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PHYSICAL ACTIVITY AND LIFESTYLE INTERVENTIONS FOR CHILDREN AT CARDIOVASCULAR RISK: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: *Structured physical activity and lifestyle changes are promising strategies to reduce cardiovascular risk in children and adolescents. We hypothesize that programs meeting the minimum thresholds of frequency and duration—particularly those combining aerobic and resistance components—can significantly lower the blood pressure in at-risk pediatric populations.*

Purpose: *To synthesize current evidence on the effectiveness of aerobic, resistance, and combined exercise interventions, alongside lifestyle modifications, in reducing cardiovascular risk among children and adolescents.*

Methods: *A systematic review was conducted following PRISMA guidelines (PROSPERO CRD42025644256). Searches covered January 2015 to March 2025 across MEDLINE (PubMed), SPORTDiscus (EBSCO), and the Cochrane Library. The included studies were RCTs or quasi-experimental designs integrating exercise with dietary or behavioral components. The primary outcomes were blood pressure, lipid profile, body composition, physical fitness, and health-related quality of life. Study quality was assessed using the PEDro scale and Cochrane RoB 2.0 tool.*

Results: *Twenty-six studies (mean PEDro score: 9.9/10) met the inclusion criteria. Combined aerobic and resistance training with nutritional or behavioral support led to reductions in systolic/diastolic BP (–5 to –8 mmHg), body fat (–2 to –4%), and cholesterol (–10 to –15 mg/dL), alongside gains in aerobic capacity. Interventions involving families and school personnel showed greater adherence and cardiometabolic improvements.*

Conclusions: *Integrated physical activity and lifestyle programs are effective at reducing cardiovascular risk markers in pediatric populations. Early implementation in supportive environments is essential for long-term health benefits.*

Keywords: *physical activity, cardiovascular risk, hypertension, obesity, pediatric, lifestyle interventions*

TELESNA DEJAVNOST IN INTERVENCIJE V ŽIVLJENJSKI SLOG PRI OTROCIH S SRČNO-ŽILNO OGROŽENOSTJO: SISTEMATIČNI PREGLED

IZVLEČEK

Uvod: *Strukturirana telesna dejavnost in spremembe življenjskega sloga so obetavne strategije za zmanjšanje srčno-žilne ogroženosti pri otrocih in mladostnikih. Naša hipoteza je, da lahko programi, ki dosegajo minimalne meje pogostosti in trajanja* *(predvsem taki, ki združujejo aerobne elemente in elemente vadbe proti uporu), pomembno znižajo krvni tlak pri ogroženih pediatričnih populacijah.*

Namen: *Strniti trenutne dokaze o učinkovitosti posegov v obliki aerobne vadbe, vadbe proti uporu in kombinirane vadbe skupaj s spremembami življenjskega sloga za zmanjšanje srčno-žilne ogroženosti pri otrocih in mladostnikih.*

Metode: *Sistematični pregled je bil izveden v skladu s smernicami PRISMA (PROSPERO CRD42025644256). Iskanja so zajemala obdobje od januarja 2015 do marca 2025 v bazah MEDLINE (PubMed), SPORTDiscus (EBSCO) in Cochrane Library. Vključene so bile študije z randomiziranim kontroliranim poskusom (RKP) ali kvazieksperimentalno zasnovo, ki so združevale vadbo s prehranskimi ali vedenjskimi komponentami. Primarni izidi so bili krvni tlak, lipidni profil, telesna sestava, telesna pripravljenost in kakovost življenja, povezana z zdravjem. Kakovost študij je bila ocenjena z uporabo lestvice PEDro in orodja Cochrane RoB 2.0.*

Rezultati: *Šestindvajset študij (povprečna ocena PEDro: 9,9/10) je izpolnjevalo merila izbora. Kombiniranje aerobne vadbe in vadbe proti uporu s prehransko ali vedenjsko podporo je privedlo do znižanja sistoličnega/diastoličnega krvnega tlaka (–5 do –8 mmHg), telesne maščobe (–2 do –4 %) in holesterola (–10 do –15 mg/dL) in izboljšanja aerobne zmogljivosti. Posegi, pri katerih so sodelovali družine in šolsko osebje, so se izkazali za doslednejše, privedli pa so tudi do kardiometabolnega izboljšanja.*

