monitor and improve the present and future health status [16,17]. Although PE may be an important platform for promoting children's and adolescents' CRF, investigations on its role still present inconsistent results. Therefore, the aim of this study was to assess whether students' health-related CRF improved from the beginning to the end of the school year. Also, the roles of PE class intensity and habitual PA in promoting students' CRF were examined.

## 2. Materials and Methods

### *2.1. Study Design and Procedures*

This was an observational study. It employed a longitudinal design, where 7th and 8th grade (middle school) students from two schools were followed during one school year, from October 2017 to June 2018. Individual data were collected at baseline, September and October 2017, and follow-up, May and June 2018. Data assessed in these periods included sociodemographic characteristics, PA (assessed only at baseline), and physical fitness. Data on PE classes were collected between January and April 2018.

The two participating public schools were located in Sintra, Portugal. Both schools are from urban areas and located in middle-to-low income neighborhoods. These schools serve a population of approximately 800 students each, and have courses for students from the 5th to the 9th grades. School directors were approached by the research team, and authorization to conduct the study was granted. Afterwards, PE teachers were contacted and asked whether they were willing to participate in the study. Then, students, from the teachers who agreed to participate in the study, were recruited by the research team in a PE class, where the aim and overall aspects of the study were explained, and informed consents were distributed. Students who returned the informed consent signed by their legal guardians were eligible to participate in the study. Before initiating this process, the study protocol was approved by the ethics committee of the Faculty of Human Kinetics, University of Lisbon (no. 19/2017) and by the Portuguese National Data Protection Commission (no. 9249/2017).

### *2.2. Participants*

A total of 294 students, from 21 different classes, enrolled in the study. From the 294 students, five were lost to follow-up (1.7%). Additionally, 24 participants did not have data on CRF, and 53 participants had invalid accelerometer data. Therefore, a total of 212 students (105 boys, 107 girls), mean age 12.9 years old, were included in the analysis. The flow diagram of the study sample is presented in Figure 1.

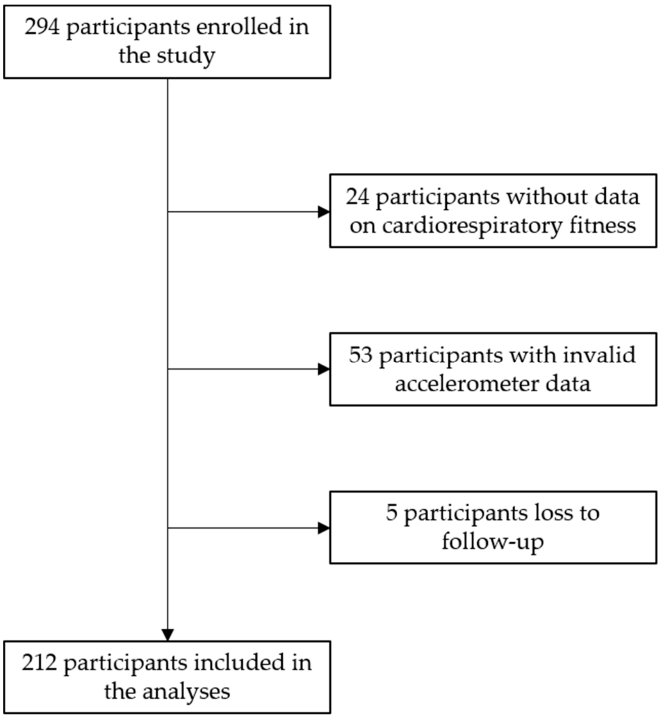


**Figure 1.** Flow diagram of the study sample.

### *2.3. Measures*

#### 2.3.1. Cardiorespiratory Fitness

CRF was assessed using the Progressive Aerobic Cardiovascular Endurance Run (PACER), also known as the 20-m shuttle run, as part of the FITescola battery, which is widely used by PE teachers in Portugal [18]. The main aim of this test was to perform the maximum number of laps with a defined cadence. An audio signal was used to help the participants manage running speed during the test. The test starts with a cadence of 8.5 km per hour and increases progressively 0.5 km per hour every minute. The PACER was performed twice by each participant, at the beginning of the school year (baseline) and at the end of the school year (follow-up). Results from the PACER were recorded in number of laps and $VO_2$ peak. (mL/kg/min). For estimating $VO_2$ peak, the equations of Saint-Maurice et al. [19] were used, and, afterwards, participants were classified into being in or out of the CRF healthy fitness zone, according to existing standards [20].

