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EFEITOS DE DIFERENTES ESTRATÉGIAS DE EXERCÍCIO FÍSICO SOBRE A APTIDÃO FÍSICA DE CRIANÇAS E ADOLESCENTES: UMA REVISÃO SISTEMÁTICA E META-ANÁLISE

Porto Alegre
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Orientador: Dr. Giovani dos Santos Cunha

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RESUMO

Introdução: A aptidão física tem sido considerada um importante indicador de saúde. Diversos fatores podem impactar no aumento de aptidão física, entre eles: idade cronológica, sexo e índice de massa corporal (IMC), além das variáveis de treinamento como frequência semanal, duração da sessão e da intervenção e os tipos de exercícios realizados. O objetivo foi realizar uma revisão sistemática da literatura com meta-análise e identificar a efetividade de diferentes estratégias de exercício físico sobre a aptidão física de crianças e adolescentes de ambos os sexos e com diferentes padrões de IMC. **Métodos:** A revisão sistemática e meta-análise foi conduzida de acordo com as recomendações Cochrane e devidamente registrada na plataforma PROSPERO. Três avaliadores revisaram sistematicamente as plataformas PubMed, Cochrane Library, Embase e Scopus. Os artigos foram selecionados de acordo com os seguintes critérios: crianças e adolescentes entre 7-17 anos que realizassem todos os tipos de exercício físico estruturado; grupo controle sem exercício como comparador; e realizar uma intervenção que avaliasse a aptidão física no âmbito da força ou potência muscular, aptidão cardiorrespiratória (APCR) ou velocidade de corrida. Três autores independentes realizaram a seleção dos estudos, a extração dos dados e a análise do risco de viés que foi classificado em baixa, média ou alta qualidade. **Resultados:** Foram incluídos 80 estudos que analisaram crianças e adolescentes de ambos os sexos e diferentes padrões de IMC, apresentando um total de 5769 participantes. No grupo exercício, 2894 sujeitos realizaram exercício de força, aeróbico (caminhada/corrida/ciclo ergômetro), *high intensity interval training* (HIIT) ou esportes e foram comparados com 2875 sujeitos do grupo controle que não praticavam exercício físico. A prática de exercício físico impacta nos ganhos de força muscular (ES: 0.967; CI: 0.635, 1.299). Sessões de longa duração (>60 minutos) parecem ser adequadas para aumentar a força muscular. Os exercícios de força (ES: 1.073; CI: 0.612, 1.533; p<0.001), combinado (ES: 1.054; CI: 0.255, 1.853; p=0.010) e esportes (ES: 0.573; CI: 0.015, 1.132; p=0.044) demonstraram ser os mais efetivos para crianças e adolescentes de ambos os sexos aumentarem a força muscular. A prática de exercício físico com atividades aeróbicas (ES: 0.514; CI: 0.220, 0.808; p<0.001), esportivas (ES: 0.271; CI: 0.146, 0.394; p<0.001) ou HIIT (ES: 0.668; CI: 0.333, 1.003; p<0.001) resultam em aumento na APCR (ES: 0.400; CI: 0.258, 0.542; p>0.001) em sujeitos de ambos os sexos (ES: 0.395; CI: 0.222, 0.567; p<0.001). Sujeitos com menor IMC (ES: 0.048; CI: 0.016, 0.081; p=0.004) apresentam maiores ganhos cardiorrespiratórios. A prática de exercício físico impacta no aumento da potência muscular (ES: 0.241; CI: 0.053, 0.429; p=0.012) em sujeitos de ambos os sexos (ES: 0.292; CI: 0.050, 0.535; p=0.018). A prática de exercício físico impacta nos ganhos de MAS (ES: 0.488; CI: 0.050, 0.926; p=0.029). O treinamento de HIIT parece influenciar nesses ganhos (ES: 0.488; CI: 0.050, 0.926; p=0.029). Quanto maior a idade (ES: 0.118; CI: 0.003, 0.232; p=0.044) e maior o IMC (ES: 0.172; CI: 0.052, 0.292; p=0.005), maior a magnitude de ganho de velocidade. **Conclusão:** Conclui-se que a prática de exercício físico é capaz de melhorar a aptidão física de crianças e adolescentes, devendo levar em conta no momento da prescrição do exercício, o sexo e o IMC dos sujeitos, além do tipo de exercício realizado (atividades aeróbicas, exclusivas de força, HIIT ou esportes) para melhorar componentes da aptidão física (força, APCR, potência e velocidade).

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Palavras-chave: força muscular; aptidão cardiorrespiratória; potência muscular; velocidade máxima aeróbica; infantil;

ABSTRACT

Introduction: Physical fitness has been considered an important health indicator. Several factors can impact the increase in physical fitness, including chronological age, sex and BMI, in addition to training variables such as weekly frequency, session and intervention duration, and types of exercises performed. The aim was to systematically review and meta-analyze the effectiveness of different physical exercise strategies on the physical fitness of children and adolescents of both sexes and with different BMIs. **Methods:** The systematic review and meta-analysis were conducted in accordance with Cochrane recommendations and duly registered on the PROSPERO platform. Three evaluators systematically reviewed the PubMed, Cochrane Library, Embase and Scopus platforms. Relevant articles were selected based on the following criteria: children and adolescents aged 7-17 years old, who performed all types of structured and supervised physical exercise, had a control group without exercise as a comparator, and should undergo an intervention evaluating physical fitness in the field of muscle strength or power, CRF or maximal aerobic speed. Three independent evaluators performed data extraction and risk of bias analysis. **Results:** Eighty studies were included that analyzed children and adolescents of both sexes and different BMIs, with a total of 5769 participants. 2894 subjects performed strength, aerobic exercise (walking/running/cycle ergometer), high-intensity interval training (HIIT) or sports and were compared with 2875 subjects from the control group who did not perform physical exercise. The practice of physical exercise impacts in muscle strength gains (ES: 0.967; CI: 0.635, 1.299). Long duration sessions (>60 minutes) seem to be adequate to increase muscle strength. Strength exercises (ES: 1.073; CI: 0.612, 1.533; p<0.001), combined (ES: 1.054; CI: 0.255, 1.853; p=0.010) and sports (ES: 0.573; CI: 0.015, 1.132; p =0.044) seems to be the most effective for children and adolescents of both sexes to increase muscle strength. The practice of physical exercise with aerobic activities (ES: 0.514; CI: 0.220, 0.808; p<0.001), sports (ES: 0.271; CI: 0.146, 0.394; p<0.001) or HIIT (ES: 0.668; CI: 0.333 , 1.003; p<0.001) result in increased in CRF (ES: 0.400; CI: 0.258, 0.542; p>0.001) in subjects of both sexes (ES: 0.395; CI: 0.222, 0.567; p<0.001). Subjects with lower BMI (ES: 0.048; CI: 0.016, 0.081; p=0.004) present greater cardiorespiratory gains. The practice of physical exercise has an impact on increasing muscle power (ES: 0.241; CI: 0.053, 0.429; p=0.012) in subjects of both sex (ES: 0.292; CI: 0.050, 0.535; p=0.018). The practice of physical exercise impacts on MAS gains (ES: 0.488; CI: 0.050, 0.926; p=0.029). HIIT training seems to influence these gains (ES: 0.488; CI: 0.050, 0.926; p=0.029). The greater the age (ES: 0.118; CI:

0.003, 0.232; p=0.044) and the higher the BMI (ES: 0.172; CI: 0.052, 0.292; p=0.005), the greater the magnitude of speed gain. **Conclusion:** It is concluded that the practice of physical exercise can improve the physical fitness of children and adolescents. Sex and BMI of the subjects should be considered when prescribing the exercise, in addition to the type of exercise performed (aerobic activities, exclusive to strength, HIIT or sports) to improve each fitness component (strength, CRF, power and MAS).

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Keywords: muscle strength; cardiorespiratory fitness; muscle power; maximum aerobic speed; children.

LISTA DE ABREVIATURAS E SIGLAS

ACSM – *American College of Sports Medicine*

AM – Aptidão Muscular

APCR – Aptidão Cardiorrespiratória

CMJ – *Countermovement Jump*

ESEFID – Escola de Educação Física, Fisioterapia e Dança

$FC_{máx}$ – Frequência cardíaca máxima

HIIT – *High intensity interval training*

IMC – Índice de massa corporal

MC – Massa corporal

MI – Membros inferiores

MS – Membros superiores

MAS – *Maximal aerobic speed*

OMS – Organização Mundial da Saúde

RM – Repetição máxima

VO_2 – Consumo de oxigênio

$VO_{2máx}$ – Consumo máximo de oxigênio

VO_{2pico} – Consumo de oxigênio de pico

SUMÁRIO

1.0 APRESENTAÇÃO

Essa tese foi motivada principalmente pelo aumento alarmante de crianças e adolescentes que não alcançam os níveis recomendados de atividade física e, consequentemente, acabam apresentando uma redução nos seus níveis de aptidão física. Além do mais, esses indivíduos estão mais propensos a apresentar sobrepeso e obesidade resultando em uma redução dos indicadores cardiometabólicos de saúde. Ao aplicar na prática a realização de exercício com crianças, surgiu o questionamento sobre como o exercício físico e as variáveis de treinamento físico-esportivo podem influenciar no desenvolvimento infantil. Além disso, esse público possui uma grande diversidade, sendo que crianças gostam de realizar atividades físicas específicas, enquanto adolescentes já vislumbram outros objetivos com o exercício. Meninos tem um uma maior preferência por um tipo específico de exercício, enquanto meninas preferem outro tipo e respondem de forma diferente à prática. Assim, pude constatar que faltavam maiores esclarecimentos sobre qual o tipo de treinamento mais apropriado para a população pediátrica a fim de melhorar sua aptidão física (resistência, força, potência e velocidade). Além disso, apesar das diretrizes sugerirem que crianças e adolescentes devem realizar exercício físico diário, atualmente esse público realiza diversas atividades escolares e cursos extraescolares, reduzindo o tempo dedicado a prática de atividade física, o que acarreta redução de seus níveis de aptidão física. Assim, surgiu o questionamento sobre qual a frequência semanal, a duração da sessão mais apropriadas para melhorar a aptidão física e quanto tempo é necessário para modificar os indicadores de saúde por meio do treinamento físico-esportivo. Neste sentido, a literatura não apresentava elucidações suficientes, o que motivou a realização de uma revisão sistemática com meta-análise para responder a essas questões.

Assim , a presente tese foi dividida em duas partes, a primeira contendo introdução geral e revisão de literatura relacionada aos efeitos do exercício físico sobre a aptidão física, sendo essa representada pela aptidão muscular (força e potência muscular), aptidão cardiorrespiratória e aptidão motora (velocidade).A segunda parte configura-se em artigo científico de revisão sistemática com meta-análise com o objetivo de analisar a efetividade de diferentes exercícios físicos sobre a aptidão física de crianças e adolescentes alocados de acordo com idade cronológica, sexo e índice de massa corporal.

2.0 INTRODUÇÃO GERAL

A aptidão física é um dos principais indicadores de saúde e é definida como um conjunto de habilidades relacionados à capacidade de realizar atividades físicas que requerem capacidade aeróbica, resistência, força e/ou flexibilidade e é determinada, principalmente, por uma combinação de atividade regular e capacidade herdada geneticamente (LANG *et al.*, 2022; ORTEGA *et al.*, 2018). Dentre os componentes da aptidão física estão a aptidão musculoesquelética (AM; ou seja, força, potência, resistência e flexibilidade muscular), aptidão cardiorrespiratória (APCR), aptidão motora (velocidade e agilidade) e composição corporal (massa muscular, adiposa e óssea), os quais apresentam associação com indicadores de saúde e desempenho físico-esportivo (LANG *et al.*, 2022). Para aprimorar esses níveis físicos, a prática regular de exercício físico deve ser considerada, já que estudos tem apresentado que sujeitos com altos níveis de aptidão física também possuem uma melhor saúde musculoesquelética e metabólica, maior resistência aeróbica, melhor coordenação motora, melhor desenvolvimento neural, possuem melhor bem-estar social e composição corporal favorável (menor percentual de gordura e maior massa muscular) (ANDERSEN *et al.*, 2017, 2011; CADENAS-SANCHEZ *et al.*, 2020; DE LIMA *et al.*, 2022; HENRIQUES-NETO *et al.*, 2020; LARSEN *et al.*, 2017; ORTEGA *et al.*, 2011).

Para aumentar os níveis físicos, segundo a Organização Mundial da Saúde (OMS), recomenda-se que jovens pratiquem diariamente 60 minutos de atividade física de intensidade moderada-vigorosa, incluindo exercícios de força muscular pelo menos 3 vezes por semana para o desenvolvimento saudável (WORLD HEALTH ORGANIZATION, 2020). Apesar das evidências demonstrarem a importância do exercício físico para a saúde (ORTEGA *et al.*, 2018b; POITRAS *et al.*, 2016), estima-se que fatores como avanço de idade cronológica, sexo (meninos *vs*. meninas) e diferentes composições corporais (altos valores de índice de massa corporal (IMC)) e parecem influenciar nos níveis de aptidão física, já que se estima que apenas 27-32% dos adolescentes no mundo atingem os níveis recomendado de exercício físico diariamente. Isso ocorre, em parte, devido a redução de espaços públicos para prática de atividade física aliado ao avanço tecnológico (videogames, televisão, celulares e computador). Por essas razões, crianças e adolescentes passam grande parte do tempo sem realizar exercício físico, ou seja, em comportamento sedentário. Esse quadro se agrava com o avanço da idade cronológica, no qual estudos têm apresentado que crianças em idade primária são mais ativas que adolescentes (ROSSELLI *et al.*, 2020) e que mais de 80% dos adolescentes não atingem as recomendações de exercício físico regular (GUTHOLD *et al.*, 2020), possivelmente pela falta de tempo e baixa motivação para a realização de exercícios regulares (DELFA-DE-LA-MORENA *et al.*, 2022; ROSSELLI *et al.*, 2020). Além disso, ao comparar os diferentes sexos, as meninas adolescentes parecem realizar menos exercício que suas contrapartes (ROSSELLI *et al.*, 2020; VAN HECKE *et al.*, 2016), possivelmente pelas alterações hormonais e corporais que estão ocorrendo na puberdade. Outro fator importante causado pela inatividade é o aumento precoce de indivíduos com sobrepeso e obesidade, no qual aliado com a inatividade física é uma das principais causas para o desenvolvimento precoce de doenças cardiometabólicas como: doenças cardiovasculares, diabetes, câncer, dislipidemia e depressão impactando negativamente na saúde (BERENSON, 2012; LECHNER *et al.*, 2020; LINDBERG *et al.*, 2020; SANTALIESTRA-PASÍAS; REY-LÓPEZ; MORENO AZNAR, 2013). Assim, a prática de exercício regular pode combater os efeitos deletérios da inatividade física, já que os benefícios adquiridos com a prática regular na infância perduram para a vida adulta (GARCÍA-HERMOSO; RAMÍREZ-CAMPILLO; IZQUIERDO, 2019), dessa forma, torna-se importante investigar os efeitos que o exercício físico promove sobre os componentes da aptidão física e como crianças e adolescentes com diferentes perfis de IMC e diferentes sexos são impactados pela sua prática.

De acordo com o *American College of Sports Medicine* (THOMPSON, 2018) o exercício físico deve ser supervisionado e estruturado (levando em consideração os princípios do treinamento físico-esportivo como volume, intensidade, frequência semanal, duração da sessão, duração da intervenção e tipo de exercício físico). No entanto, para a população pediátrica ainda não há consenso sobre como esses princípios influenciam nos ganhos de aptidão muscular, cardiorrespiratória e motora em indivíduos de ambos os sexos e com diferentes idades cronológicas e IMC.