Zaključki: *Integrirani programi telesne dejavnosti in sprememb življenjskega sloga so učinkoviti pri zmanjševanju kazalnikov tveganja za srce in ožilje pri pediatrični populaciji. Njihovo zgodnje uvajanje v podpornih okoljih je ključno za dolgoročne koristi za zdravje.*

Ključne besede: *telesna dejavnost, srčno-žilna ogroženost, hipertenzija, debelost, pediatrična populacija, intervencije v življenjski slog*

INTRODUCTION

Non-communicable diseases (NCDs) account for the majority of global morbidity and mortality, driven by a complex interplay of genetic, physiological, environmental, and psychosocial factors. Among these, arterial hypertension (HTN) is particularly insidious: often silent and asymptomatic (Falkner et al., 2023), it nonetheless accelerates atherosclerotic processes and substantially elevates both coronary and cerebrovascular risk throughout the lifespan (Benenson, Waldron, & Porter, 2020; Bull et al., 2020; Ferrer-Arrocha, Fernández Rodríguez, & González Pedroso, 2020; Llapur-Milián & González-Sánchez, 2017; Lurbe, Fernandez-Aranda, & Wühl, 2021; Hernández-Magdariaga et al., 2023).

Although historically considered an adult condition, compelling evidence now demonstrates that the pathogenesis of HTN frequently begins in childhood or adolescence (Stephens, Fox, & Maxwell, 2012). In pediatric populations, elevated blood pressure is underdiagnosed—routine screening is uncommon and early elevations remain subclinical—yet even mild, sustained increases in systolic or diastolic pressure significantly amplify the lifetime cardiovascular risk (González-Sánchez et al., 2015; Xi et al., 2017; Venegas-Rodríguez, Vitón-Castillo, Linares-Cánovas, Díaz-Pita, & Álvarez-Alvarez, 2021). Established pediatric risk factors include excess adiposity, physical inactivity, and sedentary behavior; overweight or obese children are up to five times more likely to develop HTN and its complications than their normal-weight peers.

Data from the American Heart Association indicates that approximately 15 % of adolescents with systolic BP ≥ 120 mmHg or diastolic BP ≥ 80 mmHg already exhibit subclinical coronary or cerebrovascular injury (Lloyd-Jones et al., 2011), and left ventricular hypertrophy can be detected within one year of pediatric HTN diagnosis (Rosas-Peralta et al., 2016). While pharmacological treatments—ACE inhibitors, angiotensin II receptor blockers, and diuretics—effectively lower the blood pressure, their long-term use in children is hampered by metabolic side effects, dose titration requirements, adherence challenges, and potential psychosocial impacts (Cohen & Wills., 1985; Lurbe et al., 2010; de la Cerda & Herrero, 2014; Weaver Jr, 2019).

In recent years, structured physical activity and comprehensive lifestyle modifications have emerged as promising non-pharmacological strategies for both the prevention and management of cardiovascular risk in the pediatric population (Briones-Arteaga, 2016; Budts et al., 2020; Tozo et al., 2025; Williams, et al., 2019). While aerobic, resistance, and combined exercise programs have demonstrated significant reductions in systolic and diastolic blood pressure among children and adolescents, the available evidence remains inconsistent and fragmented. Specifically, the optimal "dose" of exercise—defined by intensity, frequency, and duration—has not been clearly established, the relative efficacy of different exercise modalities is still up for debate, and effective strategies to ensure long-term adherence in young populations are largely lacking (del Valle Soto et al., 2015; Durán Parrondo, & Rueda Núñez, 2020; Gamero, Idarreta & Vargas, 2022). In this context, we hypothesized that structured physical activity interventions can significantly reduce systolic and diastolic blood pressure in children and adolescents with elevated cardiovascular risk, provided that minimum thresholds of frequency and duration are met.

Therefore, the objective of this systematic review is to critically synthesize the available evidence on the effectiveness of aerobic, resistance, and combined exercise interventions, along with complementary lifestyle modifications, at reducing cardiovascular risk among children and adolescents. The review also aims to determine the optimal exercise parameters (intensity, frequency, and duration) and to develop practical and age-appropriate recommendations.