#### 2.3.2. Physical Activity

PA was assessed using accelerometers (ActiGraph, GT3X model, Fort Walton Beach, FL, USA), between September and October 2017. The accelerometers used in this research ignored high-frequency vibrations associated with mechanical equipment. All participants were asked to wear the accelerometer on the right side, near the iliac crest, for seven consecutive days, and instructed to remove the devices only when performing water activities (e.g., bathing or swimming) and during sleep. To increase compliance, study staff instructed children how to wear the accelerometer during the initial in-school assessment. Accelerometers were activated on the morning of the first wear day. Individual data were recorded and downloaded into 15 s epochs that were reintegrated into 60 s epochs. This technique is consistent with previously published research [21]. Periods of at least 60 consecutive minutes of zero counts were considered as non-wear time. Only when, in a single day, at least 600 min (10 h) of wear time was recorded, it was considered valid. Participants had to present at least three valid days (including at least one weekend day and two weekdays) in order to have valid accelerometer data.

The cut-points capture the sporadic nature of children's activity and provide the best classification accuracy among the currently available cut-points for PA in children. Activity levels were expressed in terms of counts per minute, and intensity thresholds were defined according to Evenson et al.'s criteria [22,23]. Accelerometer counts ≥100 counts/min were identified as active time, and posteriorly separated as moderate PA (2296 to 4011 counts/min) and vigorous PA (≥4012 counts/min).

#### 2.3.3. Physical Education Class Intensity

PE class intensity was assessed using the System for Observing Fitness Instruction Time (SOFIT), by a member of the research team. SOFIT is a visual observation instrument previously validated as a measure of PA during PE classes [24]. SOFIT scores activity using a 5-point Likert scale (1—lying down; 2—sitting; 3—standing; 4—walking; 5—very active). A total of 63 PE classes, three PE classes from each student class, were observed. Both schools had three spaces where PE classes were performed (a big outdoors space; a big indoor space; and a small indoor space). One observation was scheduled for each space per student class. For each student class, mean values from the three PE classes were calculated. Intensity values were transformed to percentages of PE time, because class length was not equal for every class. In one school, three PE classes of 50 min were performed per week, while in the other school, two PE classes, one of 50 min, and one of 100 min, were performed per week.

#### 2.3.4. Covariates

Covariates included sex, age, height, weight, body mass index (BMI), age at peak height velocity (PHV), and organized sports participation, at baseline. All participants were weighed to the nearest 0.01 kg on an electronic scale (model 799 SECA, Seca GmbH, Hamburg, Germany) while wearing minimal clothes (t-shirt and shorts) and without shoes. Height was measured to the nearest 0.1 cm with a flexible anthropometric tape on the wall, without shoes. BMI was calculated as body mass (kg)/height$^2$ (m). The BMI z-score was calculated, and BMI categories were defined based on the World Health Organization (WHO) classification. Age at PHV was estimated as suggested by Moore et al. [25]. Participants were asked whether they participated in organized sports outside of school (yes/no).

### *2.4. Statistical Analysis*

Descriptive statistics were calculated for all variables (means, standard deviation, and percentages) for the entire sample, and separated by sex. Differences between boys and girls were tested by the independent samples t-test, for continuous variables, and chi-square test, for nominal variables. Paired samples t-test and McNemar test were performed to compare the PACER laps, $VO_2$ peak, and being, or not, in the healthy fitness zone between the beginning and the end of the school year. Multivariate linear regression models were conducted to assess which factors explained changes in PACER laps from the beginning to the end of the school year, including sex, age, BMI categories, PA (moderate and vigorous), organized sports participation, and percentage of PE time walking and being very active. Models were run for the total sample and by sex, and adjusted to age at peak height velocity, accelerometer wear time, PACER laps at baseline, and each explaining variable. Unstandardized coefficients (B) and standardized coefficients (β) were calculated to have indicators of both measured unit estimates (absolute magnitude) and z-score estimates (relative magnitude). Data analysis was performed using IBM SPSS Statistics version 26.0 (IBM, Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