Em relação a AM, há uma associação entre maiores valores de força e potência muscular de membros superiores e inferiores com uma melhor saúde cardiovascular (HENRIKSSON *et al.*, 2019; ORTEGA, F B *et al.*, 2008). Peterson et al., (2018) realizaram um estudo de coorte longitudinal com meninos e meninas em diferentes idades cronológicas durante um período de dois anos. Os autores perceberam que os sujeitos com maiores valores de força muscular possuem uma manutenção da saúde cardiometabólica conforme o seu crescimento. Por outro lado, a fraqueza muscular pode ser usada como um prognóstico indicador de início de risco cardiometabólico.

Embora tenha um aumento de esforços procurando promover uma melhor aptidão muscular nos jovens, ainda são questionáveis o efeito do ganho de força através de diferentes métodos e variáveis de treinamento para a população infantil (FALK, 2019). Contudo, quando prescrito corretamente e levando em consideração as variáveis de treinamento, crianças e adolescentes possuem um desenvolvimento de força muscular, neural e biomecânico (LLOYD *et al.*, 2014; MILLER; CHEATHAM; PATEL, 2010). Dessa forma, intervenções com atividades de força têm apresentado um efeito moderado a grande na aptidão muscular (LESINSKI *et al.*, 2020). Já para potência, as respostas são ainda mais controversas, já que os efeitos do treinamento variam entre pequeno a grande em crianças e adolescentes (LESINSKI *et al.*, 2020), sendo que crianças pré-púberes parecem se beneficiar somente com o treinamento pliométrico, enquanto pós-púberes se beneficiam tanto do treinamento pliométrico quanto de força (RADNOR; LLOYD; OLIVER, 2017). Já em relação as variáveis de treinamento como frequência semanal, duração da sessão e intervenção, uma recente meta-análise (WU *et al.*, 2021) apresentou que exercícios com baixa-frequência, alta-intensidade e curta-duração são efetivos para melhorar a AM de crianças. Por outro lado, Faigenbaum, (2017) apresentou que intervenções de baixo volume e intensidade são as mais apropriadas para iniciantes, enquanto para atletas, intensidades elevadas são as mais efetivas. Dessa forma, se percebe que ainda são controversas a efetividade do exercício físico para o ganho muscular e que é de grande importância compreender as respostas do exercício em crianças e adolescentes, para que sejam beneficiados pela prática com o intuito de melhorar a AM através de uma prescrição adequada de intervenção.

A APCR reflete na capacidade geral do sistema cardiovascular e respiratório em realizar exercícios prolongados e dinâmicos envolvendo grandes músculos do corpo. Esse marcador tem sido alvo historicamente de pesquisas devido a sua relação com saúde e desempenho. No âmbito da saúde, para crianças e adolescentes, há uma associação em baixos níveis cardiorrespiratórios com maiores riscos cardiovasculares e desenvolvimento de obesidade durante a infância e vida adulta (MINTJENS *et al.*, 2018). Dessa forma, a prática de exercício físico na infância tem apresentado causar um efeito protetivo na saúde cardiovascular (HENRIKSSON *et al.*, 2020). Para o público infanto-juvenil inúmeras são as atividades para aumentar a APCR, sendo as atividades de alta intensidade um reflexo de suas atividades diárias, dessa forma, tanto o treinamento intervalado de alta-intensidade (HIIT) quanto os exercícios com alta-duração e intensidade moderada parecem ser eficazes a partir de 7 semanas de treinamento (CAO;

QUAN; ZHUANG, 2019; WILLIAMS *et al.*, 2019). Em termos da prática esportiva, as revisões têm apresentado efeitos positivos sobre parâmetros cardiovasculares (MILANOVIĆ *et al.*, 2015b, 2019; OJA *et al.*, 2015). Uma recente revisão apresentou os efeitos do futebol na saúde de crianças e constatou que duas sessões semanais de 60 minutos podem ser recomendadas para melhorar a saúde cardiorrespiratória (CLEMENTE *et al.*, 2022). Por outro lado, Pinho et al. (2023) (PINHO *et al.*, 2023) não encontraram diferença após 12 semanas de treinamento de futebol com duas sessões semanais.

Existem muitas evidências sobre os componentes da aptidão física e seus efeitos em crianças e adolescentes que praticam exercícios físicos, mas também há uma grande demanda para compilar essas evidências e apresentar uma conclusão prática para treinadores e professores desse público que devem considerar a idade cronológica, sexo diferente e padrões de IMC no momento da prescrição do exercício. É importante notar que todas as revisões sistemáticas focaram em desfechos específicos como MF [35,36], CRF [10], saúde [37,38] e, até onde sabemos, nenhuma revisão com meta-análise apresentou mais de um componente (MF (força e potência), CRF e velocidade máxima) com diferentes métodos de treinamento de exercícios. Assim, os efeitos do treinamento físico e esportivo nos componentes da aptidão física têm sido controversos, o que dificulta a identificação e prescrição de estratégias efetivas de exercício físico para a população pediátrica. Por todo o exposto, percebe-se o seguinte problema de pesquisa: Qual a dose-ideal de exercício físico, baseado nas variáveis de treinamento, para melhorar a aptidão física (AM (força e potência), APCR e velocidade) de crianças e adolescentes de ambos os sexos e com diferentes padrões de IMC?

2.1 OBJETIVO GERAL

O objetivo desta revisão e meta-análise é explorar os efeitos de diferentes prescrições de treinamento físico na aptidão física de crianças e adolescentes de diferentes idades, sexo e padrões de IMC nas variáveis de treinamento, usando AM, APCR e velocidade máxima como índices de resultado.

2.2 OBJETIVOS ESPECÍFICOS

- Identificar o impacto do exercício físico sobre a AM nos componentes de força e potência;

- Identificar impacto do exercício físico sobre a APCR;
- Identificar o impacto do exercício físico sobre a aptidão motora no componente de velocidade;
- Realizar subanálises do efeito do exercício físico sobre a aptidão física em crianças e adolescentes de diferentes idades, sexo e IMC.

3.0 REVISÃO DE LITERATURA

3.1 O EFEITO DO EXERCÍCIO FÍSICO SOBRE A APTIDÃO MUSCULAR – FORÇA E POTÊNCIA MUSCULAR

A AM é definida como a capacidade do músculo de gerar trabalho a partir de uma determinada resistência (ORTEGA, F. B. *et al.*, 2008), sendo composta por força, potência, resistência e flexibilidade muscular. A AM tem relação com a saúde e desempenho físico-esportivo e vem sendo frequentemente estudada devido a sua relação com as altas taxas de mortalidade em sujeitos que apresentam baixos níveis de força muscular (ORTEGA *et al.*, 2012). A força muscular é mensurada a partir de avaliações como o teste de força máxima (1RM) ou com utilização de dinamômetro isocinético principalmente de membros superiores e inferiores. Já as atividades que exigem movimentos em alta velocidade e baixa carga são consideradas atividades de potência muscular como por exemplos saltos e arremessos (CAPPA; BEHM, 2011). Ambos exigem adaptações neuromusculares e são importantes para aprimorar a AM. Recentemente, (Castro-Piñero et al., (2019) analisaram o risco cardiovascular e sua associação com a AM de crianças com idade a partir de seis anos, durante um período de dois anos. Os autores estabeleceram que a AM está inversamente associada com o risco cardiovascular, independentemente da sua APCR. Em relação ao desenvolvimento precoce de doenças cardiometabólicas, 1 milhão de adolescentes com idades entre 16 e 19 anos foram avaliados e aqueles com menores níveis de força muscular de membros superiores e/ou inferiores apresentaram maiores riscos a saúde (problemas metabólicos), independente do IMC (ORTEGA *et al.*, 2012).

O exercício físico auxilia no controle dos indicadores de saúde, pois o músculo esquelético é um tecido responsável por aproximadamente 30% do consumo energético e libera milhões de mioquinas na circulação, sendo um dos principais responsáveis pela captação, liberação e estoque de glicose (GRAF; FERRARI, 2019; PAULI *et al.*, 2009). Além disso, aumentar os níveis de força e potência muscular estão associados a diversos benefícios à saúde como por exemplo: redução da sobrecarga articular, prevenção de lesões, melhora da postura corporal, da composição corporal (aumento da densidade mineral óssea e massa muscular e redução da massa adiposa), da saúde cardiovascular, do controle glicêmico, do desempenho cognitivo para o aprendizado, do humor e da autoestima (GARCÍA-HERMOSO *et al.*, 2020). Tais ganhos podem ser atribuídos as alterações hormonais provenientes do exercício com aumento na circulação de hormônios andrógenos e mecanismos fisiológicos resultante de adaptações neuromusculares, como alterações nas funções proteicas musculares que ativam vias específicas para adaptações neurais e morfológicas (SMALL *et al.*, 2008).

Por esse motivo, as recomendações de atividade física da OMS sugerem que seja realizado um programa de treinamento de força a partir dos seis anos de idade com frequência semanal mínima de três vezes por semana (WORLD HEALTH ORGANIZATION, 2020). Esses exercícios devem ser orientados e supervisionados por profissionais especializados na área contendo atividades que incluem brincadeiras, jogos esportivos, exercício específico de força e potência muscular, treinamento combinado (força + aeróbico) e HIIT (WORLD HEALTH ORGANIZATION, 2020). Além disso, é importante levar em consideração variáveis de treinamento como: frequência semanal, volume e duração das sessões e tempo de intervenção, já que essas irão influenciar as respostas referentes aos ganhos de AM. Nesse sentido, o estímulo, o tipo de exercício e a manipulação das variáveis que compõem o exercício físico podem apresentar diferentes respostas na população pediátrica. Além disso, estabelecer a dose ideal de exercício (sobrecarga) é importante para maximizar os ganhos da AM nas dimensões de saúde e performance.

A frequência semanal é definida pelo número de sessões de exercício realizado na semana. Para adultos é estimado que quatro sessões semanais são ideias para aumento de força muscular priorizando os movimentos multiarticulares (IVERSEN *et al.*, 2021). Contudo, para crianças ainda não há um consenso sobre a frequência semanal ideal para aumentar a força muscular. Com duas sessões semanais meninos e meninas foram capazes de aumentar a força muscular em 26% após oito semanas de intervenção com exercício de força para membros superiores e inferiores (BENSON; TORODE; FIATARONE SINGH, 2008). Já com três sessões semanais de exercício específico de força foi encontrado um aumento de 27,8% na força de membros inferiores de adolescentes (OZMUN; MIKESKY; SURBURG, 1994). Por outro lado, cinco sessões semanais de intervenção esportiva (taekwondo) foram capazes de aumentar em 4% a força muscular de membro inferior (ROH; CHO; SO, 2020). Procurando compreender a frequência semanal ideal para melhorar a AM, recente meta-análise de Wu et al., (2021) estabeleceram que baixa frequência semanal (<3x por semana) resulta em um efeito grande no ganho de força muscular e moderado no ganho de potência muscular. Contudo, ainda existe uma lacuna no conhecimento sobre a utilização de maiores frequência semanais de exercício físico na população infantil e apesar de apresentarem diferentes respostas, a frequência semanal deve ser levada em consideração na prescrição do exercício, visto que é de suma importância para organização do treinamento de forma apropriada a fim de maximizar os ganhos de força e potência muscular.

A prescrição de volume (tempo de duração da sessão) e de intensidades apropriadas de exercício físico são fatores determinantes para maximização dos ganhos de AM. O metabolismo de crianças e adolescentes difere-se da população adulta e prescrever os mesmos volumes, intensidades e duração das sessões para ambos os públicos pode não ser apropriado. O sistema neuromuscular infantil ainda não está completamente maduro e seu organismo possui diferenças nos tipos de fibras muscular quando comparado aos adultos, ou seja, apresentam maior percentual de fibras oxidativas, o que impacta em uma melhor adaptação a exercícios de longa duração, contudo apresentam menor capacidade anaeróbica (KENNEY; WILMORE; COSTILL, 2013). Em relação ao efeito da duração da sessão sobre os ganhos de força e potência muscular, os estudos ainda são controversos e percebe-se uma lacuna no conhecimento sobre os melhores métodos e estratégias de exercícios. Estudos têm apresentado que intervenções com duração inferior a 60 minutos em uma única sessão parece ser a mais apropriada para melhorar a força muscular (WU *et al.*, 2021). Em sessões de 30 minutos o ganho de força muscular foi de 24,9% (FAIGENBAUM *et al.*, 2002). Contudo, sessões de longa duração (>60 minutos), também parecem ter efeito sobre a AM, promovendo um aumento de 32% na força muscular após treinamento combinado (ALBUQUERQUE FILHO *et al.*, 2015).

Em relação a potência muscular, os ganhos dependem das adaptações neurais provenientes do treinamento, da carga e da velocidade em que o exercício é realizado (KAWAMORI; HAFF, 2004). Para o público infantil, o aumento de potência é influenciado pela maturação biológica. Atividades de potência como saltos exigem um alto padrão motor e crianças ainda não estão com o equilíbrio e coordenação aprimorados, o que pode afetar esses ganhos (BEHM *et al.*, 2017). Ao analisar a literatura, os estudos têm apresentado que tanto crianças como adolescentes são capazes de aumentar a potência muscular através da altura de salto de CMJ após exercício físico (ALVES *et al.*, 2016-; ARABATZI, 2018; BOGATAJ *et al.*, 2021; GRANACHER *et al.*, 2011; OTHMAN *et al.*, 2020; RACIL *et al.*, 2015, 2017), sendo que crianças são capazes de aumentar em 3,3% (GRANACHER *et al.*, 2011), enquanto adolescentes apresentam um aumento entre 7,7 e 17% (GRANACHER *et al.*, 2011; MUEHLBAUER; GOLLHOFER; GRANACHER, 2012). Porém, ainda faltam elucidações sobre como o aumento da potência pode contribuir para o crescimento muscular, além de análises sobre os diferentes métodos de exercício para essa população.

A literatura tem apresentado que diferentes durações de sessões de exercício físico têm ganhos semelhantes para a potência muscular, não apresentando grandes efeitos do treinamento sobre essa valência na população pediátrica. Alves et al., (2016) estabeleceram que sessões de 45 minutos de duração com exercícios de força muscular em pré-púberes aumentaram a potência muscular em 5%, enquanto sessões de 90 minutos de duração com exercício de força foi capaz de aumentar entre 6 e 8% a altura do salto (GRANACHER *et al.*, 2011; MUEHLBAUER; GOLLHOFER; GRANACHER, 2012) em adolescentes. Assim, parece ser importante considerar o processo maturacional para estabelecer a duração da sessão ideal para o aumento de potência muscular.

O tipo de exercício físico realizado também pode influenciar a AM. Intervenções exclusivas de treinamento força têm apresentado um efeito moderado-alto no ganho de força muscular (COHEN *et al.*, 2021). Já o treinamento esportivo ou HIIT que utilizam principalmente a massa corporal como sobrecarga de treinamento e apresentam uma dinâmica de atividades diferente do treinamento de força tradicional tem apresentado um efeito pequeno-moderado no ganho de força e potência muscular (FAIGENBAUM *et al.*, 2002; RACIL *et al.*, 2017). Faigenbaum et al., (2002) apresentaram que o treinamento de força foi capaz de aumentar em 24,9% a força muscular de membros inferiores em crianças, enquanto a altura do salto aumentou em 9%. BOGATAJ et al., (2021) estabeleceram um aumento de 5% na força muscular de membros superiores e de 5,6% na altura do salto em adolescentes após intervenção com HIIT. Intervenções esportivas são agradáveis ao público infantil devido ao seu dinamismo e ludicidade e tem apresentado efeito moderado no ganho de potência muscular (MILANOVIĆ *et al.*, 2019). Assim, Cvetkovic et al., (2018) encontraram um aumento de 18% na altura do salto de crianças que realizaram treinamento de futebol, enquanto o grupo que realizou HIIT aumentou em 6% a altura de salto. Quando comparadas as duas modalidades, percebe-se que o HIIT é executado em corridas lineares, enquanto o futebol apresenta saltos e sprints com constantes trocas de direção (BANGSBO, 2015; BANGSBO *et al.*, 2014).