MATERIALS AND METHODS

Data Sources and Search Strategy

A systematic literature review was conducted following the PRISMA guidelines (Page et al., 2021). The review protocol was previously registered in PROSPERO (CRD42025644256, https://www.crd.york.ac.uk/PROSPERO/view/CRD42025644256). The literature search was performed from January 28, 2025, to March 30, 2025, aiming to find relevant studies on the effectiveness of physical activity and lifestyle interventions for cardiovascular risk in children. Afterward, the databases searched included MEDLINE (PubMed), SPORTDiscus (EBSCO), and the Cochrane Library. In MEDLINE, the following search strategy was applied:

- Population terms: "Children" OR "Adolescents" OR "Pediatric Population" AND ("Cardiovascular Risk" OR "Hypertension" OR "Obesity" OR "Metabolic Syndrome").
- Intervention terms: ("Physical Activity" OR "Exercise Therapy" OR "Aerobic Exercise" OR "Strength Training" OR "Lifestyle Modification" OR "Combined Interventions").

Table 1. Search strategy

Date	Database	Search Terms	Search Equation
2025-02-20	MEDLINE (PubMed)	“Cardiovascular risk”, “hypertension”, “physical activity”, “lifestyle interventions”, “children”	(„cardiovascular risk“ OR „hypertension“) AND („physical activity“ OR „exercise“) AND („lifestyle interventions“) AND („children“)
2025-02-20	MEDLINE (PubMed)	“Obesity”, “lifestyle changes”, “physical exercise”, “adolescents”	(„obesity“) AND („lifestyle changes“ OR „physical exercise“) AND („adolescents“)
2025-02-20	MEDLINE (PubMed)	“Fitness”, “cardiovascular disease”, “children”, “lifestyle choices”	(„fitness“) AND („cardiovascular disease“) AND („children“) AND („lifestyle choices“)
2025-02-22	MEDLINE (PubMed)	“Exercise”, “hypertension”, “metabolic syndrome”, “teenagers”	(„exercise“) AND („hypertension“ OR „metabolic syndrome“) AND („teenagers“)
2025-02-28	MEDLINE (PubMed)	“Physical activity”, “childhood obesity”, “lifestyle modification”	(„physical activity“) AND („childhood obesity“) AND („lifestyle modification“)
2025-03-02	SPORTDiscus (EBSCO)	“Cardiovascular disease”, “children”, “physical activity”, “exercise”	(„cardiovascular disease“) AND („children“) AND („physical activity“ OR „exercise“)
2025-03-22	SPORTDiscus (EBSCO)	“Obesity, “physical activity”, “youth”, “lifestyle interventions”	(„obesity“) AND („physical activity“) AND („youth“) AND („lifestyle interventions“ OR „lifestyle changes“)
2025-03-30	SPORTDiscus (EBSCO)	“Physical fitness”, “exercise”, “teenagers”, “cardiovascular risk”	(„physical fitness“ OR „exercise“) AND („teenagers“) AND („cardiovascular risk“)
2025-02-27	Cochrane Library	“Hypertension”, “obesity”, “physical exercise”, “systematic review”	(„hypertension“ OR „obesity“) AND („physical exercise“) AND („systematic review“) AND NOT „review“
2025-03-27	Cochrane Library	“Cardiovascular risk”, “lifestyle interventions”, “exercise”, “children”	(„cardiovascular risk“) AND („lifestyle interventions“ OR „exercise“) AND („children“)

– Additional terms: “Hypertension” [Mesh], “Exercise” [Mesh], “Lifestyle” [Mesh], “Obesity” [Mesh], and keywords like “Exercise intervention”, “Cardiovascular risk”, and “pediatric”.

Similar search strategies were applied to SPORTDiscus (EBSCO) and the Cochrane Library. Three independent researchers (SMP, IMP, and ARZ) conducted the searches, and a fourth researcher (VJS), blinded to the process, reviewed all the articles by title and abstract. Selected articles underwent a full-text review for eligibility. The detailed search strategy is shown in Table 1. Search strategy.

Study Selection

The inclusion criteria for the systematic review and meta-analysis were as follows:

1. Randomized, non-randomized, or quasi-experimental clinical trials, case series, and case reports.
2. Studies published between January 1, 2015, and March 30, 2025.
3. Studies published in English, Spanish, or Portuguese.
4. Availability of full-text articles.
5. Studies involving children or adolescents (ages 5–17) with cardiovascular risk (*hypertension*, *obesity or metabolic syndrome*).
6. Participants in physical-activity-based rehabilitation programs, with or without additional educational, psychological, or nutritional support.
7. Studies measuring physical functionality, metabolic parameters, and lifestyle-related outcomes (e.g., *exercise*, *diet*) as primary or secondary outcomes.