## 3. Results

Sample baseline characteristics for the entire sample and by sex are presented in Table 1. The majority of participants were normal weight (66.5%), while 22.2% were overweight, and 8.5% obese. Boys spent more time in moderate PA (34.2 min versus 25.9 min, $p < 0.001$) and vigorous PA (22.0 min versus 10.5 min, $p < 0.001$) than girls. Also, a greater percentage of boys than girls participated in organized sports outside of school (55.2% vs. 37.4%, $p = 0.013$). Boys performed more laps in PACER (49.1 versus 30.2, $p < 0.001$), and had a greater estimated $VO_2$ peak (48.4 mL/kg/min versus 41.9 mL/kg/min, $p < 0.001$). Most participants, 73.1%, were in the CRF healthy fitness zone; however, a greater percentage of boys was at the CRF healthy fitness zone than girls (83.8% versus 62.6%, $p = 0.001$). On average, participants spent 29.8% of the observed PE time walking, and 24.8% being very active.

**Table 1.** Sample baseline characteristics.

| Variables | M (SD) or % | | | *p* |
|---|---|---|---|---|
| | **Total (*n* = 212)** | **Boys (*n* = 105)** | **Girls (*n* = 107)** | |
| Age (years) | 12.9 (1.0) | 13.0 (1.0) | 12.8 (1.1) | 0.201 |
| Height (m) | 1.59 (0.08) | 1.61 (0.10) | 1.57 (0.07) | 0.011 |
| Weight (kg) | 52.5 (12.8) | 51.6 (12.4) | 52.5 (13.2) | 0.582 |
| BMI (kg/m$^2$) | 20.4 (4.1) | 19.9 (3.4) | 21.0 (4.6) | 0.026 |
| BMI (categories) | | | | 0.224 |
| Underweight | 2.8 | 2.9 | 2.8 | |
| Normal weight | 66.5 | 71.4 | 61.7 | |
| Overweight | 22.2 | 16.2 | 28.0 | |
| Obese | 8.5 | 9.5 | 7.5 | |
| Age at PHV (years) | 12.9 (0.9) | 13.6 (0.5) | 12.1 (0.5) | <0.001 |
| Daily MPA (min) | 30.0 (11.8) | 34.2 (12.5) | 25.9 (9.4) | <0.001 |
| Daily VPA (min) | 16.2 (12.7) | 22.0 (13.6) | 10.5 (8.4) | <0.001 |
| Sport participation | | | | 0.013 |
| No | 53.8 | 44.8 | 62.6 | |
| Yes | 46.2 | 55.2 | 37.4 | |
| PACER (laps) | 39.6 (19.4) | 49.1 (20.0) | 30.2 (13.4) | <0.001 |
| $VO_2$ peak (mL/kg/min) | 45.1 (6.8) | 48.4 (6.9) | 41.9 (5.0) | <0.001 |
| CRF healthy fitness zone | | | | 0.001 |
| No | 26.9 | 16.2 | 37.4 | |
| Yes | 73.1 | 83.8 | 62.6 | |
| % of PE time walking | 29.8 (5.3) | 30.1 (5.1) | 29.5 (5.4) | 0.422 |
| % of PE time very active | 24.8 (4.8) | 25.0 (4.7) | 24.5 (4.9) | 0.475 |

Note: M: mean; SD: standard deviation; BMI: body mass index; PHV: peak height velocity; VPA: vigorous physical activity; PACER: Progressive Aerobic Cardiovascular Endurance Run; $VO_2$ peak: peak oxygen uptake; CRF: cardiorespiratory fitness; PE: physical education. Differences between sexes were tested by independent samples t-test for continuous variables, and by chi-square test for nominal variables.

Table 2 presents the comparison between aerobic capacity and healthy fitness zone at the beginning and the end of the school year. When considering the total sample from the beginning to the end of the school year, participants improved the number of PACER laps (39.6 to 45.0, $p < 0.001$), and the estimated $VO_2$ peak (45.1 mL/kg/min to 46.5 mL/kg/min, $p < 0.001$). Furthermore, the percentage of students in the CRF healthy fitness zone increased (73.1% to 79.7%, $p = 0.022$) from the beginning to the end of the school year.