Dessa forma, percebe-se que o tipo de exercício realizado tem grande influência nos ganhos de AM, impactando na saúde e performance. Não obstante, é importante analisar as diferentes modalidades de exercícios físico e a relação da dose-resposta entre as variáveis de treinamento (frequência semanal, duração da sessão e tipo de intervenção) com os níveis de AM e saúde.

3.2 O EFEITO DO EXERCÍCIO FÍSICO SOBRE A APTIDÃO CARDIORRESPIRATÓRIA

A APCR é definida como a capacidade integrada do corpo para fornecer oxigênio aos tecidos e utilizá-lo para ressintetizar energia durante o exercício físico (ARMSTRONG; WELSMAN, 2020). Ainda, é considerada e um importante biomarcador de engajamento regular ao exercício físico e um potente indicador de saúde em crianças e adolescentes (ARMSTRONG; WELSMAN; WINSLEY, 1996; LANG *et al.*, 2018). O consumo máximo de oxigênio (VO_{2max} ou VO_{2pico}) é considerado o melhor indicador da APCR, sendo mensurado como a mais alta taxa de oxigênio consumido (VO_2) durante um teste progressivo de exercício máximo. O VO_{2max} pode ser mensurado diretamente ou estimado indiretamente a partir de testes máximos ou submáximos. Os testes comummente mais utilizados são caminhada/corrida ou pedalada em ciclo ergômetro utilizando o método ergoespirométrico (padrão-ouro) (ARMSTRONG; WELSMAN, 2020). O VO_{2max} é uma das variáveis fisiológicas mais investigadas na literatura científica principalmente devido a sua relação com o desempenho físico-esportivo. Contudo, atualmente tem sido amplamente estudada por ser um considerado um potente indicador de saúde cardiometabólica e preditor de expectativa de vida, morbidade e mortalidade em crianças, adolescentes e adultos (MARTA *et al.*, 2013; MILANOVIĆ *et al.*, 2015; RANDERS *et al.*, 2012; WILLIAMS *et al.*, 2019).

Altos níveis de VO_{2max} na infância tem apresentado um efeito cardiometabólico protetivo para o desenvolvimento de doenças crônicas na vida adulta. Por outro lado, baixos níveis de APCR na infância aumentam a incidência de obesidade e risco cardiometabólico (MINTJENS *et al.*, 2018). Recentemente, foi realizada uma análise sobre as tendências de aptidão física no último século e foi constatado que houve uma redução significativa nos níveis de APCR de crianças, e atualmente esses indicadores se mantém baixos devido ao elevado número de crianças e adolescentes que não realizam atividade física regular (FÜHNER *et al.*, 2021). Um estudo analisou 590 crianças com idades entre 9-10 anos e encontrou uma associação entre menores valores de VO_{2max} com maior risco cardiovascular (HURTIG-WENNLÖ *et al.*, 2007; MINTJENS *et al.*, 2018) Dados similares são encontrados em adolescentes, público este, que apresenta menores níveis de atividade física em comparação às crianças e, consequentemente, apresentam menor APCR e maior o risco à saúde (HURTIG-WENNLÖ *et al.*, 2007; MINTJENS *et al.*, 2018). Portanto, é importante compreender e identificar essas características nas fases iniciais da vida, a fim de prevenir futuros eventos adversos relacionados às doenças cardiometabólicas.

No intuito de classificar o risco à saúde baseado na APCR, Ruiz et al., (2016) têm proposto pontos de corte de 42 $ml.kg^{-1}.min^{-1}$ e 35 $ml.kg^{-1}.min^{-1}$ para meninos e meninas, respectivamente. Nesta classificação, crianças e adolescentes que apresentarem valores de APCR inferiores a esses pontos de corte estão mais suscetíveis a problemas de saúde.

Altos níveis de APCR tem sido associado a melhoras na saúde cardiometabólica, cognitiva e psicossocial de crianças (LANG *et al.*, 2018). Adicionalmente, auxilia no controle do peso corporal, reduzindo principalmente o percentual de gordura e consequentemente o IMC; associa-se ao menor risco de obesidade e hipertensão arterial, melhor controle glicêmico e lipídico. Neste sentido, torna-se importante proporcionar, através do exercício físico, estímulos para que o público infantil aumente seus níveis de APCR e atinjam as recomendações de atividade física.

Diversos fatores podem influenciar nos valores de APCR. A diferença entre meninos, meninas e o estágio maturacional vem ganhando destaque, principalmente pelas meninas pós-púberes representarem um maior percentual de inatividade física quando comparada aos meninos (ARMSTRONG; WELSMAN, 2020; GUTHOLD *et al.*, 2020). Os valores de VO_{2max} das meninas são cerca de 10% menores do que meninos durante a infância e a diferença entre os sexos pode chegar até 35% na adolescência (ARMSTRONG; TOMKINSON; EKELUND, 2011). Essas diferenças podem estar relacionadas ao nível de atividade física, já que os meninos são mais ativos do que as meninas. Além disso, durante a puberdade meninas passam a acumular maior gordura corporal enquanto meninos passam a ter maior massa muscular devido as alterações hormonais (KENNEY; WILMORE; COSTILL, 2013). Essas diferenças acabam se destacando no momento de analisar os valores de APCR, já que o $VO_{2máx}$ relativo ($ml.kg^{-1}.min^{-1}$) é normalizado pela massa corporal. Assim, durante o desenvolvimento do processo maturacional os meninos são capazes de manter um consumo de oxigênio constante, enquanto as meninas apresentam um declínio (ARMSTRONG; TOMKINSON; EKELUND, 2011). Ademais, com a massa corporal adequadamente controlada, o $VO_{2máx}$ dos meninos aumenta durante a infância e adolescência até a idade adulta, enquanto o $VO_{2máx}$ das meninas aumenta pelo menos na puberdade e possivelmente na idade adulta (WELSMAN *et al.*, 1996).

Ao analisar a diferença entre meninos e meninas pré-púberes, estudos tem mostrado um efeito pequeno da influência do sexo sobre a prática de exercício físico (MARTA *et al.*, 2013). Mandigout et al., (2002) analisaram meninos e meninas e encontraram que ambos foram capazes de aumentar o VO_{2max} após um treinamento aeróbico, contudo, as meninas aumentaram em 8,6%, enquanto os meninos aumentaram 5,2%, possivelmente pelo fato de serem mais ativos que suas contrapartes e possuir uma janela de treinabilidade menor.

Segundo a OMS, é recomendado que crianças e adolescentes pratiquem pelo menos 60 minutos de exercício físico de intensidade moderada a vigorosa diariamente (WORLD HEALTH ORGANIZATION, 2020). As atividades realizadas podem ser inúmeras desde que sejam atrativas. A prática esportiva, exercícios aeróbicos, combinados (força + aeróbico) e HIIT têm mostrado sua relevância nos ganhos físicos (ALMEIDA *et al.*, 2021; BAQUET *et al.*, 2002; BARBEAU *et al.*, 2007). Essas modalidades podem apresentar respostas cardiorrespiratórias diferentes, principalmente quando se trata do público infantil porque apresentam proporções menores no que diz respeito ao tamanho do coração, vasos sanguíneos e pulmões, sendo importante investigar os efeitos dessas modalidades sobre a APCR (CAO; QUAN; ZHUANG, 2019; FAIGENBAUM *et al.*, 2022).

Dentre as modalidades esportivas, os esportes são comumente bem aceitos pelo público infantil devido ao seu dinamismo, motivação e sociabilidade durante a prática, produzindo grandes efeitos no VO_{2max} (MILANOVIĆ *et al.*, 2015). García-Hermoso et al., (2020) realizaram oito semanas de intervenção com jogos cooperativos e encontraram um efeito moderado na APCR (1,55 $ml.kg^{-1}.min^{-1}$) após intervenção realizada por crianças. Além do mais, os sujeitos aumentaram seus níveis de atividade física e a performance escolar. Com a prática exclusiva de futebol, crianças saudáveis foram capazes de aumentar os valores de VO_{2max}, representando um aumento de 1,77 $ml.kg^{-1}.min^{-1}$, valor significativo que pode reduzir o risco para doenças cardiometabólicas (WENG *et al.*, 2018).

Exercícios predominante de alta intensidade como o HIIT também tem sido efetivos e atrativos às crianças, já que possuem um tempo de estímulo seguido por descanso, o que proporciona uma dinâmica à atividade. Chuensiri; Suksom; Tanaka, (2018) analisaram que tanto o HIIT com intensidade de 90% da potência de pico e o supra-HIIT com intensidade a 170% da potência de pico foram agradáveis e capazes de melhorar o VO_{2max}. Por outro lado, apesar do treinamento aeróbico gerar ganhos significativos na APCR (ARMSTRONG; WELSMAN, 2001; KELLY *et al.*, 2004), esse tipo de exercício geralmente é composto por corrida regular em longa distância e velocidade moderada, o que às vezes não é agradável às crianças. Com isso, durante os anos de crescimento e desenvolvimento, parece ser vantajoso recorrer a diversas modalidades, visando maior motivação e maior engajamento ao exercício físico. Ainda, é importante analisar os efeitos de diferentes métodos de treinamento com o intuito de compreender qual o mais atrativo e capaz de promover melhoras significativas na saúde de crianças e adolescentes.

3.3 O EFEITO DO EXERCÍCIO FÍSICO SOBRE APTIDÃO MOTORA – VELOCIDADE

A velocidade é uma habilidade motora fundamental que é definida como a capacidade de realizar ações vigorosas em curto espaço de tempo (DANTAS, 2003). Essa habilidade exige um desenvolvimento motor completo, pois envolve controle corporal e neural para produção de força rápida, o que indica que adolescentes, por serem mais desenvolvidos, são capazes de produzir maiores níveis de velocidade em comparação as crianças. Berthoin et al., (1995) observaram que adolescentes (14 a 17 anos) de ambos os sexos aumentaram sua velocidade máxima de corrida em 5,5% após uma intervenção de 12 semanas. No contexto infanto-juvenil, ainda faltam maiores elucidações quanto a efetividade de diferentes estratégias e métodos de treinamento sobre a velocidade.

Recente revisão realizou uma comparação entre uma intervenção de HIIT e exercício de intensidade moderada e concluiu que o HIIT foi capaz de provocar maiores adaptações fisiológicas em crianças e adolescentes (CAO; QUAN; ZHUANG, 2019). Ao comparar HIIT e atividade moderada em adolescentes, um estudo encontrou que ambas as modalidades foram capazes de melhorar velocidade aeróbica máxima, a composição corporal e sensibilidade à insulina, contudo, somente o HIIT apresentou um efeito grande na velocidade e foi capaz de alterar os níveis do hormônio da tireoide. Dessa forma, atividades de alta-intensidade e curta duração têm apresentado efeito positivo sobre a aptidão física (GIBALA *et al.*, 2012; GIBALA; MCGEE, 2008; GILLEN; GIBALA, 2018), sendo importante investigar seus efeitos na população pediátrica.

Para crianças e adolescentes o treinamento de alta intensidade é atrativo devido ao seu dinamismo, sendo caracterizado por sessões repetidas de exercícios intermitentes relativamente breves, muitas vezes realizados em uma intensidade próxima a capacidade aeróbica máxima ou acima do VO_{2max}, sugerindo um esforço “total” (BUCHHEIT; LAURSEN, 2014). Dependendo da intensidade do treinamento, um único esforço pode durar alguns segundos ou até vários minutos, realizado em séries de estímulos intercalados com descanso passivo ou exercício de baixa-intensidade. Em contraste com o treinamento de força, que tem por objetivo aumentar a força e a massa muscular através de esforços intensos, breves e com intervalos, o HIIT é normalmente associado a atividades como ciclismo ou corrida (ROSS; LEVERITT, 2001).

Pode-se destacar que corridas de alta-intensidade são executadas com múltiplos contatos que geram uma força de reação no solo, levando a um aumento da densidade mineral óssea, sendo importante para o desenvolvimento e aumento de conteúdo mineral ósseo na vida adulta (MELLO *et al.*, 2022). Além disso, são capazes de melhorar a capacidade cognitiva, controlar o peso corporal e reduzir os riscos de desenvolvimento de doenças cardiometabólicas. Essas respostas são decorrentes de adaptações fisiológicas induzidas pelo exercício. Estudos tem mostrado que o HIIT é capaz de provocar alterações mitocondriais, melhorar a capacidade muscular oxidativa, alterações no metabolismo de carboidratos, aumento do conteúdo de glicogênio em repouso, menor utilização de glicogênio, produção de lactato durante o exercício e aumento do conteúdo total de proteína do transportador de glicose muscular (BURGOMASTER *et al.*, 2007; BURGOMASTER; HEIGENHAUSER; GIBALA, 2006) resultando em aumento de VO_{2max} e melhor capacidade de produzir intensidades de exercício elevadas (GILLEN; GIBALA, 2014; HOOD *et al.*, 2011).

As adaptações provenientes do treinamento são de grande importância para o público jovem, principalmente no período de transição entre infância e a vida adulta, já que é um período em que, dependendo do estilo de vida, pode ocorrer acúmulo excessivo de gordura corporal, desenvolvendo sobrepeso ou obesidade e consequentemente aumentando os riscos para o desenvolvimento de doenças crônicas. Hamila et al., (2017) estabeleceram em adolescentes com IMC >29kg/m^2 um aumento na velocidade aeróbica máxima de 8,7%, com aumento concomitante do $VO_{2máx}$ de 14,1% após 8 semanas de intervenção de educação física escolar. Da mesma forma, meninas com IMC de 33 kg/m^2 aumentaram sua velocidade aeróbica máxima de 11,0 para 13,4 km/h após 12 semanas com melhora da sensibilidade à insulina. Por outro lado, crianças com IMC de 23,7 kg/m^2 não apresentaram diferença significativa nos ganhos de velocidade (pré: 11,0 km/h; pós: 11,1 km/h), porém aumentaram seu VO_{2max} em 7% após 6 semanas de treinamento (LAMBRICK *et al.*, 2016). Esses achados mostram a relevância que a prática regular de exercício físico provoca na APCR de crianças e adolescentes com diferentes padrões de IMC, sendo importante analisar quais são as respostas induzidas pelo treinamento sobre a velocidade aeróbica máxima e aptidão aeróbica com o intuito de prevenir o desenvolvimento precoce de sobrepeso e obesidade.

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5.0 SYSTEMATIC REVIEW AND META-ANALYSIS ARTICLE

Effects of different training strategies on the physical fitness of children and adolescents: a systematic review and meta-analysis

Different strategies on the physical fitness of children and adolescents

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Declarations

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Authors' contributions CDFP and GSC conceived the idea and design of the article. CDFP, NCB and SDCL performed the literature search, data acquisition, analysis and/or interpretation. CDFP, NCB, SDCL, JBM and GSC drafted and/or critically reviewed the work. All authors read and approved the final version.

Abstract

Background: Physical fitness is the primary outcome of training, and differentiating the different training methods' effects on physical fitness is essential for strength-and-conditioning coaches' decisions. **Objective:** The aim was to systematically review and meta-analyze the effects that supervised and structured physical exercise promotes on the physical fitness of children and adolescents of both genders and with different body mass index (BMI). **Methods:** PubMed, Cochrane Library, Embase and Scopus platforms databases were searched in September of 2021 and updated in July 2022. Relevant articles were selected based on the following criteria: children and adolescents aged between 7 and17 years, who performed any types of structured physical exercise, compared to a control group without exercise as a comparator and evaluating physical fitness (strength or muscular power, cardiorespiratory fitness (CRF) or speed). Three independent authors performed the selection of studies, the data extraction, and the analysis of risk of bias that was classified in low, medium, or high quality.