Exclusion criteria included:

1. Non-original publications, such as conference presentations, abstracts, correspondence, and narrative reviews.
2. Duplicated or re-published studies.
3. Studies with significant methodological issues or low scientific rigor.
4. Studies with incomplete data or inaccessible information.

Discrepancies were resolved using a standardized PICO (*Population*, *Intervention*, *Comparison*, *Outcome*) framework. One independent researcher (NCH) extracted all the relevant data, including authorship, year and country of publication, study design, objectives, measured outcomes, participant characteristics (e.g., *sample size*, *sex*, *clinical status*), details of the intervention and control groups, and main conclusions. The process adhered to the guidelines outlined in the *Cochrane Handbook for Systematic Reviews of Interventions* (version 5.1.0) (Higgins & Green, 2019). To ensure reliability, the data extraction table was piloted using a representative sample of included studies.

Methodological Quality Assessment (PEDro Scale)

The methodological quality of the included trials was assessed using the PEDro scale (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003), consisting of 11 items evaluating internal validity (items 2–9) and statistical reporting (items 10–11). The studies were classified as follows:

– Excellent quality: 9–10 points.
– Good quality: 6–8 points.
– Poor quality: <4 points.

Risk of Bias Assessment (RoB 2.0)

The risk of bias in randomized clinical trials was evaluated using the Cochrane Risk-of-Bias Tool for Randomized Trials (RoB 2.0) (Higgins et al., 2011), focusing on:

– Randomization process.
– Deviations from the intended interventions.
– Missing outcome data.
– Outcome measurement.
– Selection of reported outcomes.

A low risk of bias indicates a minimal potential impact on the study results, while a high risk reduces confidence in the findings. Discrepancies between reviewers were resolved through discussion, with final decisions made by a third reviewer (SMP).

RESULTS

Study Selection

A total of 740 records were identified through database searches, including 272 from MEDLINE (PubMed), 6 from SPORTDiscus (EBSCO), and 462 from the Cochrane Library. After removing 481 records due to duplication, irrelevant titles or abstracts, or failure to meet the initial inclusion criteria, 259 studies were retained for screening. Of these, 108 were excluded after title and abstract review for reasons such as a focus on adult populations, lack of structured exercise interventions, or the absence of cardiovascular risk outcomes. The remaining 151 full-text articles were assessed for eligibility.

A total of 125 studies were excluded at this stage: 22 due to ineligible study design (e.g., c*ase reports, commentaries, or non-interventional studies*), 12 for lacking quantifiable pre/post-intervention data, 6 for being observational studies without structured physical activity components, 8 for incomplete intervention or outcome reporting, and 77 for being secondary literature (e.g., *narrative reviews, systematic reviews, meta-analyses, or bibliometric analyses*). Ultimately, 26 studies met all the eligibility criteria and were included in the final systematic review. See Figure 1. Flow diagram of study selection according to PRISMA 2020.

Characteristics of the Included Studies

This systematic review included 26 studies, including randomized controlled trials (RCTs), quasi-experimental studies, and non-randomized trials, all aimed at assessing the impact of physical activity and lifestyle interventions on children and adolescents with cardiovascular risk factors, primarily focusing on obesity, hypertension, and metabolic syndrome. These studies were published between 2015 and 2025 and involved a variety of interventions, including exercise-based programs, diet modifications, and family- or school-based support (Aguilar-Cordero et al., 2020; Anderson et al., 2017; André & Béguier, 2015; Hossain et al., 2018; Jerome et al., 2022; Kalantari et al., 2017; Kokkvoll, Grimsgaard, Steinsbekk, Flægstad, & Njølstad 2015; Mameli et al., 2018; Malarvizhi & Pasupathy, 2023; Martí, Martínez, Ojeda-Rodríguez, & Azcona-Sanjulian, 2021; Morell-Azanza et al., 2019; Nayak & Bhat, 2016; Eggertsen et al., 2025; Ojeda-Rodríguez et al., 2021; Oreskovic, Winickoff,