**Table 2.** Aerobic capacity and healthy fitness zone at the beginning and at the end of the school year.

| Total | M (SD) or % | | $p$ |
|---|---|---|---|
| | Beginning of The School Year | End of The School Year | |
| PACER (laps) [a] | 39.6 (19.4) | 45.0 (20.7) | <0.001 |
| $VO_2$ peak (mL/kg/min) [a] | 45.1 (6.8) | 46.5 (7.2) | <0.001 |
| CRF healthy fitness zone (%) [b] | | | 0.022 |
| No | 26.9 | 20.3 | |
| Yes | 73.1 | 79.7 | |
| **Boys** | | | |
| PACER (laps) [a] | 49.1 (20.0) | 57.3 (20.3) | <0.001 |
| $VO_2$ peak (mL/kg/min) [a] | 48.4 (6.9) | 50.8 (7.1) | <0.001 |
| CRF healthy fitness zone (%) [b] | | | 0.039 |
| No | 16.2 | 9.5 | |
| Yes | 83.8 | 90.5 | |
| **Girls** | | | |
| PACER (laps) [a] | 30.2 (13.4) | 32.9 (12.3) | 0.007 |
| $VO_2$ peak (mL/kg/min) [a] | 41.9 (5.0) | 42.3 (4.4) | 0.210 |
| CRF healthy fitness zone (%) [b] | | | 0.210 |
| No | 37.4 | 30.8 | |
| Yes | 62.6 | 69.2 | |

Note: M: mean; SD: standard deviation; PACER: Progressive Aerobic Cardiovascular Endurance Run; $VO_2$ peak: peak oxygen uptake; CRF: cardiorespiratory fitness. [a] Tested by paired samples t-test. [b] Tested by McNemar.

However, when analyses were stratified by sex, significant changes for all these variables were only found for boys. For girls, differences in estimated $VO_2$ peak and percentage in the CRF healthy fitness zone were not significant.

Linear regression models, to explain the change in PACER laps from the beginning to the end of the school year, are presented in Table 3. Considering the entire sample, change in PACER laps was positively associated with being a boy (B = 13.21, 95% CI: 7.64, 18.72), having daily vigorous PA (B = 0.25, 95% CI: 0.10, 0.41), participating in organized sports (B = 4.60, 95% CI: 1.92, 7.28), and the percentage of PE time being very active (B = 0.41, 95% CI: 0.14, 0.68). On the other hand, being overweight or obese (B = −3.01, 95% CI: −5.98, −0.05) was negatively associated with change in PACER laps. It was observed that sex (β = 0.60), followed by daily vigorous PA (β = 0.29), organized sports participation (β = 0.21), and percentage of PE time being very active (β = 0.19) presented the greatest magnitude of association to PACER change.

Interestingly, stratified analysis revealed some sex differences in the variables explaining the change in PACER laps from the beginning to the end of the school year. For boys, participating in organized sports (B = 4.61, 95% CI: 0.33, 8.88) and the percentage of PE time being very active (B = 0.90, 95% CI: 0.44, 1.35) were positively associated with the change in PACER laps. Percentage of PE time being very active had the greatest magnitude of association to PACER change (β = 0.37). For girls, daily vigorous PA (B = 0.38, 95% CI: 0.15, 0.60) and participating in organized sports (B = 4.10, 95% CI: 0.93, 7.27) were also positively associated, while being overweight or obese (B = −5.11, 95% CI: −8.28, −1.93) was negatively associated with PACER change. Minutes of daily vigorous PA had the greatest magnitude of association with PACER change (β = 0.32) (Table 3).

**Table 3.** Linear regression to explain the change in Progressive Aerobic Cardiovascular Endurance Run (PACER) laps from the beginning to the end of the school year.