Results: Eighty studies were included that analyzed children and adolescents of both sexes and different BMIs, with a total of 5769 participants. 2894 subjects performed strength, aerobic exercise (walking/running/cycle ergometer), high-intensity interval training (HIIT) or sports and were compared with 2875 subjects from the control group who did not perform physical exercise. The practice of physical exercise impacts in muscle strength gains (ES: 0.967; CI: 0.635, 1.299). Long duration sessions (>60 minutes) seem to be adequate to increase muscle strength. Strength exercises (ES: 1.073; CI: 0.612, 1.533; $p<0.001$), combined (ES: 1.054; CI: 0.255, 1.853; $p=0.010$) and sports (ES: 0.573; CI: 0.015, 1.132; $p=0.044$) seems to be the most effective for children and adolescents of both sexes to increase muscle strength. The practice of physical exercise with aerobic activities (ES: 0.514; CI: 0.220, 0.808; $p<0.001$), sports (ES: 0.271; CI: 0.146, 0.394; $p<0.001$) or HIIT (ES: 0.668; CI: 0.333 , 1.003; $p<0.001$) result in increased in CRF (ES: 0.400; CI: 0.258, 0.542; $p>0.001$) in subjects of both sexes (ES: 0.395; CI: 0.222, 0.567; $p<0.001$). Subjects with lower BMI (ES: 0.048; CI: 0.016, 0.081; $p=0.004$) present greater cardiorespiratory gains. The practice of physical exercise has an impact on increasing muscle power (ES: 0.241; CI: 0.053, 0.429; $p=0.012$) in subjects of both sex (ES: 0.292; CI: 0.050, 0.535; $p=0.018$). The practice of physical exercise impacts on MAS gains (ES: 0.488; CI: 0.050, 0.926; $p=0.029$). HIIT training seems to influence these gains (ES: 0.488; CI: 0.050, 0.926; $p=0.029$). The greater the age (ES: 0.118; CI: 0.003, 0.232; $p=0.044$) and the higher the BMI (ES: 0.172; CI: 0.052, 0.292; $p=0.005$), the greater the magnitude of speed gain. **Conclusion:** Supervised and structured physical exercise can improve the physical fitness (strength, CRF, power and speed) in children and adolescents. Sex and BMI of the subjects should be considered when prescribing the exercise, in addition to the type of exercise performed (aerobic activities, exclusive to strength, HIIT or sports).

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Keywords: muscular strength; cardiorespiratory fitness; muscular power; maximum aerobic speed; children.

Key Points

- All physical fitness components (muscular, cardiorespiratory fitness and speed) can be improved by supervised and structured physical exercise.
- Strength and combined training are more appropriate to increase muscular fitness in children and adolescents. Long sessions (>60 minutes) seem to be more effective. Aerobic, High Intensity Interval Training, and sports training appear to be more effective in increasing CRF than strength and combined training for children and adolescents. In addition, High Intensity Interval Training improves Maximum Aerobic Activity in children and adolescents.

5.1 Introduction

Physical fitness is one of the main health indicators and is defined as a set of skills related to the ability to perform physical activities that require aerobic capacity, endurance, strength and/or flexibility and is mainly determined by a combination of regular activity and genetically inherited ability [1]. Components of physical fitness include musculoskeletal fitness (MF; i.e. muscle strength, power, endurance, and flexibility), cardiorespiratory fitness (CRF), motor fitness (speed and agility), and body composition (muscle, fat, and bone mass), which are associated with health indicators and physical-sports performance [1]. To improve these physical levels, the regular practice of physical exercise should be considered, since studies have shown that subjects with high levels of physical fitness also have better musculoskeletal and metabolic health, greater aerobic resistance, better motor coordination, better neural development, have better social well-being and favorable body composition (lower percentage of fat and greater muscle mass) [2–7].

To increase physical levels, according to the World Health Organization (WHO), it is recommended that young people practice 60 minutes of physical activity of moderate-vigorous intensity daily, including muscle strength exercises at least 3 times a week for healthy development [8]. Despite the evidence demonstrating the importance of physical exercise for health [9,10], it is estimated that factors such as advancing chronological age, gender (boys vs. girls) and different body compositions (high values of body mass index (BMI)) seem to influence the levels of physical fitness, since it is estimated that only 27-32% of adolescents in the world reach the recommended levels of daily physical exercise. It means that young people are more predisposed to have low physical fitness, becoming sedentary and at high risk for metabolic diseases in adult life [11].

According to the American College of Sports Medicine [12] physical exercise must be supervised and structured, considering the principles of physical-sports training (volume, intensity, weekly frequency, session duration, intervention duration and type of physical exercise). However, for the pediatric population, there is still no consensus on how these principles influence muscular, cardiorespiratory and motor fitness gains in individuals of both sexes and with different chronological ages and BMI.

Regarding MF, there is an association between higher values of upper and lower limb muscle strength and power with better cardiovascular health [13,14]. Peterson et al., (2018) [15] conducted a longitudinal cohort study with boys and girls at different chronological ages over a two-year period. The authors found that subjects with higher values of muscle strength maintain their cardiometabolic health as they grow. On the one hand, muscle weakness can be used as a prognostic indicator of early cardiometabolic risk. Although there has been an increase in efforts to promote better muscular fitness in young people, the effect of strength gain through different training methods and variables for the child population is still questionable [16]. However, when correctly prescribed and considering the training variables, children and adolescents have a muscular, neural and biomechanical strength development [17,18]. Regarding training variables such as weekly frequency, session duration and intervention, a recent meta-analysis [19] showed that low-frequency, high-intensity and short-duration exercises are effective in improving MF of children. On the other hand, Faigenbaum, (2017) [20] showed that low volume and intensity interventions are the most appropriate for beginners, while for athletes, high intensities are the most effective. Thus, the effectiveness of physical exercise for muscle gain is still controversial and that it is of great importance to understand the responses of exercise in children and adolescents, so that they can benefit from the practice with the aim of improving MF through an appropriate prescription of intervention.

The CRF consist of the general ability of the cardiovascular and respiratory system to perform prolonged and dynamic exercises involving the body's large muscles [21]. This marker has historically been the target of research due to its relationship with health and performance [22–26]. In the field of health, for children and adolescents, there is an association between low cardiorespiratory levels and higher cardiovascular risks and the development of obesity during childhood and adult life [27]. Thus, the practice of physical exercise in childhood has been shown to have a protective effect on cardiovascular health [28]. For children and youth, there are a lot of activities to increase the CRF, with high-intensity activities reflecting their daily activities. Also, both high-intensity interval training (HIIT) and high-duration and moderate-high intensity exercises seems to be effective from 7 weeks of training [25,29]. In terms of sports practice, reviews have shown positive effects on cardiovascular parameters [30–32]. A recent review presented the effects of soccer on children's health and found that two weekly sessions of 60 minutes can be recommended to improve cardiorespiratory health [33]. On the other hand, Pinho et al. (2022) [34] found no difference after 12 weeks of soccer training with two weekly sessions.

There is a lot of evidence about the components of physical fitness and their effects on children and adolescents who practice physical exercise, but there is also a great demand to compile this evidence and present a practical conclusion for coaches and teachers of this public that must consider the chronological age, different sex and BMI patterns at the time of exercise prescription. It is important to note that all systematic reviews focused on specific outcomes such as MF [35,36], CRF [10], health [37,38] and, to our knowledge, no review with meta-analysis presented more than one component (MF (strength and power), CRF and maximum speed) with different exercise training methods. Thus, the effects of physical and sports training on physical fitness components have been controversial, which makes it difficult to identify and prescribe effective physical exercise strategies for the pediatric population. Therefore, the aim of this review and meta-analysis is to explore the effects of different physical training prescriptions on the physical fitness of children and adolescents of different ages, sex and BMI patterns on training variables, using MF, CRF and maximum speed as result indices.

5.2 Materials and Methods

This systematic review was conducted using a predetermined protocol established according to the recommendations of the Cochrane Handbook[39] and was previously registered at the international prospective register of systematic reviews (PROSPERO number registration CRD42021266583) and available in: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42021266573). The results are reported in accordance with the PRISMA 2020 (PRISMA Statement)[40] Supplementary Material 1).

5.2.1 Eligibility criteria

Original articles published in journals or "ahead of print" were eligible for consideration. The search included no time or language restrictions. Only eligible full texts in English, Portuguese, or Spanish were considered for review. Studies were considered eligible for inclusion if provided relevant information on PICOS strategy (participants, interventions, comparators, outcomes, and study design) and met the following inclusion criteria: (1) participants: children and adolescents aged 7-17 years; (2) interventions: all types of structured and supervised physical activity intervention; (3) comparator: control groups that did not receive exercise intervention; (4) outcome: at least one evaluation of physical fitness (muscular strength, cardiorespiratory fitness, muscular power and speed); (5) study design: clinical trials (randomized or not) with pre- and post-measures. The exclusion criteria were as follows: (1) trials contained adults; (2) interventions targeted specific groups of children, such as those mental illness or disability; (3) young athletes; (4) the physical activity involved using smart devices, such as mobile phones or videogames; (5) control group performed an intervention (physical education + exercise); (6) duplicate publications or sub studies of included trials.

5.2.2 Information Source

A search for articles was performed in September 2021 and updated in July 2022 using the following electronic databases: MEDLINE (accessed by PubMed), Cochrane Library, Embase, and Scopus. The abstracts of these articles were checked for the relevant inclusion criteria, and, if necessary, the full text was investigated.

5.2.3 Search Strategy

The search terms included “children”, “adolescents”, “strength training”, “aerobic exercise”, “plyometric exercise”, “sport”, “muscular fitness”, “cardiorespiratory fitness”, “sprint” and related entry terms. The complete “MEDLINE” search strategy is described in the Supplementary Material 2 (available online). The records identified were PubMed (n=3391), Cochrane Library (n=5973), Embase (n=956) and Scopus (n=1516)

5.2.4 Selection Process and Data Extraction Process

The titles and abstracts of retrieved articles were independently evaluated by 3 investigators (C.D.F.P., N.C.B, and S.D.C.L.). One reviewer (C.D.F.P.) independently screened all studies and two reviewers independently screened a half of the studies (N.C.B. and S.D.C.L.), both in the selection of studies and in the data extraction. The reviewers were not blinded to authors, institutions, or manuscript journals. Abstracts that did not provide enough information regarding the inclusion and exclusion criteria were retrieved for full-text evaluation. Reviewers independently evaluated full-text articles and determined study eligibility. Disagreements were resolved by consensus, and if any disagreement persisted, it was resolved with a third reviewer (C.D.F.P.). To avoid possible double counting of participants included in more than one report by the same authors or working groups, the participant recruitment periods were evaluated, and if necessary, authors were contacted for clarification. The corresponding author was contacted as needed to obtain data not included in the published full-text report. A standardized form was used for data extraction, which was presented to the reviewers, and they should describe the author and year of the article. subsequently, the total number of participants and their characteristics (gender, age, body mass, height, %BF, FFM and BMI) were described when they had this information. The characteristics of the interventions should be described with the type of exercise performed, duration of follow-up, duration of session, intensity, and weekly frequency. Finally, the results should be extracted for the exercise and control groups. The outcomes of interest extracted were muscular strength (Kg), cardiorespiratory fitness ($ml.kg^{-1}.min^{-1}$), muscular power (*countermovement jump* – CMJ) and maximum aerobic speed (MAS – $km.h^{-1}$). Studies that presented other units of measurement were selected, but not described in the statistical analysis due to the choice of using gold standard tests to present the results. The same 3 reviewers (C.D.F.P., N.C.B and S.D.C.L.) who screened the articles, conducted data extraction in an independent way. Disagreements were resolved by consensus or by the reviewer (C.D.F.P.).

5.2.5 Assessment of Methodological Quality

The same two reviewers (C.D.F.P and S.D.C.L.) who independently performed the study selection and data extraction and a third reviewer (J.B.M) assessed the methodological quality of the included studies. For this, the tool for the assessment of study quality and reporting in exercise training studies, as proposed by Smart et al. (2015)[41]. As such, the assessment included the following items: (a) specified eligibility criteria; (b) specified randomization; (c) allocation concealment, that is, patients are unaware of which group they would be allocated; (d) similar groups at baseline, with no significant difference after randomization; (e) blinding of outcome evaluators; (f) outcome measures evaluated in at least 85% of patients; (g) intention-to-treat analysis; (h) reporting of statistical comparison between groups; (i) point measures and measures of variability for all reported outcomes; (j) monitoring of activities in the control group; (k) whether relative exercise intensity remained constant; (l) relative volume and energy expenditure of the exercise. The quality score of the papers were based on terciles, where 0 to 5 points were considered low quality, 6 to 10 points were considered medium quality, and 11 to 15 points were considered high quality. This instrument was chosen because it is specific for interventions with physical exercise.

5.2.6 Statistical Analysis

The pooled effect estimates were computed from the change scores between the baseline and the end of intervention, their standard deviations (SDs), and the number of participants in each group. Data from intention-to-treat analyses were entered whenever available in the included studies. The authors were contacted through e-mails for unreported data, and if no answer returned or if the data requested were not available, the studies were excluded. The results are presented as standardized mean differences (a measure of effect, recommended to be used when the study report efficacy of an intervention on continuous measurements, especially in cases of different methods of measurement) and calculations were performed using random effects models. Statistical heterogeneity of treatment effects among studies was evaluated by Cochran Q test and the I^2 inconsistency test; it was considered that values >50% indicated high heterogeneity[39]. Forest plots were generated to present the pooled effects and standardized mean differences with 95% confidence intervals (CIs). In addition, sensitivity analyses were conducted to investigate the possible influence of sex (male, female or both sexes) and type of training (strength training, aerobic training, HIIT, combined training, and sports) on adaptations achieved. Meta-regression analyses were performed to investigate potential moderators: mean age (years), BMI ($kg.m^{-2}$), follow-up duration (weeks), weekly frequency (number of sessions per week), and session duration (min). Values of $p<0.05$ were considered statistically significant. All analyses were performed using OpenMeta Analyst Software, version 10.10 [42].

5.3 Results

5.3.1 Studies Selection

The search of databases yielded a total of 11837 citations. After adjusting for duplicates, 9285 studies remained. Of these, 8967 were discarded because after reviewing the titles and abstracts it appeared that these papers did not meet the eligibility criteria. The full texts of the remaining 318 citations were examined in more detail. It appeared that 238 studies did not meet the inclusion criteria. Thus, 80 studies [43–109] met the inclusion criteria and were included in the quantitative analysis (Figure 1). No additional studies were identified by checking the references of the included papers. No relevant unpublished studies were obtained.