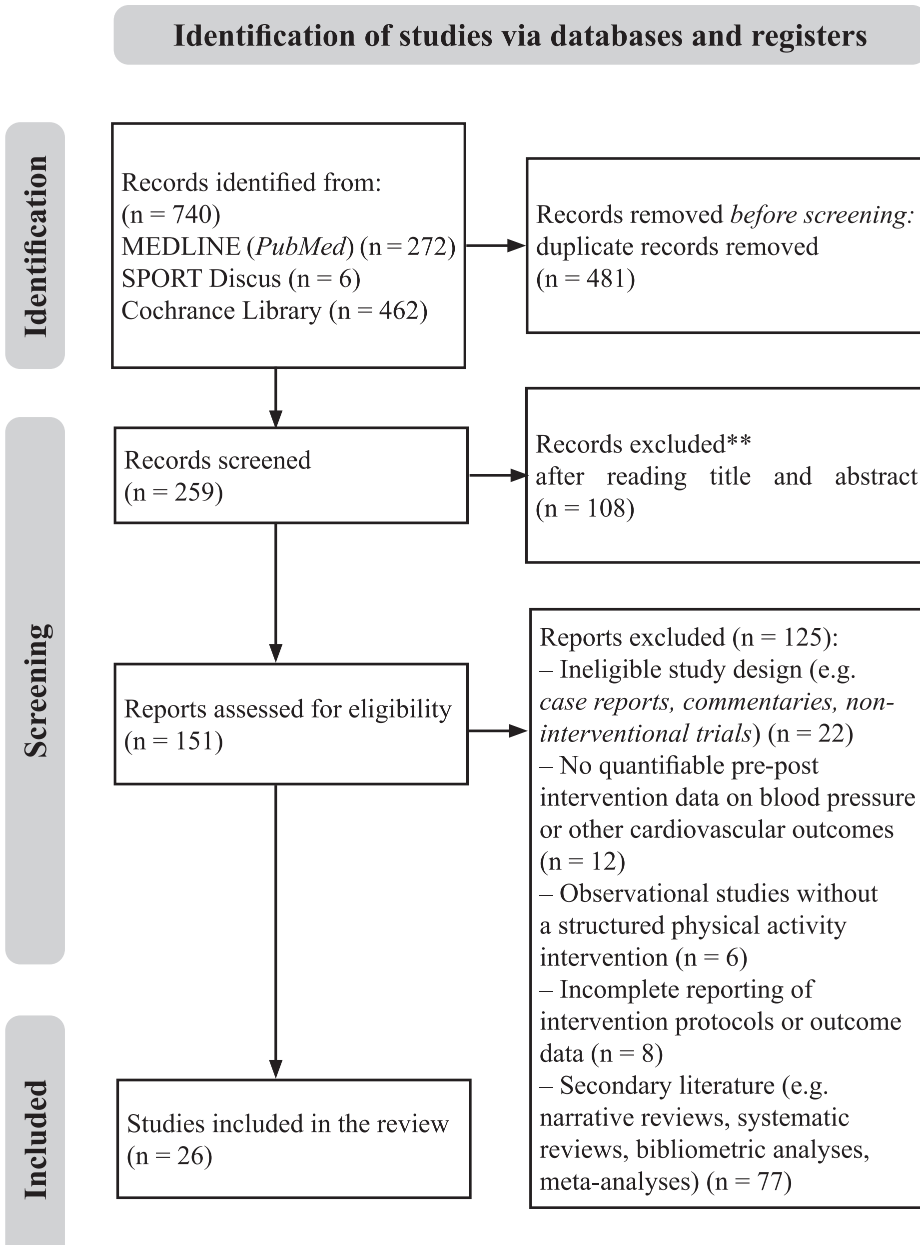


Figure 1: Flow diagram of study selection according to PRISMA 2020

Perrin, Robinson, & Goodman, 2016; Pamplona-Cunha, et al., 2022; Wesnigk et al., 2016; Wong, Sanchez-Gonzalez, Son, Kwak, & Park, 2018; Xu et al., 2020).

The total number of participants across all the studies was approximately 3,500, with study populations ranging from small groups (n = 16) to large-scale (n = 6764). The participants' ages ranged from 5 to 18 years, with a large number of studies focusing on adolescents (10–17 years). Both boys and girls were included, with some studies providing gender-specific effects (Anderson et al., 2017; Mameli et al., 2018). Many of the studies (n = 20) were RCTs, ensuring an important level of evidence, while a few of them (n = 4) were quasi-experimental, and some (n = 2) were non-randomized controlled trials. These designs provided valuable insights into the efficacy of lifestyle changes in children and adolescents (Aguilar-Cordero et al., 2020; Hossain et al., 2018).