| Explaining Variables | Change in PACER from The Beginning to The End of The School Year | | | | | |
|---|---|---|---|---|---|---|
| | Total | | Boys | | Girls | |
| | B (95% CI) | β | B (95% CI) | β | B (95% CI) | β |
| Sex | | | | | | |
| Girl | 0.00 (ref) | | NA | NA | NA | NA |
| Boy | **13.21 (7.64, 18.72)** | **0.60** | | | | |
| Age (years) | 0.59 (−0.80, 1.98) | 0.06 | −1.00 (−3.36, 1.37) | −0.08 | 0.95 (−0.60, 2.50) | 0.10 |
| BMI categories | | | | | | |
| Not overweight or obese | 0.00 (ref) | | 0.00 (ref) | | 0.00 (ref) | |
| Overweight or obese | **−3.01 (−5.98, −0.05)** | **−0.13** | 0.82 (−4.22, 5.85) | 0.03 | **−5.11 (−8.28, −1.93)** | **−0.25** |
| Daily MPA (min) | −0.09 (−0.23, 0.06) | −0.09 | −0.09 (−0.31, 0.13) | −0.09 | −0.10 (−0.30, 0.09) | −0.10 |
| Daily VPA (min) | **0.25 (0.10, 0.41)** | **0.29** | 0.16 (−0.05, 0.36) | 0.19 | **0.38 (0.15, 0.60)** | **0.32** |
| Sport participation | | | | | | |
| No | 0.00 (ref) | | 0.00 (ref) | | 0.00 (ref) | |
| Yes | **4.60 (1.92, 7.28)** | **0.21** | **4.61 (0.33, 8.88)** | **0.20** | **4.10 (0.93, 7.27)** | **0.21** |
| % of PE time walking | −0.11 (−0.36, 0.14) | −0.05 | −0.36 (−0.77, 0.05) | −0.16 | 0.02 (−0.28, 0.33) | 0.15 |
| % of PE time very active | **0.41 (0.14, 0.68)** | **0.19** | **0.90 (0.44, 1.35)** | **0.37** | 0.02 (−0.29, 0.32) | 0.15 |

Note. PACER: Progressive Aerobic Cardiovascular Endurance Run; CI: confidence interval; BMI: body mass index; MPA: moderate physical activity; VPA: vigorous physical activity; PE: physical education; NA: not applicable. B coefficients show the unstandardized values, and β coefficients show the standardized values. Model was adjusted for age at peak height velocity, accelerometer wear time, PACER laps at baseline, and each presented variable. Significant values are in bold.

## 4. Discussion

With the aim of examining the promotion of CRF in PE classes, these findings demonstrated that from the beginning to the end of the school year, a greater percentage of participants were in the CRF healthy fitness zone. Also, sex, being overweight or obese, minutes of daily vigorous PA, organized sports participation, and the percentage of PE classes being very active were associated with the change in PACER laps from the beginning to the end of the school year.

Boys are known to have higher CRF than girls from late childhood onwards, and the difference increases throughout the years, reaching approximately 40% in late adolescence [26]. Thus, as expected, in this study, boys performed more PACER laps and had higher estimated $VO_2$ peak than girls. Notwithstanding, a greater percentage of boys were in the CRF healthy fitness zone than girls, at both baseline and follow-up. Also, even though findings have demonstrated that from the beginning to the end of the school year a greater percentage of participants were in the CRF healthy fitness zone, sex differences were found. At the beginning of the school year, 83.8% of boys were in the CRF healthy fitness zone, and this percentage increased to 90.5% at the end. On the other hand, 62.6% of girls were in the CRF healthy fitness zone at the beginning of the school year, and 69.2% at the end, however, this difference was not significant. The healthy fitness zone uses health criterion-referenced standards for each sex and age, therefore differences in the percentages of boys and girls in the CRF healthy fitness zone may reveal health disparities. The healthy fitness zone difference between boys and girls is in accordance with previous studies in the Portuguese population [27]. These differences may also be a reflection of the lower levels of PA that girls present when compared to boys [28], which was also observed in this study, as habitual PA is still considered a crucial factor in improving fitness [4].

According to a recent systematic review, age, weight status, and PE class intensity are relevant factors for promoting students' CRF [11]. In this study, sex, weight status, habitual vigorous PA, participation in organized sports, and the percentage of PE classes being very active were associated with the change in PACER laps from the beginning to the end of the school year. For both boys and girls, age was not associated with changes in CRF, suggesting that both younger and older students can improve. Although this is not in accordance with other studies [11], it should be taken into consideration that 88.7% ($n$ = 188) of participants were aged 12 to 14 years old, and thus, age differences may not be identifiable.

Participating in organized sports was associated with a positive change in PACER from the beginning to the end of the school year. Also, sports participation was the only common variable to be associated with changes in PACER in both boys and girls. Previous studies have demonstrated that children and adolescents participating in organized sports have better CRF than their non-participating peers, and that appropriate exercise training is known to increase CRF levels in youth, irrespective of sex, age, or maturity [29,30]. This evidence reinforces that planned and structured exercise programs with adequate frequency, duration, and intensity induce changes in fitness. Considering the school setting, it is possible to plan for activities that fulfil these requirements, especially in PE programs, and therefore promote health-related CRF in PE. However, evidence has demonstrated that most students spend less than 50% of PE time in moderate-to-vigorous PA [31], and that PE time is not associated with students' CRF [32].