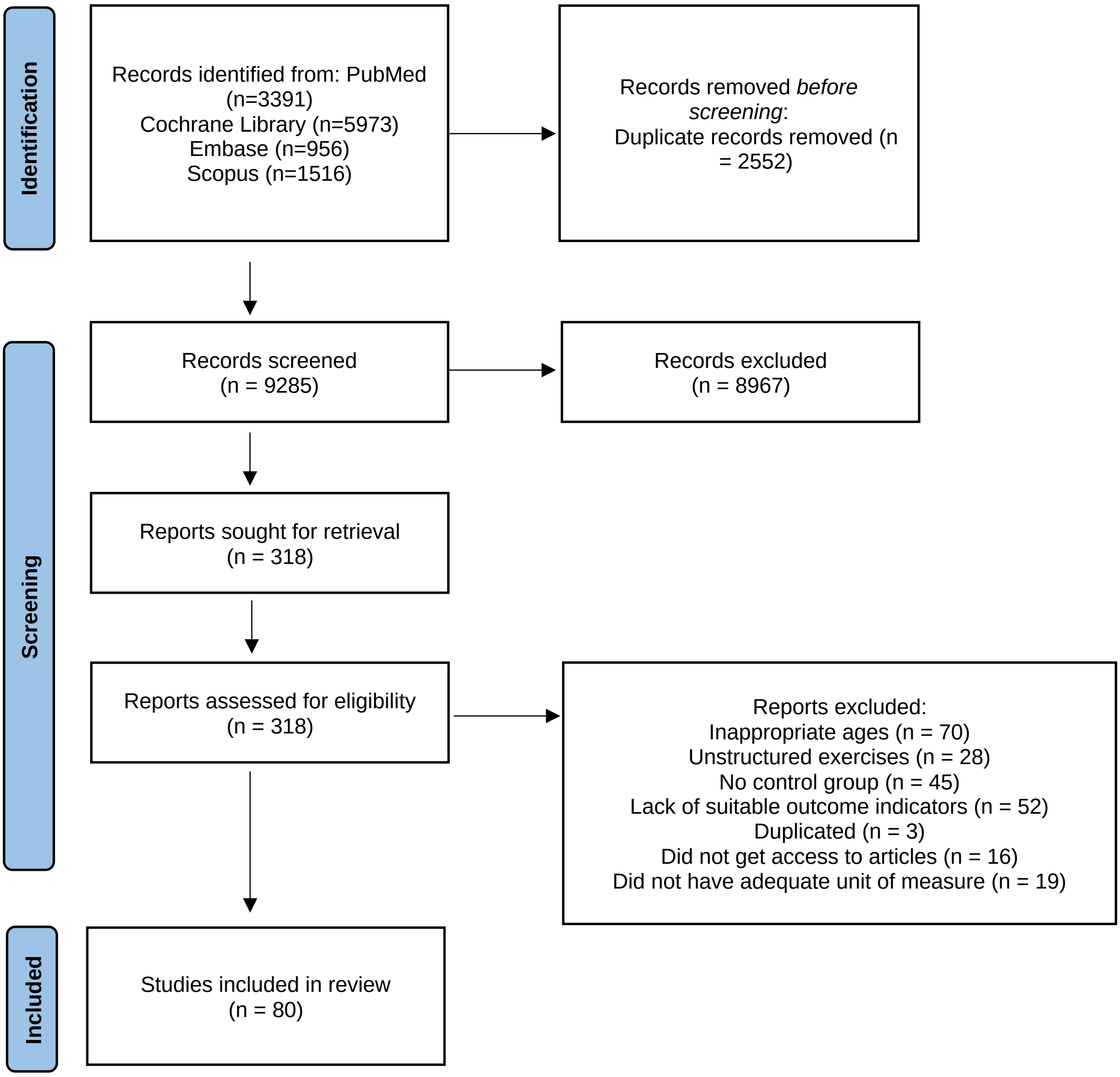


Figure 1 — Flowchart of number of articles retrieved during the literature search and study selection.

5.3.2 Studies Characteristics

In total, 5769 participants were included in the meta-analyze. Among these, 2894 were included in the exercise group and 2875 participants were included in the control groups. Of these, 65% were studies with both sexes, 22.5% were only boys and 12.5% only girls. Considering only quantitative studies that presented "MF – muscular strength" was included 297 children or adolescent in exercise group, while 241 were included in the control group. A total of 43.75% of the studies analyzed both sexes, 43.75% analyzed only boys, whereas 12.5% analyzed only girls. In 75% of studies, participants were classified by normal BMI, and 25% were overweight or obese children.

For the CRF outcome a total of 2273 children or adolescent was included in exercise group, while 2340 were included in the control group. A total of 76.7% of the studies analyzed both sexes, 16.3% analyzed only boys, whereas 7.0% analyzed only girls. In 44.2% of studies, participants were classified by normal BMI, 34.9% were overweight or obese children and 20.9% of the studies did not provide this information. For the "MF – muscular power" outcome was included 220 children or adolescent in exercise group, while 225 were included in the control group. A total of 46.2% of the studies analyzed both sexes, 23.1% analyzed only boys, while 30.7% analyzed only girls. In 53.8% of studies, participants were classified by normal BMI, 15.4% were overweight or obese children and 30.8% of the studies did not provide this information. For the MAS outcome was included 104 children or adolescent in exercise group, while 71 were included in the control group. A total of 83.3% of the studies analyzed both sexes, 16.7% analyzed only girls and no study analyzed only boys. In 33.3% of studies, participants were classified by normal BMI, 33.3% were overweight or obese children and 33.3% of the studies did not provide this information.

5.3.3 Intervention Characteristics

The studies selected to selected to "MF – muscular strength" analyzed children and adolescents from strength training interventions, concurrent training and sports. The selected studies with strength training intervention were carried out during a period between 8 and 20 weeks, with a weekly frequency of 2 to 3 times a week. Regarding the duration of the session, the average of the sessions was 30 to 60 minutes, and the intensity controlled by the rating of perceived exertion (BORG scale 15 - 18), percentage of 1RM (62-97%), percentage of 10RM (50-100 %) and 6-20RM. The selected studies with concurrent training intervention were carried out during a period between 8 and 12 weeks, with a weekly frequency of 3 times a week. Regarding the duration of the session, the average of the sessions was 60-70 minutes and the intensity was low-moderate for aerobic exercises, which could be controlled by maximum heart rate (70-95% HR_{max}) or VO_{2peak} (50-85%) while strength training was performed with an intensity of 8-10RM. Interventions with sports practice were carried out for 12 or 16 weeks, with a weekly frequency of 3 times a week, the duration of the session was 50-60 minutes, and the intensity was above 90% of HR_{max}.

The studies selected to analyze the CRF were classified according to moderate-intensity aerobic activities (treadmill, bicycle, running or jumping rope), which had an intervention duration between 7 and 18 weeks, performed 3 and 4 times a week. The duration of the sessions ranged from 30 to 63 minutes and the intensity varied between 50-80% VO_{2peak}, 70-95% HR_{max} and >70% of the maximum aerobic speed.

Interventions with concurrent training were carried out between 8-12 weeks, with a weekly frequency of 2-4 times a week. The duration of the session was between 20-90 minutes and the intensity was controlled by maximum aerobic speed (>70%) and 50-85% of VO_{2peak}, while for strength training the intensity was between 70-80% 1RM. Sports practices were carried out between 8 weeks and up to 2 years of intervention, with activities being carried out three times a week to daily. Session durations ranged from 20 to 80 minutes and the intensity was controlled to be >78% HR_{max}. Finally, studies that performed a HIIT intervention lasted from 7 to 12 weeks, being practiced between 1 and 3 times a week. Sessions lasted from 16 to 60 minutes, with intensity controlled by maximal aerobic velocity (>100%), HR_{max} (85-95%) and VO_{2peak} velocity (100%).

For muscular power, studies selected analyzed strength training lasting between 8 and 10 weeks and activities were performed two or three times a week. The sessions lasted from 45 to 90 minutes and intensity was controlled based on maximum repetitions (1RM, 6 or 10RM) or maximum aerobic speed. The study that carried out concurrent training (plyometrics on the trampoline + strength training) lasted four weeks with 45-minute sessions and a weekly frequency of three times a week. The studies that performed HIIT intervention had intervention duration between 7 and 12 weeks and weekly frequency of three times a week. The sessions lasted 30 minutes and the intensity was controlled based on HR_{max} or VO_{2peak} velocity.

All studies that analyzed the maximum aerobic speed performed a HIIT intervention lasting between six and 12 weeks and weekly frequency ranging from two to three times a week. The sessions lasted from six minutes to one hour and the intensity was measured through the maximum aerobic speed (>70%).

5.3.4 Methodological Quality of the Included Trials

Details about the general score in the TESTEX scale is in supplementary material 3 (table 1, 2, 3, and 4). Overall, the studies included in this review were of medium quality (between 5 and 10 points on the TESTEX scale). Studies with “MF – muscular strength”[44,47–58,110–112] outcomes (supplementary table 1) were mostly of medium quality (9 studies scored between 7 and 10). Only three were rated high-quality. The best-evaluated criteria were the “presentation of results for comparison within and between groups” and the “volume and intensity prescription of exercises in the intervention are described”. However, most of the studies did not carry out an allocation and/or blinded assessment, as well as only three studies carried out some type of monitoring of the control group.

Studies with VO_{2max} [44,52,56,59–89,92–97,106,109,111,112] results were mostly of medium quality (supplementary table 2). Only seven were classified as high quality (scored between 11 and 14). In these studies, the best-evaluated criteria were equality between the intervention and control groups at baseline, presentation of results for comparison within and between groups, and volume and intensity prescription of exercises in the intervention. However, most studies did not perform allocation and/or blind assessment, as well as only three studies performed some type of monitoring of the control group. Furthermore, only six of the 45 studies performed intention-to-treat analysis.

Studies with "MF – muscular power" [60,87,90,98–106,110] results were mostly of medium quality (10 studies scored between 6 and 10) (supplementary table 3). In this case, no study was of low quality. In these studies, the best evaluated criteria were the equality between the intervention and control groups at baseline, and the process of sample randomization, in addition to the presentation of results for comparison within and between groups, and volume and intensity prescription of exercises in the intervention. However, none of the studies did not perform blind allocation, as well as perform intention-to-treat analysis.

All studies with maximal aerobic speed [62,75,82,107,108,113] results were of average quality (6 studies scored between 6 and 10) (supplementary table 4). In these studies, the best-evaluated criteria were the constant progression during the intervention and the volume and intensity prescription for the intervention exercises. As in the previous results, in this case, all studies did not perform blinded allocation, blinded evaluation, intention-to-treat analysis, and the monitoring of the control group.

5.3.5 Effectiveness of Supervised Physical Exercise on Muscular Fitness – Muscular Strength

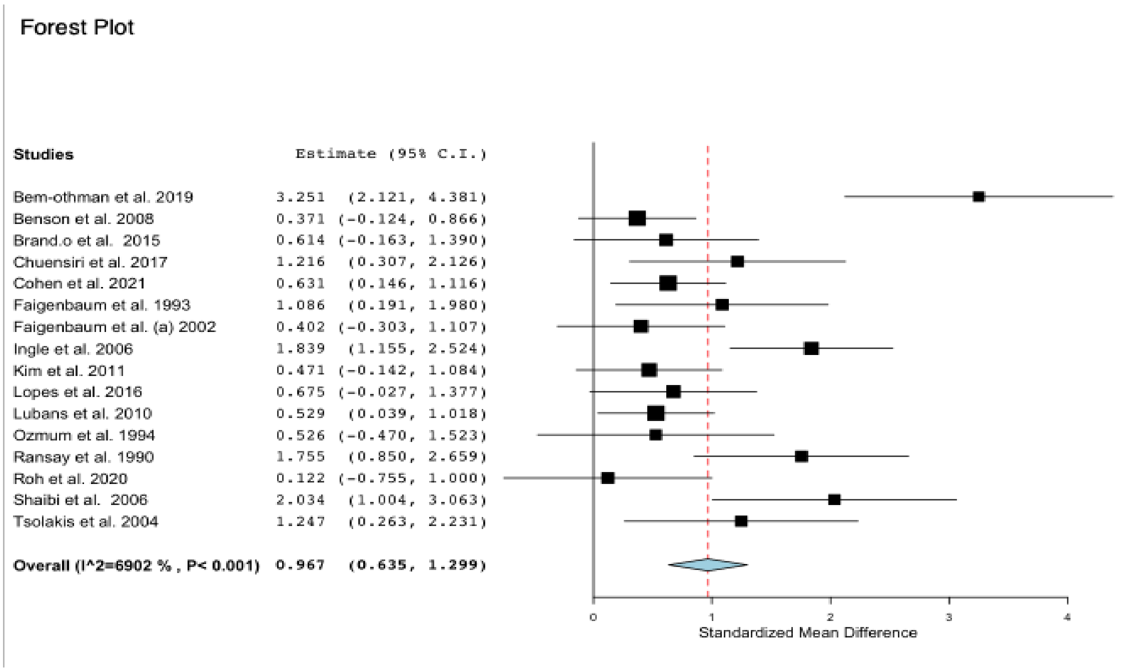
Data concerning MF were available from 16 studies, which compared exercise training interventions versus control groups in a total of 455 participants aged between 8 and 15 years old (figure 2). Regarding the intervention, 10 studies performed a strength training intervention, three studies performed a concurrent training and three studies performed sports training. Muscular strength was measured using repetition maximum (RM) (1RM, 6RM or 10RM) of upper-lower body strength with bench press, elbow flexors, squats, leg press or knee extension. The exercise intervention was associated with an increase in muscular strength compared with no intervention (ES: 0.967; 95% CI, 0.635 to 1.299; $P < 0.001$; I^2: 69%). Children and adolescents who exercise have experienced an improvement of approximately 16.1 kg in muscular strength compared with controls who did not exercise.

Regarding the subgroup analysis the sex of participants can impact the magnitude of gains in strength. According to the seven studies that analyzed only boys, physical exercise can increase muscular strength by approximately 20 kg (ES: 1.67; 95% IC, 0.911 to 2.440; P<0.001; I^2: 76%). In girls, two studies analyzed muscular strength and exercise can impact an increase of approximately 25 kg (ES: 0.55; 95% IC, 0.097 to 1.021; P<0.018; I^2: 0). On the other hand, seven studies analyzed both sexes and muscular strength can increase approximately 8.3 kg (ES: 0.59; 95% IC, 0.364 to 0.816; P<0.001; I^2: 0%).

Additionally, regarding the subgroup analysis considering the type of training, studies with strength training intervention (ES: 1.073; 95% CI, 0.612 to 1.533; P<0.001; I2: 74%) result in an increase of 21.3 kg in the magnitude of the muscular strength, as well as combined training (strength + aerobic) (ES: 1.054; 95% CI, 0.255 to 1.853; P<0.010; I2: 72%) which provides an increase of 21 kg. On the other hand, studies with sports (ES: 0.573; 95% CI, 0.015 to 1.132; P<0.044; I2: 34%) result in an increase of 6.5 kg in strength magnitude.

According to the results of meta-regression analysis the longer the duration of the session the greater the increases in muscular strength (β: 0.041; 95% CI; 0.014 to 0.069; P= 0.003). However, mean age, BMI, weekly frequency, and follow-up (weeks) were not associated with improvements in strength (table 1).

Figure 2: Standardized mean differences of "MF – muscular strength" in intervention versus control group (no intervention)



Note: CI: confidence interval

5.3.6 Effectiveness of Supervised Physical Exercise on Cardiorespiratory Fitness

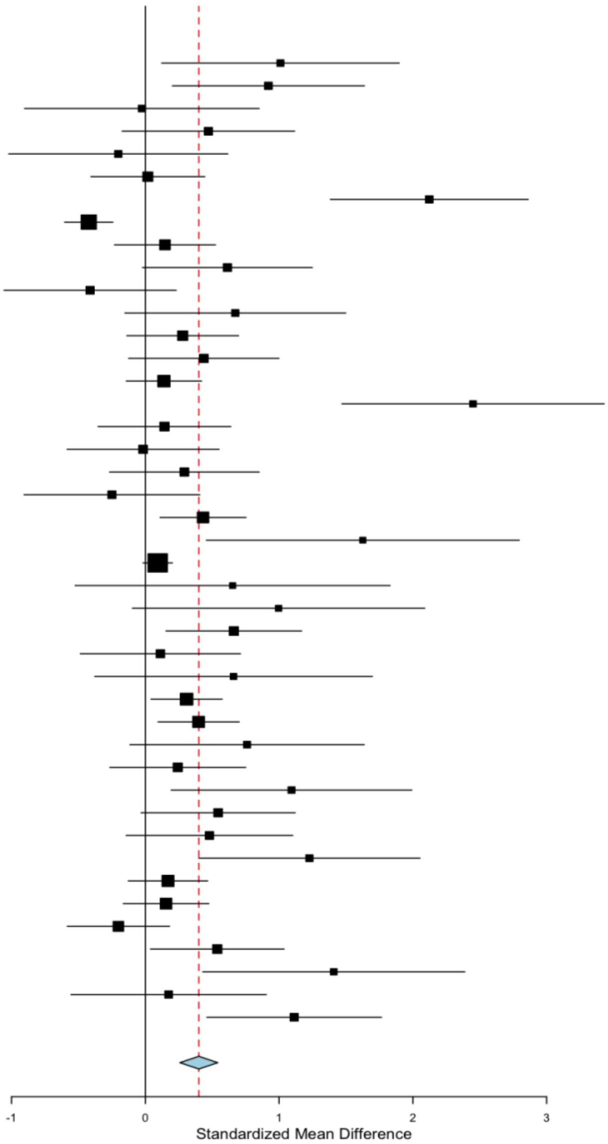
Data concerning CRF were available from 43 studies, which compared exercise training interventions versus control groups in a total of 4363 participants aged between 7 and 17 years old (figure 3). Regarding the intervention, ten studies performed aerobic training, five studies performed a strength training intervention, seven studies performed a concurrent training, fourteen studies performed sports training and five studies performed HIIT. CRF was measured using maximum or peak oxygen consumption (VO_{2max} or VO_{2peak}). The exercise group was associated with an improvement in CRF compared with no intervention (ES: 0.400; 95% CI, 0.258 to 0.542; P <0.001; I^2: 74%). Children and adolescents who exercise have experienced to improvement of approximately 2.12 $ml.kg^{-1}.min^{-1}$ in VO_{2max} compared with controls who did not exercise.