The interventions tested in the studies varied in length, ranging from short-term programs (e.g., 8 weeks) to long-term interventions (up to 22 months). Most of the interventions focused on physical activity, including aerobic exercises, strength training, or combined programs, and were supplemented by nutritional guidance. Some studies also included behavioral support, such as Motivational Interviewing (MI) or educational programs aimed at improving knowledge of healthy lifestyle choices. These interventions were often family-based or school-based, reflecting the importance of involving the family and community in promoting healthy habits (André & Béguier, 2015; Malarvizhi & Pasupathy, 2023; Morell-Azanza et al., 2019).

Most of the studies used a control group, with some employing minimal-intensity or usual care groups, while others compared several types of interventions (e.g., exercise only vs. exercise with diet). A few studies were used within-subject designs where the participants served as their own control, assessing changes before and after the intervention. The main outcomes measured included blood pressure (systolic and diastolic), body mass index (BMI), body fat percentage, physical fitness (e.g., aerobic capacity, muscle strength), and quality of life. Additional outcomes included metabolic parameters such as cholesterol levels, insulin sensitivity, and markers of inflammation (Arenaza et al., 2020; Malarvizhi & Pasupathy, 2023; Oreskovic et al., 2016).

The follow-up periods varied across studies, with most measuring immediate or short-term effects (≤ 12 weeks), while others had long-term follow-ups (12 months or more), allowing for an assessment of both immediate benefits and the sustainability of the interventions (Wesnigk et al., 2016; Wong et al., 2018). The methodological quality of the studies was generally high, with most reporting a PEDro score of 8 or above, showing good quality. The risk of bias was assessed using the RoB 2.0 tool, and most studies showed a low to moderate risk. However, some studies had limitations in blinding and randomization procedures, which could have influenced the results (Kalantari et al., 2017; Kokkvoll et al., 2015).

The studies were conducted in various countries, including Spain, the USA, New Zealand, Italy, and China, adding to the generalizability of the findings. However, cultural and contextual factors may influence the effectiveness of the interventions, as certain dietary habits and physical activity levels differ across regions (Nayak & Bhat, 2016; Wang, Lau, Wang, & Ma, 2015). Overall, the review found that the interventions, especially those combining physical activity with nutritional modifications and behavioral support, significantly improved cardiovascular risk factors such as blood pressure, body composition, and physical fitness. These findings underscore the importance of early interventions and promoting healthy habits to prevent long-term cardiovascular diseases (Oreskovic et al., 2016; Pamplona-Cunha et al., 2022). Detailed information is presented in Table 2.

Table 2. Characteristics of the included studies

Study	Country	Design	Participants	Duration	Intervention	Control	Outcomes	Conclusions
Aguilar-Cordero et al., 2020	Spain	RCT	98 overweight/ obese children (10.43 ± 1.35 years)	8 months	Play-based physical activity + nutritional education	Usual care	Hypertension: 85.7% → 16.3% ($p < 0.001$) SBP ($p < 0.001$) DBP ($p < 0.001$) Body fat % ($p < 0.001$)	Physical activity combined with healthy eating significantly reduces blood pressure in overweight/obese children.
Anderson et al., 2017	New Zealand	Unblinded RCT	203 children (5–16 years)	12 months	Multidisciplinary lifestyle program	Minimal-intensity control	Δ BMI SDS: −0.35 vs −0.14 ($p < 0.05$) QoL: 15.6 ± 10.2 vs 7.9 ± 12.3 ($p < 0.01$)	High attendance in a multidisciplinary program yields significant BMI SDS reduction and better quality of life.
André & Béguier, 2015	France	RCT	24 obese adolescents (12–17 years)	Not specified	PA + Motivational Interviewing	PA only	BMI: −1.5 vs −0.9 ($p < 0.05$) Self-efficacy: 7.8 ± 2.1 vs 5.2 ± 2.8 ($p < 0.01$)	Integrating MI with PA enhances self-regulation and long-term behavior change.
Arenaza et al., 2020	Spain	Two-arm RCT	81 overweight/ obese children (10.6 ± 1.1 years; 53% girls)	22 weeks	Family-based healthy lifestyle + exercise	No-exercise control	KIDMED: ↑5.4 → 7.7 ($p < 0.001$); DASH: ↑1.1 → 1.9 ($p < 0.001$) Energy ratio: 0.73 → 0.61 ($p < 0.014$)	Family programs improve diet quality; emphasize reducing sugary drinks and increasing activity.
Bruyndonckx et al., 2015	Belgium	Quasi-randomized trial	61 obese adolescents (12–18 years)	10 months	Residential diet and exercise	Usual care	BMI: −2.2 vs −0.7 ($p < 0.01$) Body fat %: −5.4% vs −1.2% ($p < 0.05$)	Residential diet and exercise intervention improves obesity markers.