Habitual PA is associated with children's and adolescents' fitness [4]. In this study, moderate PA was not associated with a change in PACER, while vigorous PA was only related to a positive CRF change in girls, and when considering the entire sample. Nonetheless, vigorous PA presented the greatest magnitude of association with PACER change among girls. In fact, engaging in regular vigorous PA is most beneficial for improving CRF [33], and is often achieved for those who participated in adequately planned and structured organized sports [29,30]. Surprisingly, in this study, vigorous PA was not associated with PACER change in boys; only in girls. This may be the result of consistent higher levels of PA (moderate and vigorous) in boys, that made it impossible to distinguish levels of vigorous PA between those with positive and negative changes in PACER. Notwithstanding, once again, PE classes have the opportunity to contribute to youth PA levels, including vigorous PA, and thus promote CRF. However, few students spend more than 50% of PE time in moderate-to-vigorous PA [31].

Percentage of PE time walking was not associated with positive changes in CRF. However, percentage of PE time being very active was, although only among boys. Furthermore, among boys, the percentage of PE time being very active was found to have the greatest magnitude of association with PACER change. These are relevant findings for PE, as they demonstrate that PE classes may have an important role in promoting health-related CRF. This is in agreement with a recent systematic review that identified PE class intensity as a key factor for promoting students' CRF [11]. However, as reported earlier, most of the students spent less than 50% of PE time in moderate-to-vigorous PA [31]. In this study, this was not the case, as more than 50% of PE time was estimated to be in moderate-to-vigorous PA (walking plus being very active). As it is for habitual PA and training, in PE, sufficient intensity together with adequate frequency and duration are key for promoting fitness.

Other aspects of PE besides intensity, such as frequency and duration, can also have an important role in promoting CRF. This study's participants had 150 weekly minutes of PE. In one school, those minutes were distributed among three classes of 50 min, while in the other school, they were divided into two classes, of 50 and 100 min. Several investigations have proposed that daily PE provides better opportunities for enhancing PA and fitness [34–37]. Also, the content of PE is of importance. Content that provides greater chances for engaging in moderate-to-vigorous PA (e.g., fitness activities and team games), may help promoting CRF in PE [11]. Therefore, high-quality PE, considering time, frequency, and intensity, can be a successful strategy to promote children's and adolescents' CRF levels.

Finally, only for girls, being overweight or obese was negatively associated with the change in PACER laps from the beginning to the end of the school year. A previous longitudinal study showed that although normal-weight girls enrolled in an eight-month PE program improved fitness, their obese peers showed no improvements in response to the same PE program [38]. Overweight and obese youth engage in less habitual PA [39], and are estimated to be 27% and 54% more likely to have school absenteeism, respectively, than their normal-weight peers [40]. These two factors, associated with the fact that PACER is a weight-bearing test, may explain why overweight and obese students have more difficulties in improving CRF.

This study has some limitations that must be acknowledged. The percentage of PE time walking and being very active were estimated through a visual observation instrument (SOFIT), instead of objectively measured (as habitual PA was), which can overestimate PA levels in PE. Nonetheless, SOFIT is validated as a measure of PA intensity during PE classes [24]. Similarly, CRF was assessed using a field test, giving an estimation and not a direct measure [41]. The two schools participating in the study are both from urban areas and middle-to-low-income neighborhoods, which does not take into account participants from other settings. Despite these limitations, the study presents some strengths. Habitual PA was objectively measured using accelerometers. Furthermore, the study employed a longitudinal design, following participants for a whole school year, allowing us to infer temporal directions in the associations assessed.

## 5. Conclusions

From the beginning to the end of the school year, a greater percentage of participants were in the CRF healthy fitness zone; however, differences were only significant for boys. Additionally, being overweight or obese, daily vigorous PA, and participating in organized sports for girls, and organized sports participation and the percentage of PE classes being very active for boys, were associated with the change in PACER laps from the beginning to the end of the school year. Thus, findings suggest that PE has a positive and significant role in the promotion of CRF, especially among boys. Among girls, habitual PA seems to have a greater contribution for the promotion of CRF. From a public health perspective, PE classes can play a significant role in the promotion of health-related fitness, and thus, in improving children's and adolescents' health.

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