Regarding the subgroup analysis, the sex of participants can impact the magnitude of gains in CRF. According to the seven studies that analyzed only boys, physical exercise can increase CRF by approximately 1.8 $ml.kg^{-1}.min^{-1}$ (ES: 0.378; 95% IC, 0.169 to 0.586; P<0.001; I^2: 0%). Studies with both sex (n=33) physical exercise can increase CRF by approximately 2.2 $ml.kg^{-1}.min^{-1}$ (ES: 0.395; 95% IC, 0.222 to 0.567; P<0.001; I^2: 78%). However, three studies analyzed only girls and exercise were not associated with an increase in magnitude of CRF (ES: 0.669; 95% IC, -0.024 to 1.361; P=0.059; I^2: 79%).

Furthermore, in subgroup analysis of type of training, studies with intervention with aerobic training (n=11) showed a significant increase in magnitude of CRF (ES: 0.514; 95% IC, 0.220 to 1.808; P<0.001; I^2: 66%), resulting in an increased of 3.11 $ml.kg^{-1}.min^{-1}$. In addition, studies with sports (ball games, soccer, taekwondo, dance, and *capoeira*) (n=14) showed a significant increase in magnitude of CRF (ES: 0.271; 95% IC, 0.148 to 0.394; P<0.001; I^2: 15%), resulting in an increased of 2.08 $ml.kg^{-1}.min^{-1}$. Studies with HIIT (n=6) training also show a significant difference in magnitude of CRF (ES: 0.668; 95% IC, 0.333 to 1.003; P<0.001; I^2: 29%) resulting in an increased of 3.54 $ml.kg^{-1}.min^{-1}$. However, exclusive strength training (n=5) (ES: 0.440; 95% IC, -0.460 to 1.341; P=0.338; I^2: 93%) and combined training (strength + aerobic) (n=8) (ES: 0.360; 95% IC, -0.054 to 0.775; P=0.089; I^2: 77%) did not show significant increase in CRF adaptations. The grater the BMI of participants, the greater the magnitude of improvement (β: 0.048; 95% CI; 0.048 to 0.081; P= 0.004;). However, mean age, weekly frequency, duration of session, and follow-up (weeks) were not associated with improvements in this outcome (table 1).

Figure 3: Standardized mean differences of CRF in intervention versus control group (no intervention)

Studies	Estimate (95% C.I.)
Chuensiri et al. 2017	1.010 (0.123, 1.897)
Lopes et al. 2016	0.920 (0.202, 1.638)
Roh et al. 2020	-0.026 (-0.902, 0.851)
Chae et al. 2010	0.472 (-0.173, 1.116)
Ignico et al. 1995	-0.202 (-1.021, 0.617)
Alves et al. 2015	0.019 (-0.407, 0.444)
Marta et al. 2013	2.123 (1.384, 2.861)
Kennedy et al. 2017	-0.423 (-0.603, -0.242)
Almeida et al. 2020	0.147 (-0.230, 0.524)
Wang et al. 2018	0.614 (-0.020, 1.248)
Lee et al. 2010	-0.413 (-1.056, 0.231)
Tan et al. 2016	0.673 (-0.153, 1.498)
Alves et al. (a) 2016	0.279 (-0.138, 0.697)
Baquet et al. (a) 2002	0.437 (-0.125, 0.999)
Barbeau et al. 2007	0.139 (-0.142, 0.420)
Bem-Ounis et al. 2010	2.449 (1.469, 3.429)
Benson et al. 2008	0.143 (-0.353, 0.639)
Berntsen et al. 2010	-0.017 (-0.584, 0.551)
Carrel et al. 2005	0.292 (-0.267, 0.851)
Crouter et al. 2015	-0.250 (-0.906, 0.407)
Gracia-Hermoso et al. 2020	0.432 (0.110, 0.753)
Hamilia et al. 2017	1.626 (0.456, 2.795)
Harrel et al. 1996	0.093 (-0.018, 0.203)
Hergenroeder et al. 1993	0.653 (-0.524, 1.830)
Landt et al. 1985	0.996 (-0.097, 2.089)
Mandigout et al. 2002	0.662 (0.155, 1.169)
Marta et al. (b) 2013	0.113 (-0.486, 0.711)
Meucci et al. 2013	0.660 (-0.378, 1.697)
Nogueira et al. 2017	0.309 (0.043, 0.575)
Resaland et al. 2017	0.398 (0.095, 0.702)
Rosenkranz et al. 2012	0.761 (-0.115, 1.636)
Seabra et al. 2016	0.243 (-0.265, 0.751)
Song et al. 2012	1.093 (0.194, 1.992)
Vajda et al. 2007	0.544 (-0.032, 1.120)
Baquet et al. (b) 2010	0.480 (-0.143, 1.102)
Brand.o et al. 2015	1.227 (0.400, 2.053)
Davis et al. 2020	0.170 (-0.127, 0.467)
Davis et al. (a) 2012	0.155 (-0.165, 0.475)
Fairclough et al. 2016	-0.201 (-0.583, 0.181)
Ingul et al. 2018	0.538 (0.039, 1.037)
Kelly et al. 2004	1.409 (0.429, 2.388)
Lambrick et al. 2015	0.174 (-0.555, 0.904)
Racil et al. 2016	1.113 (0.460, 1.765)
Overall (I^2=7445 %, P< 0.001)	**0.400 (0.258, 0.542)**



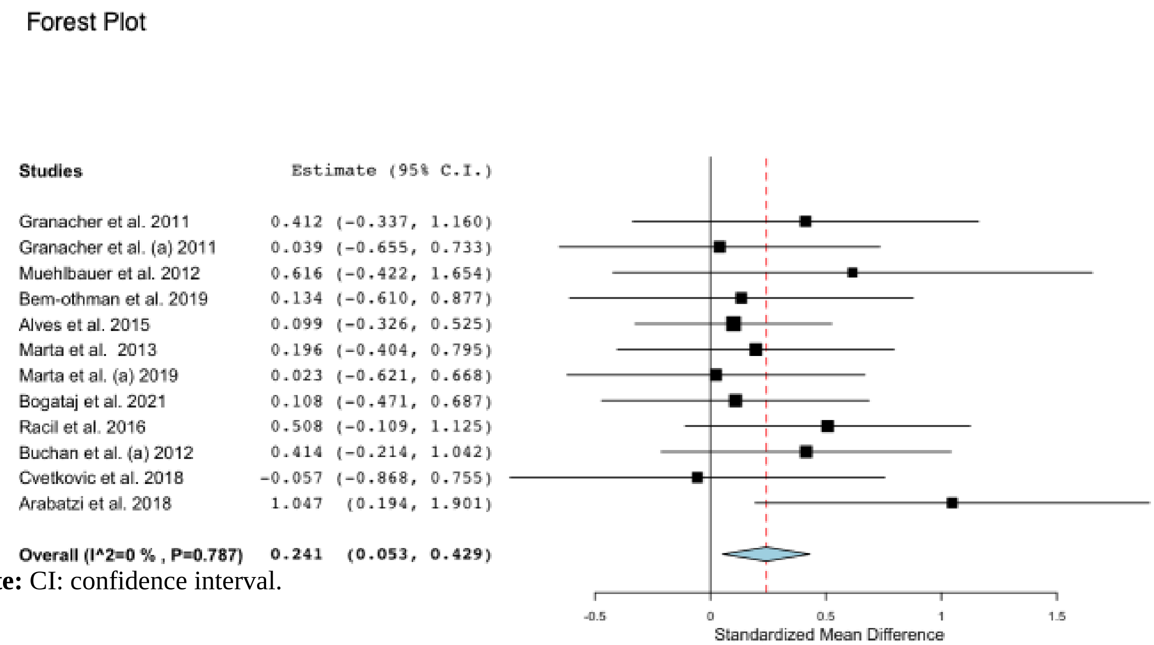
Note: CI: confidence interval.

5.3.7 Effectiveness of Supervised Physical Exercise on Muscular Fitness – Muscular Power

Data regarding muscular power variables were available from 12 studies, which compared exercise training interventions *versus* control groups in a total of 445 participants aged between 8 and 17 years old (figure 4). Regarding the intervention, seven studies performed a strength training intervention, one studies performed a concurrent training, three studies performed HIIT and two studies performed sports training. In all studies muscular power was measured using CMJ. The exercise intervention was associated with an improvement in jumping height in 1.5cm (ES: 0.241; 95% CI, 0.053 to 0.429; P =0.012; I^2: 0%) compared to control group.

Regarding the subgroup analysis considering sex, studies with intervention with boys and girls in the same group (n=6) (ES: 0.292; 95% IC, 0.050 to 0.535; P=0.018; I^2: 0%) increased the magnitude of jumping height in 1.6 cm. However, studies with only boys (n=3) (ES: 0.037; 95% IC, -0.381 to 0.455; P=0.213; I^2: 0%) or only girls (n=4) (ES: 0.295; 95% IC, -0.127 to 0.717; P=0.171; I^2: 0%) were not associated with an increase in magnitude of jumping height. Additionally, in sub-group analyses of type of training, studies did not show significant increase in jumping height with only strength training (n=7) (ES: 0.189; 95% IC, -0.102 to 0.481; P=0.203; I^2: 0%), combined training (n=2) (ES: 0.498; 95% IC, -0.419 to 1.416; P=0.287; I^2: 73%), and HIIT (n=3) (ES: 0.332; 95% IC, -0.018 to 0.682; P=0.063; I^2: 0%). Sports intervention could not enter the analysis due to the low number of studies (n=2). Mean age, BMI, weekly frequency, duration of session and follow-up (weeks) were not associated with improvements in jumping height (Table 1).

Figure 4: Standardized mean differences of "MF – muscular power" in intervention versus control (no intervention).



Note: CI: confidence interval.

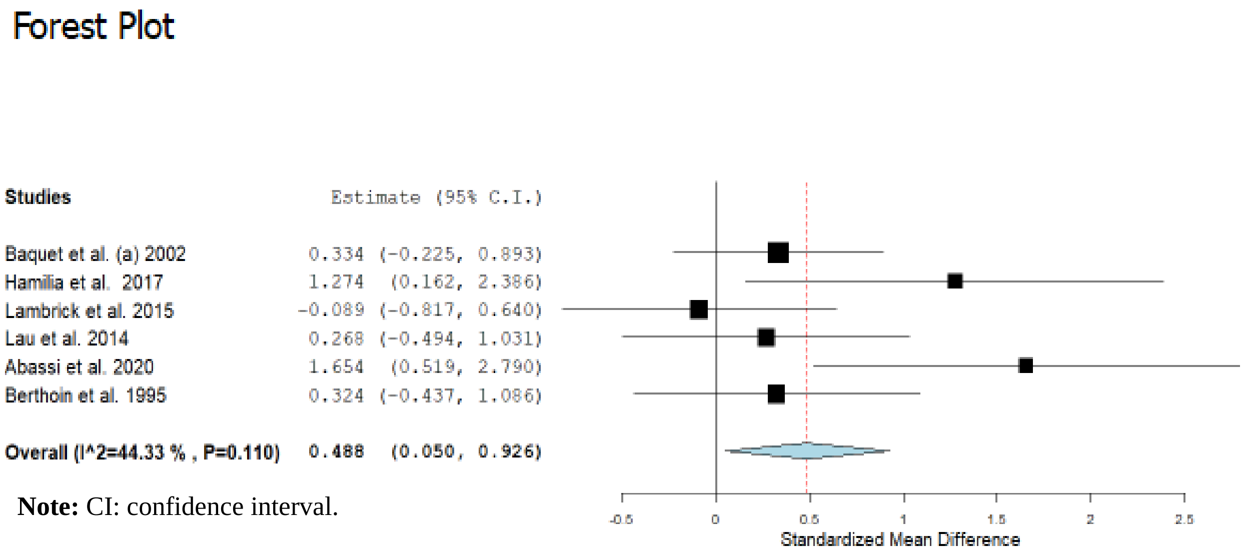
3.1.8 Effectiveness of Supervised Exercise Training in Maximal Aerobic Speed

Data regarding maximal aerobic speed variables were available from 6 studies, which compared exercise training interventions *versus* control groups in a total of 175 participants aged between 9 and 17 years old (figure 5). Regarding the intervention, all six studies performed a HIIT intervention. In all studies, was measured using MAS. The exercise group was associated with an improvement in magnitude of MAS in 0.59 $km.h^{-1}$ (ES: 0.048; 95% CI, 0.050 to 0.026; P =0.029; I^2: 44%) compared to control group.

Regarding the subgroup analysis considering sex, studies with intervention for boys and girls in the same group did not show a significant change of magnitude of the MAS of children and adolescents (n=5) (ES: 0.317; 95% IC, -0.013 to 0.647; P=0.060; I^2: 1%). When separately boys (n=0) and girls (n=1) the analyzes were not possible due to the small number of studies. In addition, when analyzing the type of training, all 6 studies performed an intervention with HIIT, and only this method could be analyzed showing a significant increase of 0.59 $km.h^{-1}$ in the magnitude of the MAS in children and adolescents who perform physical exercise (ES: 0.488; 95% CI, 0.050 to 0.926; P =0.02; I^2: 44%).

Meta-regression analysis of age (β: 0.118; 95% CI; 0.003 to 0.232; P= 0.004) and BMI (β: 0.172; 95% CI; 0.052 to 0.292; P= 0.005) are associated with increase in magnitude of gains in speed. In this way, older children or adolescents are more likely to increase their MAS with physical training than younger children. In relation to BMI, children or adolescents who have a higher BMI are more likely to increase MAS. However, weekly frequency, duration of session, and follow-up (weeks) were not associated with improvements in this outcome (table 1).

Figure 5: Standardized mean differences of maximal aerobic speed in intervention versus control (no intervention).



Note: CI: confidence interval.

Table 1: Meta-regression of Moderators of the Physical Fitness

Outcome/moderator	Number of study estimates	β	95% IC	P value
Muscular Fitness – Muscular Strength				
Mean age	16	-0.071	-0.251 to 0.110	.44
BMI	16	-0.015	-0.129 to 0.099	.79
Weekly frequency	16	0.042	-0.407 to 0.490	.85
Session duration	16	0.041	0.014 to 0.069	**.03**
Follow-up duration (weeks)	16	0.030	-0.060 to 0.120	.50
Aerobic Training				
Mean age	43	0.074	-0.008 to .156	.78
BMI	43	0.048	0.016 to 0.081	**.04**
Weekly frequency	43	0.016	-0.115 to 0.146	.81
Session duration	43	0.003	-0.002 to 0.007	.26
Follow-up duration (weeks)	43	-0.005	-0.014 to 0.004	.27
Muscular Fitness – Muscular Power				
Mean age	12	-0.003	-0.074 to 0.067	.92
BMI	12	-0.020	-0.113 to 0.047	.67
Weekly frequency	12	0.223	-0.167 to 0.614	.26
Session duration	12	0.002	-0.009 to 0.013	.70
Follow-up duration (weeks)	12	-0.035	-0.139 to 0.069	.50
Maximal Aerobic Speed	6			
Mean age	6	0.118	0.003 to 0.232	**.04**
BMI	6	0.172	0.052 to 0.292	**.05**
Weekly frequency	6	0.325	-0.132 to 0.782	.16
Session duration	6	-0.001	-0.017 to 0.015	.86
Follow-up duration (weeks)	6	0.102	-0.030 to 0.234	.12

Bold denotes statistically significant difference ($p<0.05$). Abbreviations: BMI: body mass index; CI: confidence interval.