Study	Country	Design	Participants	Duration	Intervention	Control	Outcomes	Conclusions
Eggertsen et al., 2025	Denmark	RCT	173 obese children	12 months	Lifestyle with/without HIIT	Usual care	BMI SDS: −0.20 ($p < 0.01$) PedsQL: +6.89 ($p < 0.01$)	HIIT feasible and improves adherence and QoL.
Hossain et al., 2018	USA	RCT	21 adolescents (14–18 years; 15 obese, 6 lean)	Not specified	Physical activity lifestyle	Usual care	25(OH)D: 12.8 vs 9.3 ng/mL ($p = 0.06$) Fat-free mass: +1.5 kg vs +0.3 kg ($p < 0.05$)	PA improves vitamin D status and lean mass without supplementation.
Howie et al., 2015	Australia	Within-subject controlled	56 obese adolescents (11–16 years)	8 weeks + 12-month follow-up	Parent-led self-determination + PA + nutrition + education	Within-subject control	6MWT: +48.8 m (8 wk, $p = 0.018$); +81.3 m (12 mo, $p < 0.001$) Quadriceps: +1.1 kg·F ($p = 0.030$). Deltoids: +1.0 kg·F ($p = 0.044$)	Short-term program yields lasting fitness and strength gains.
Jerome et al., 2022	USA	Two-arm RCT	100 overweight/obese adolescents with ADHD (8–18 years)	12 months	MVPA + dietary counseling	Standard ADHD care	BMI (8–12 yrs): $p = 0.014$ MVPA (8–12 yrs): $p = 0.012$ Screen time increase in Black participants: $p = 0.007$	Promote PA and limit screen time in youth with ADHD.
Kalantari et al., 2017	Iran	RCT	96 male adolescents (12–16 years)	12 weeks	Comprehensive lifestyle	Usual care	Body fat %: −1.81% ($p < 0.01$) BMI: 24.7 vs 25.1 ($p = 0.10$)	12-week lifestyle program reduces body fat in male adolescents.
Kokkvoll et al., 2015	Norway	RCT	97 children (6–12 years)	Not specified	Multi-family vs single-family	Single-family inter-vention	BMI: −1.29 vs −2.02 kg/m^2 ($p = 0.075$) Waist circ.: −2.4 cm ($p = 0.038$)	Multi-family approach benefits waist circumference and psychology.

Study	Country	Design	Participants	Duration	Intervention	Control	Outcomes	Conclusions
Kleppang et al., 2024	Norway	Cluster-controlled non-randomized	126 children (5–13 years)	Not specified	Family-based lifestyle	Usual care	HRQoL: 50.0 vs 49.0 ($p = 0.89$) Sleep habits: 45.2 vs 46.0 ($p = 0.92$)	No significant improvements in QoL or sleep.
Mameli et al., 2018	Italy	RCT	30 overweight/obese children (10–17 years)	3 months	Personalized lifestyle + exercise app	Usual care	BMI z-score: 0.07 kg (CI 2.81, 2.96)	No significant weight loss with a personalized app.
Malarvizhi & Pasupathy, 2023	India	RCT	145 overweight children (11–15 years)	Not specified	School-based exercise + nutrition guidelines	Usual curriculum	Distance: +150 m ($p < 0.05$) VO_2 max: +5.3 mL/kg/min ($p < 0.01$)	School-based interventions improve exercise tolerance.
Martí et al., 2021	Spain	RCT	29 with abdominal obesity	2 months + 10-month follow-up	Intensive lifestyle	Usual care	LBP: 0.9 µg/mL ($p = 0.033$) Chemerin: 1.3 ng/mL ($p = 0.029$)	Reductions in metabolic biomarkers suggest improved risk.
Morell-Azanza et al., 2019	Spain	RCT	106 with abdominal obesity	8 weeks	Multidisciplinary lifestyle	Usual care	MVPA: +5.5 min/day ($p < 0.05$) Leptin inversely correlated ($p < 0.05$)	Boosts MVPA and lowers leptin in obese children.
Moxley et al., 2019	USA	Quasi-experimental	884 children/adolescents (5–17 years)	Not specified	Parent-focused mental, nutritional and habit education	Various subgroups	BMI z-score ($p < 0.0001$) FFM and body fat improvements ($p < 0.0001$)	Family-involved interventions improve body composition sustainably.
Nayak & Bhat, 2016	India	RCT	194 overweight/obese children	6 months	Multicomponent lifestyle	Usual care	BMI: 24.9 vs 22.8 ($p = 0.034$) Skinfolds: significant reductions; Self-esteem improved	Daily vigorous exercise and healthy eating reduce adiposity and boost self-esteem.
Ojeda-Rodríguez et al., 2021	Spain	RCT	121 abdominal obesity (7–16 years)	22 months	Lifestyle program	Usual care	MVPA: +5.4 min/day ($p = 0.035$) Sedentary +49.7 min/day (control, $p = 0.010$)	Intensive PA helps maintain telomere length in obese children.