5.4 DISCUSSION

These meta-analyze examined the effectiveness of different types of exercise training (strength training, aerobic training, HIIT and sports) on physical fitness parameters (MF (strength and power); CRF, MAS) of children and adolescents. In addition, explored the effects of age, sex, BMI, and exercise training variables on physical fitness. The main results of this study demonstrate that children and adolescents who perform structured and supervised exercise training have significantly higher values of physical fitness compared to their peers who did not perform any training. Meta-regression analyses identify that MF, CRF, muscular power, and MAS are impacted by physical fitness's mediators such as weekly frequency, duration of the session and intervention, and type of training, as well as an individual's chronological age and BMI.

The evidence presented in this study can be applied in different context, such as diseases prevention and treatment, sports training, or school physical education. The prescription of structured physical exercise, which considers the specificities of the pediatric population, is essential for effective exercise training programs in several settings and can guide new research.

5.4.1 Muscular Fitness – Muscular Strength

Our results indicated that boys and girls who practice physical exercises with a focus on strength training, concurrent training (strength and aerobic), or sports participation (ball games or fights) can increase the magnitude of muscular strength when compared to individuals who only perform physical education or do not practice exercises. However, to optimize gains, sensitivity analyzes demonstrate that session duration is important. Long-term interventions of strength, concurrent, or sports training seem to have a greater impact on strength gains in children [49,57,111]. These results can be explained by the greater muscular stimulus during training with higher volume, in which there is a greater recruitment in the number of muscular fibers and motor units [114].

The literature clearly demonstrates the benefits that increased muscular strength provide to different special populations (children, elderly, and obesity people) [36,115,116]. The WHO [12] suggests that muscular strengthening should be carried out at least three times a week. Although we found no differences in weekly training frequency and follow-up duration, in this way the session duration (volume of training) seems to be the most appropriate way to improve muscular strength in children and adolescents.

Furthermore, strength gains are associated with better metabolic health [47] and several studies have reported interventions with childhood obesity [52,56,57,111,117]. Lopes et al. (2016) [118] and Shaibi et al. (2006)[57], for example, found that boys and girls can improve muscular strength and insulin sensitivity after a concurrent or strength training programs. In this way, Roh et al. (2020) [56] shows that sports such as taekwondo improve inflammation provide for obesity and muscular strength. The importance of these results is justified by recent reviews and meta-analysis [4,35,119], in which presents that muscular fitness (strength, endurance, and muscular power) is associated with lower obesity indicators and better cardiovascular and metabolism during childhood and adult life. However, different training methods can impact muscular strength gains.

Trying to analyze the different types structured and supervised exercise training programs, the magnitude of muscular strength gains differ in each methodology. Interventions that performed only strength training showed an increase of 21.3 kg in muscular strength, similar results to groups that performed concurrent training (+21 kg). On the other hand, analyses shows that sports interventions improve muscular strength in 6.5 kg. In sports the magnitude of improvement of muscular strength is smaller possibly because sports modalities use body weight and not an additional external overload in comparison to strength or concurrent training [50,106]. Furthermore, the specificity of the training during the tests and interventions may influence the adaptations, since the strength training and concurrent training interventions performed exercises similar to the assessments, unlike sports studies performed combat training (Taekwondo) [56,117] or HIIT (sprint cycling training) [112], and assessed leg strength with dynamometer. The increase of muscular strength (+16 kg) seems to be associated with the neuromuscular adaptations resulting from the training [48,50] that occur at all maturational stages. These mechanisms include changes in agonist-antagonist coactivation, increases in motor unit firing rates, and changes in the downward drive to motor neurons responsible for muscular contraction [120]. The answers are found in boys and girls, in which they can increase neuromuscular activity by 16.8% [54], bench press 1RM by 35%, and leg strength by 22% [55] after strength or concurrent training. Moreover, guidelines have shown that strength training for children and adolescents can be a safe and effective method to improve physical fitness [12,36].

5.4.2 Cardiorespiratory Fitness

Our results indicated that CRF is a highly responsive to training in children and adolescents. However, the sensitivity analysis demonstrates that the type of training chosen is essential to optimize gains.

In this way, it is fully acceptable that studies included in this review that proposed only strength training, for example, presented smaller effects than interventions with HIIT.

These results can be understood because aerobic fitness reflects the general capacity of the cardiorespiratory system to supply oxygen during sustained physical activity [121]. In this way, exercises of longer duration or intervals, but with high intensity, seem to stimulate greater adaptation in the body through vascular pathways [122]. Although the child has smaller proportions when it comes to the size of the heart, blood vessels, and lungs the training effects described in our study is explained by the priority of energy demand that children in general have, being more susceptible to interval and high intensity activities[29].

The benefits of adequate levels of CRF for improving the cardiometabolic, cognitive, and psychosocial health of children and adolescents have already been established[10]. However, these benefits can often be attenuated by other conditions such as overweight. Our results indicated that the effect of exercise training on CRF was dependent on BMI, in line with other reviews that demonstrate the strength of the relationship between these variables [37,123].

The VO_{2max} and the amount of adipose tissue accumulated in the body are both established predictors of cardiovascular disease (CVD such as hypertension), and morbidity and are also highly correlated with quality of live, morbidity, and mortality [124–126]. CRF has been inversely related to BMI [127,128] showing that overweight and obese adolescents tend to have a lower CRF and higher risk for cardiovascular diseases[129]. The importance of carrying out adequate exercise training, which produces significant effects on the body, is justified by a 15-year cohort study by Carnethon et al. (2003)[130] where young adults aged 18 to 30 years with lower CRF were more likely to develop diabetes, hypertension, and metabolic syndrome. Aerobic, HIIT, and sports training appear to be more effective to increase CRF than strength and combined training for children and adolescents.

5.4.3 Muscular Fitness – Muscular Power

Our results indicate that muscular power is a highly responsive to exercise training in children or adolescents of both sexes when compared to control group. These results can be explained due to the neural and muscular adaptations that occur with training, improving the maximum power output in a short time[131]. This answer is related to a greater activation of motor neurons, better activation, and synchronization of motor units, improve of elastic potential, and greater spinal excitability that are associated with increased in strength and, consequently, muscular power [131]. This is important for sports and health development influencing on physical fitness [4].

Muscular fitness (i.e., incorporation of phenotypes of muscular strength, including muscular power, maximum isometric and dynamic strength, and muscular endurance) is considered an important health predictor that should be improved during childhood. This directly impacts the risk reduction for metabolic diseases due to increase in muscular strength, muscular mass, and lower BMI value[4,132]. Although, in sensitivity analyses we did not find a significant response in different BMI or age of participants. Our results indicate that physical exercises (strength training, concurrent training and HIIT) are safe and can be practice for children or adolescents increasing the jumping height and muscular power. Recent meta-analyze have indicated that the improvement in MF contributes to a better basal metabolic response and greater muscle metabolic efficiency, improving fat oxidation, glucose uptake and transport due to better insulin sensitivity[90,133], and this can occur in all age groups, with pre- and post-puberty being more predisposed to improve jumping height in CMJ test, while mid-puberty has a small effect for trainability[134], according to our results that show that children and adolescents can improve your jumping height.

The improvements in MF are indifferent between the frequency of intervention, duration of sessions, or follow-up. This is according to Markovic et al. (2010)[131] that suggest that short-term intervention (6-15 weeks) can change muscular components and increase muscular power. Arabatzi et al. (2018)[98] showed that 4-weeks intervention increased vertical jumping performance in prepubertal children. Results like were established by Cvetkovic et al. (2018)[101] showed that 12-weeks soccer intervention was able to induce a moderate increase in CMJ in obese children. Our subgroup analysis also shows no difference between the type of exercise, indicating that strength training, concurrent training, or HIIT are responsible to increase jumping height. In obese adolescent girls who perform HIIT can increase of 5.6% in CMJ[99], similar responses were established in prepubescents who practice strength training, HIIT, or sports [60,106]. This seems to be due to the specificity of activities performed in interventions that requires the movement must be performed at high speed and explosiveness[103], using an anaerobic metabolism and the stretch-shortening cycle[135] as well as CMJ test. In soccer, activities such as sprints, jumps, and change of direction results in a moderate effect on muscular power in children[101]. Also, strength training and HIIT that performed squats and sprints results an increase in jumping height in CMJ test and muscular strength[90,103]. However, no study has analyzed continuous aerobic exercise, presuming that the increase found in CMJ height is a result of the better neural response that anaerobic exercise causes in neuromuscular system. These results show that all types of exercises should be performed by children and adolescents, so they can benefit from exercise by increasing MF in 1.5cm.

5.4.4 Maximal Aerobic Speed

Our results indicate that children and adolescents who perform physical exercise increase the magnitude of MAS gains when compared to the control group. These gains are directly linked to the type of training. All studies selected for this meta-analysis analyzed maximal speed from interventions with HIIT, showing that this type of training is efficient to improve MAS. These results are related to physiological adaptations induced by training, through increased VO_{2max} and running economy [62], resulting from better muscle oxidative capacity and mitochondrial adaptations that occur in HIIT practitioners [136,137]. Furthermore, executing high intensity running movements requires advanced motor skills[138], as it involves body and neural control for rapid force production, which indicates why adolescents have greater MAS gains compared to children. Berthoin et al. (1995)[107] found that adolescents of both sexes increased their MAS by around 5.5% after a 12-week intervention. These findings are of great relevance since, over the years, adolescents tend to reduce the practice of physical exercise and HIIT is considered a pleasant, dynamic, and short-term activity that can produce important physical gains for the transition between adolescence and adulthood.

MAS gains resulting from training are well established in the literature, because of a better CRF, metabolic and physiological adaptations that HIIT training causes in metabolism[136,139–141]. However, the transition among childhood, adolescence, and adult life is a period in which, depending on the lifestyle, an excessive accumulation of body fat can occur, developing overweight or obesity and increasing the risks for CVD. In our review, most of studies analyzed overweight or obese subjects and we found that subjects with higher BMI have a greater effect on the magnitude of MAS gains, having greater adaptations in response to training, regardless of weekly frequency, session duration, or follow-up duration. Hamila et al. (2017)[75] found in adolescents with a BMI of >29 kg/m^2 an increase in the MAS of 8.7%, with a concomitant increase in VO_{2max} of 14.1% after 8-weeks of intervention. In the same way, girls with a BMI of 33 kg/m^2 increased their MAS from 11.0 to 13.4 $km.h^{-1}$ after 12-weeks with improvement in insulin sensitivity, an important health marker[113]. On the other hand, children with a BMI of 23.7 kg/m^2 did not show a significant difference in MAS gains after 6-weeks of training (pre: 11.0 $km.h^{-1}$; post: 11.1 $km.h^{-}$

^{1})[82]. Thus, obese individuals seem to respond more to increase MAS, improving speed on a larger scale, possibly because they have a larger window of trainability when compared to overweight individuals[142].

Although we found no difference between the training variables (weekly frequency, session duration, or follow-up), the literature has shown the importance of intensity to improve health markers[143]. Thus, MAS appears to be an important marker for obesity control due to its relationship with CRF and CVD biomarkers. Thus, this review suggests the applicability of this measure through HIIT training to improve the health markers of the pediatric population through pleasant and beneficial training.

5.5 Strengths and Methodological Limitations

This review presents findings on the highest level of evidence regarding the effects of different training strategies on physical fitness of children and adolescents. First, this is the first systematic review with meta-analyze that analyzes more than one physical fitness component (MF: muscular strength and muscular power, CRF, and speed) combining age, BMI, and training variables. This enhances the literature, as it presents the type of training, weekly frequency, and session duration are necessary to improve the physical fitness of children and adolescents. Second, the gains found in the analyzes have a great social impact, as they indicate that regular physical exercise is important to increase physical fitness levels resulting in best health markers.

However, the present study has some limitations. One of the limitations of this study is related to the number of studies for muscular power and MAS variables, which limited the deeper analysis of different types of training for the present population. Second, despite the selected studies have a moderate methodological quality, some studies did not have a description of the training periodization, not presenting the necessary data to calculate the volume of physical activity, which made the sensitivity analysis of the training variables difficult. Third, the lack of intensity control in the sessions is a general problem since the studies do not propose an intensity control and progression during the follow-up. Despite the consensus guidelines that children and adolescents perform activities of moderate-to-vigorous intensity, most of these data are missing, which leaves a gap on the appropriate exercise intensity for this population. Thus, studies of high methodological quality are important and should report the progression of intensity and volume of exercise sessions to deepen knowledge about training in children and adolescents and estimate the effects of exercise on physical fitness.

5.6 Conclusion

The meta-analysis results collectively indicated that the practice of supervised and structured physical exercise can improve the physical fitness of children and adolescents, in addition, the sex and BMI of the subjects should be considered when prescribing the exercise. For the MF, we suggest that boys and girls can be impacted by the increase in strength through all types of exercise, however activities with muscular strength or combined training should be prioritized, as they present greater gains in long-lasting sessions. CRF can be impacted by the practice of supervised physical exercise through activities that require aerobic metabolism such as aerobic training, sports, or HIIT, and individuals with lower BMI are more impacted by cardiorespiratory gains. The increase in muscular power is also impacted by the practice of physical exercise with no difference between children and adolescents of both sexes and training variables. Finally, maximal speed is also impacted by physical exercise, and adolescents and individuals with higher BMI respond better to the intervention, increasing the maximum running speed. Recommendations for future research include carrying out interventions that control the intensity of physical exercise for children and adolescents, to improve knowledge about training variables and their relationship with cardiometabolic health, being able to prescribe the ideal dose of physical exercise for each component of physical fitness.

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5.8 Supplementary Material

5.8.1 Supplementary Material – 1 – Check list from PRISMA

Reporting checklist for systematic review (with or without a meta-analysis).
Based on the PRISMA guidelines.

		Reporting Item	Page Number
Title			
Title	#1	Identify the report as a systematic review	1
Abstract			
Abstract	#2	Report an abstract addressing each item in the PRISMA 2020 for Abstracts checklist	3
Introduction			
Background/rationale	#3	Describe the rationale for the review in the context of existing knowledge	6-7
Objectives	#4	Provide an explicit statement of the objective(s) or question(s) the review addresses	7
Methods			
Eligibility criteria	#5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses	8
Information sources	#6	Specify all databases, registers, websites, organisations, reference lists, and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted	9
Search strategy	#7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used	9
Selection process	#8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and, if applicable, details of automation tools used in the process	9 e 10
Data collection process	#9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and, if applicable, details of automation tools used in the process	10
Data items	#10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (for example, for all measures, time points, analyses), and, if	10

		not, the methods used to decide which results to collect	
Study risk of bias assessment	#11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and, if applicable, details of automation tools used in the process	10 e 11
Effect measures	#12	Specify for each outcome the effect measure(s) (such as risk ratio, mean difference) used in the synthesis or presentation of results	11
Synthesis methods	#13a	Describe the processes used to decide which studies were eligible for each synthesis (such as tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5))	11
Synthesis methods	#13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics or data conversions	11
Synthesis methods	#13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses	11
Synthesis methods	#13d	Describe any methods used to synthesise results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used	11
Synthesis methods	#13e	Describe any methods used to explore possible causes of heterogeneity among study results (such as subgroup analysis, meta-regression)	11
Synthesis methods	#13f	Describe any sensitivity analyses conducted to assess robustness of the synthesised results	11
Reporting bias assessment	#14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases)	n/a
Certainty assessment	#15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome	11
Data items	#10b	List and define all other variables for which data were sought (such as participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information	13
Results			
Study selection	#16a	Describe the results of the search and selection process, from the number of records	14

		identified in the search to the number of studies included in the review, ideally using a flow diagram (http://www.prisma-statement.org/PRISMAStatement/FlowDiagram)	
Study selection	#16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded	n/a
Study characteristics	#17	Cite each included study and present its characteristics	14 e 15
Risk of bias in studies	#18	Present assessments of risk of bias for each included study	16
Results of individual studies	#19	For all outcomes, present for each study (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (such as confidence/credible interval), ideally using structured tables or plots	17 a 23
Results of syntheses	#20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies	16
Results of syntheses	#20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (such as confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect	17 a 23
Results of syntheses	#20c	Present results of all investigations of possible causes of heterogeneity among study results	17 a 23
Results of syntheses	#20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesised results	17 a 23
Risk of reporting biases in syntheses	#21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed	n/a
Certainty of evidence	#22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed	17 a 23
Discussion			
Results in context	#23a	Provide a general interpretation of the results in the context of other evidence	25
Limitations of included studies	#23b	Discuss any limitations of the evidence included in the review	32
Limitations of the review methods	#23c	Discuss any limitations of the review processes used	32
Implications	#23d	Discuss implications of the results for practice, policy, and future research	33
Other information			

Registration and protocol	#24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered	8
Registration and protocol	#24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared	8
Registration and protocol	#24c	Describe and explain any amendments to information provided at registration or in the protocol	10
Support	#25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review	34
Competing interests	#26	Declare any competing interests of review authors	34
Availability of data, code, and other materials	#27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review	34

5.8.2 Supplementary Material 2 – Boolean search syntax

The following Boolean search syntax was used: ((child OR children OR kid OR teenager OR adolescent OR juvenile OR teens OR youth OR teen) AND ("exercise therapy" OR "resistance training" OR "exercise" OR "aerobic exercise" OR "strength training" OR "physical exercise" OR "Circuit-Based Exercise" OR "Plyometric Exercise" OR "Exercise Movement Techniques" OR "High-Intensity Interval Training" OR "sport*" OR "exercise training" OR "aerobic training" OR "endurance training" OR "weight training")) AND (Musc* OR fitness OR strength OR power OR "motor fitness" OR "motor skill" OR fit* OR "fitness" OR "cardiorespiratory fitness" OR "CRF" OR "strength" OR "muscular strength" OR "agility" OR "velocity" OR "speed" OR "sprint" OR "handgrip"). In addition, the following filters were activated: Clinical Trial and Randomized Controlled Trial. The search included no time or language restrictions. Only eligible full texts in English, Portuguese, or Spanish were considered for review.

5.8.3 Supplementary Material – 3 – Risk of bias evaluation

Supplementary table 1. Risk of bias evaluation by TESTEX tool of the **muscular strength** outcome studies.

	Study quality					Study reporting							
Study	Eligibility criteria specified	Randomization specified	Allocation concealment	Groups similar at baseline	Blinding of assessor	Outcome measures assessed in 85% of patients	Intention-to-treat analysis	Between-group statistical comparisons reported	Point measures and measures of variability for all reported outcome measures	Activity monitoring in control groups	Relative exercise intensity remained constant	Exercise volume and energy expenditure	**Total Score**
Ben-outhman et al. 2019	1 point	1 point	0 point	1 point	1 point	2 points	0 point	2 points	1 point	0 point	0 point	1 point	Medium quality
Benson et al. 2008	1 point	1 point	1 point	1 point	1 point	3 points	1 point	2 points	1 point	0 point	1 point	1 point	High quality
Brandão et al. 2015	1 point	1 point	0 point	1 point	0 point	2 points	0 point	1 point	1 point	0 point	1 point	1 point	Medium quality
Chuensiri et al. 2017	1 point	1 point	0 point	1 point	0 point	1 point	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Cohen et al. 2021	1 point	0 point	1 point	1 point	0 point	2 points	0 point	2 points	1 point	1 point	1 point	1 point	High quality
Faigembaum et al. 1993	1 point	0 point	0 point	1 point	0 point	2 points	0 point	1 point	1 point	0 point	1 point	1 point	Medium quality
Faigembaum et al. 2002	0 point	0 point	0 point	1 point	0 point	3 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Ingle et al. 2006	1 point	1 point	0 point	0 point	0 point	1 point	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Kim et al. 2011	1 point	1 point	0 point	0 point	0 point	0 point	0 point	0 point	1 point	0 point	0 point	1 point	Low quality
Lopes et al. 2016	1 point	0 point	0 point	0 point	0 point	2 points	0 point	2 points	0 point	0 point	1 point	1 point	Medium quality
Lubans et al. 2010	1 point	1 point	0 point	1 point	0 point	2 points	1 point	2 points	0 point	0 point	1 point	1 point	Medium quality
Ozmum et al. 1994	0 point	0 point	0 point	1 point	0 point	1 point	0 point	1 point	0 point	0 point	0 point	0 point	Low quality
Ransay et al. 1990	0 point	0 point	0 point	0 point	0 point	0 point	0 point	1 point	0 point	0 point	1 point	1 point	Low quality
Roh et al. 2020	1 point	1 point	0 point	1 point	0 point	0 point	0 point	2 points	1 point	1 point	0 point	0 point	Medium quality
Shaibi et al. 2006	1 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	1 point	1 point	1 point	High quality
Tsolakis et al. 2004	0 point	0 point	0 point	1 point	0 point	1 point	0 point	2 points	0 point	0 point	0 point	1 point	Low quality

0 point	1 point	2 points	3 points
Low quality	Medium quality	High quality	

Supplementary table 2. Risk of bias evaluation by TESTEX tool of the **VO_2** outcome studies.

	Study quality					**Study reporting**							
Study	Eligibility criteria specified	Randomization specified	Allocation concealment	Groups similar at baseline	Blinding of assessor	Outcome measures assessed in 85% of patients	Intention-to-treat analysis	Between-group statistical comparisons reported	Point measures and measures of variability for all reported outcome measures	Activity monitoring in control groups	Relative exercise intensity remained constant	Exercise volume and energy expenditure	**Total Score**
Almeida_ et al. 2020													
Alves et al. 2015													
Alves et al. 2016													
Almeida et al. 2020													
Baquet et al. 2002													
Baquet_et al. 2010													
Barbeau et al. 2007													
BenOunis et al. 2010													
Benson et al. 2008													
Berntsen et al. 2010													
Brandao et al. 2015													
Carrel et al. 2005													
Chae et al. 2010													
Chuensiri et al. 2018													
Crouter et al. 2015													
Davi et al. 2012													
Davis et al. 2020													
Fairclough et al. 2016													
Faude et al. 2010													
Garcia_Hermoso et al. 2020													
Hamila et al. 2017													
Harrel et al. 1996													
Hergenroeder et al. 1993													
Ignico et al. 1995													
Ingul et al. 2018													

Continued…

Kelly et al. 2004	1	1	0	1	0	0	0	2	0	0	1	1	Medium
Kennedy et al. 2017	1	1	0	1	0	2	1	2	1	0	1	1	High
Lambrick et al. 2015	0	1	0	1	1	3	0	2	0	0	1	1	High
Landt et al. 1985	1	1	0	1	0	1	0	2	1	0	1	1	Medium
Lee et al. 2010	1	0	0	1	0	1	0	2	1	0	1	1	Medium
Lopes et al. 2016	1	0	0	0	0	1	0	2	1	0	1	1	Medium
Mandigout et al. 2002	1	1	0	0	0	1	0	2	1	0	1	1	Medium
Marta et al. 2013	1	1	0	1	0	1	0	2	0	0	1	1	Medium
Marta et al. 2013[b]	1	1	0	1	0	2	0	2	1	0	1	1	Medium
Meucci_et al. 2013	1	1	0	1	0	1	0	2	0	0	0	1	Medium
Nogueira et al. 2017	0	1	0	0	0	0	1	2	1	0	0	1	Medium
Racil et al. 2016	1	1	0	0	0	2	0	2	1	0	1	0	Medium
Resaland_et al. 2017	0	0	0	1	0	0	0	2	0	0	0	1	Low
Roh et al. 2020	1	1	0	1	0	1	0	2	0	0	0	1	Medium
Rosenkranz et al. 2012	0	1	0	1	0	1	0	2	1	0	1	1	Medium
Seabra_et al. 2016	1	0	0	1	0	2	0	2	1	0	1	1	Medium
Song et al. 2012	1	1	0	0	1	1	0	2	1	0	1	1	Medium
Tan et al. 2016	1	1	0	0	0	2	0	2	0	0	1	1	Medium
Vajda_et al. 2007	1	0	0	0	0	1	0	2	0	0	0	0	Low
Wang et al. 2018	1	1	0	1	0	2	0	2	1	0	1	1	Medium

0 point | 1 point | 2 points | 3 points

Low quality | Medium quality | High quality

Supplementary table 3. Risk of bias evaluation by TESTEX tool of the **Counter Movement Jump** outcome studies.

	Study quality					Study reporting							
Study	Eligibility criteria specified	Randomization specified	Allocation concealment	Groups similar at baseline	Blinding of assessor	Outcome measures assessed in 85% of patients	Intention-to-treat analysis	Between-group statistical comparisons reported	Point measures and measures of variability for all reported outcome measures	Activity monitoring in control groups	Relative exercise intensity remained constant	Exercise volume and energy expenditure	**Total Score**
Alves_et al. 2015	1 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Arabatzi 2017	0 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	0 point	0 point	0 point	0 point	Medium quality
Bem Othman et al. 2019	0 point	1 point	0 point	1 point	1 point	3 points	0 point	2 points	1 point	0 point	1 point	1 point	High quality
Bogotaj et al. 2021	1 point	1 point	0 point	0 point	0 point	3 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Buchan et al. 2012	0 point	1 point	0 point	1 point	0 point	1 point	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Cvetkovic et al. 2018	1 point	1 point	0 point	0 point	1 point	3 points	0 point	2 points	1 point	0 point	1 point	1 point	High quality
Granacher et al. 2011	0 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	1 point	1 point	1 point	Medium quality
Granacher et al. 2011	0 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Marta et al. 2013	1 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	1 point	1 point	1 point	High quality
Marta_et al. 2019	1 point	1 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Muelhbauer et al. 2012	0 point	1 point	0 point	1 point	0 point	3 points	0 point	2 points	1 point	0 point	1 point	1 point	Medium quality
Racil et al. 2016	1 point	0 point	0 point	0 point	0 point	2 points	0 point	2 points	1 point	0 point	1 point	0 point	Medium quality
Racil_ et al. 2017	0 point	0 point	0 point	1 point	0 point	2 points	0 point	2 points	1 point	0 point	0 point	1 point	Medium quality

0 point | 1 point | 2 points | 3 points

Low quality | Medium quality | High quality

Supplementary table 4. Risk of bias evaluation by TESTEX tool of the **Maximal Aerobic Speed** outcome studies.

	Study quality					**Study reporting**							
Study	Eligibility criteria specified	Randomization specified	Allocation concealment	Groups similar at baseline	Blinding of assessor	Outcome measures assessed in 85% of patients	Intention-to-treat analysis	Between-group statistical comparisons reported	Point measures and measures of variability for all reported outcome measures	Activity monitoring in control groups	Relative exercise intensity remained constant	Exercise volume and energy expenditure	**Total Score**
Sprint													
Abassi et al. 2020													
Baquet et al. 2002													
Berthoin et al. 1995													
Hamila et al. 2017													
Lambrick et al. 2015													
Lau et al. 2014													

0 point | 1 point | 2 points | 3 points

Low quality | Medium quality | High quality

6.0 Considerações finais

A infância e adolescência são períodos marcados por importantes alterações no aspecto motor, social e cognitivo no qual a prática regular de exercício físico tem grande relevância para esse desenvolvimento. Esses aspectos podem ser prejudicados por alguns fatores como: avanço da idade, elevados índices de IMC e sedentarismo, podendo aumentar o risco para doenças cardiometabólicas que afetam a saúde da infância até a vida adulta. A aptidão física tem sido considerada um importante marcador de saúde que deve ser desenvolvido desde a infância por meio de exercícios físicos regulares e supervisionados levando em conta as variáveis de treinamento (frequência semanal, duração da sessão e duração da intervenção) e o tipo de exercício realizado. Assim, para elucidar as considerações finais deste trabalho, resgatou-se o problema de pesquisa que é: Qual a dose-ideal de exercício físico, baseado nas variáveis de treinamento, para melhorar a aptidão física (AM (força e potência), APCR e velocidade) de crianças e adolescentes de ambos os sexos e com diferentes padrões de IMC? Objetivou-se então realizar uma revisão sistemática da literatura com meta-análise e identificar a efetividade de diferentes estratégias de exercício físico sobre a aptidão física de crianças e adolescentes de ambos os sexos e com diferentes IMC.

A revisão sistemática e metanálise foi conduzida de acordo com as recomendações do livro da Cochrane e devidamente registrada na plataforma PROSPERO. As buscas foram realizadas no PubMed, Cochrane Library, Embase e Scopus. Foram elegíveis estudos realizados em crianças e adolescentes entre 7-17 anos, que realizassem todos os tipos de exercício físico estruturado, tivessem um grupo controle sem exercício como comparador e deveriam realizar uma intervenção avaliando a aptidão física no âmbito de força ou potência muscular, APCR e velocidade.

Nossos principais resultados demonstram que a prática de exercício físico é capaz de impactar os aumentos de aptidão física de crianças e adolescentes. No que diz respeito a aptidão muscular no âmbito da força, sugerimos indivíduos que realizam exercício físico aumentam a força muscular, sendo que sessões de longa duração (>60 minutos) são as sugeridas para esses ganhos. Além disso, o tipo de treinamento deve ser levado em consideração, já que exercícios predominantemente de força ou combinado apresentam maiores impactos no ganho de força muscular. A APCR pode ser melhorada através de diferentes estratégias de exercício físico, entre elas podemos destacar o treinamento aeróbico, esportivo ou HIIT. O IMC também impacta no aumento de APCR, sendo que indivíduos com menor IMC apresentam maiores ganhos cardiorrespiratórios. A prática de exercício físico impacta no ganho de potência muscular. No presente estudo não encontramos diferenças entre crianças e adolescentes de ambos os sexos e variáveis de treinamento. Por fim, os ganhos de velocidade também são impactados pela prática de exercício físico, sendo que sujeitos com maior idade cronológica e indivíduos com maior IMC respondem melhor à intervenção, aumentando a velocidade máxima de corrida.

No entanto, o presente estudo tem algumas limitações. Primeiramente, apesar dos estudos selecionados apresentarem qualidade metodológica moderada, alguns estudos não apresentavam a descrição da periodização do treinamento como duração das sessões e volume de exercício realizado, o que dificultou a análise de sensibilidade das variáveis do treinamento. Em segundo lugar, a falta de controle de intensidade nas sessões é um problema geral, pois os estudos não propõem um controle de intensidade e progressão durante o acompanhamento. Apesar das diretrizes consensuais de que crianças e adolescentes devam realizar atividades de intensidade moderada a vigorosa, a maioria desses dados está ausente, o que gera uma lacuna no conhecimento sobre a intensidade do exercício adequada para essa população. Assim, estudos de alta qualidade metodológica são importantes, devendo relatar a evolução da intensidade e do volume das sessões de treinamento para aprofundar o conhecimento sobre os efeitos do treinamento sobre a aptidão física de crianças e adolescentes. Por último, a falta de estudos transversais que analisaram a potência muscular e a velocidade prejudicaram as análises de sensibilidade em relação ao sexo e tipo de exercício.

Conclui-se então que a prática de exercício físico é capaz de melhorar a aptidão física de crianças e adolescentes, devendo levar em conta no momento da prescrição do exercício o sexo e IMC dos sujeitos, além do tipo de exercício realizado (atividades aeróbicas, exclusivas de força, HIIT ou esportes) para melhorar cada componente da aptidão física (força, APCR, potência e velocidade). Recomendações para futuras pesquisas incluem a realização de intervenções que controlem a intensidade de exercício físico para crianças e adolescentes, para assim, aprimorar o conhecimento sobre as variáveis de treinamento e a relação com a saúde cardiometabólica, podendo prescrever a dose-ideal de exercício físico para cada componente da aptidão física.