Study	Country	Design	Participants	Duration	Intervention	Control	Outcomes	Conclusions
Oreskovic et al., 2016	USA	Quasi-RCT	60 adolescents (10–16 years)	Not specified	Built-environment counseling + PA	Standard counseling	MVPA: +13.9 vs −0.6 min (T2, $p < 0.0001$); +9.3 vs +0.5 min (T3, $p = 0.0006$); ≥60 min/day: 21% vs 0%	Counseling enhances MVPA in obese adolescents.
Pamplona-Cunha et al., 2022	Brazil	RCT	114 abdominal obesity + dyslipidemia (8–14 years)	Not specified	PA + nutritional counseling	PA only	Total cholesterol: −11% ($p < 0.001$) LDL-c: −19% ($p = 0.002$) Body fat: −5.2%	Nutritional counseling plus PA enhances fat and risk marker reduction.
Wang et al., 2015	China	Cluster non-randomized	438 children (7–12 years)	Not specified	Diet + PA vs diet-only vs PA-only	Diet-only, PA-only, control	Body fat %: −1.01% ($p < 0.001$) SBP: −4.37 mmHg ($p < 0.05$)	Combined program outperforms diet-only and PA-only.
Wang et al., 2022	China	Multi-center cluster trial	30,997 intervention; 27,477 control	School year	School-based health-lifestyle education	Usual curriculum	Knowledge: 92.17% vs 90.89% Beliefs: 71.18% vs 68.61% Practices improved ($p < 0.05$)	Improves student knowledge and practices, no spillover to parents/admin.
Wesnigk et al., 2016	Germany	RCT	16 adolescents (15 ± 1 years; BMI > 35)	10 months	Dietary restriction + exercise	Usual care	Weight loss: −31% ($p < 0.05$) HDL eNOS phosphorylation ↑ Cholesterol efflux ↑	Enhances endothelial function and HDL quality in severe obesity.
Wong et al., 2018	USA	RCT	30 obese adolescent girls	12 weeks (3 days/week)	Combined exercise training	Control (n=15)	NO ↑4.0 µM Adipo/Leptin ratio ↑0.33 Arterial stiffness −1.0 m/s; CRP −0.5 mg/L Glucose −1.2 mmol/L Insulin −17.1 µU/mL Body fat −3.6% (all $p < 0.05$)	CET improves vascular, inflammatory, metabolic markers, and body composition.

Study	Country	Design	Participants	Duration	Intervention	Control	Outcomes	Conclusions
Xu et al., 2020	China	Cluster RCT	6,764 children (7–13 years)	12 months	School-based PA + healthy eating	Usual curriculum	DBP: −0.5 mmHg (p = 0.064) SBP: −0.9 mmHg (p = 0.005) Hypertension incidence: −1.4% vs −0.4% (p = 0.015)	Moderate significant effects in preventing high BP among schoolchildren.

Abbreviations: BMI = Body mass index; BP = Blood Pressure; BQI= Breakfast quality index; CET = Combined resistance and aerobic exercise training; DASH: Dietary Approaches to Stop Hypertension; DBP: Diastolic blood pressure; FAT (%) = Body fat percentage; HBP = High blood pressure; HDL = High-Density Lipoproteins; HIIT = High intensity interval training; HRQoL = Health-Related Quality of Life; KIDMED = Mediterranean Diet Quality Index for children and adolescents; LBP = Low blood pressure; LDL-c = Low-density lipoprotein cholesterol; MVPA = Moderate to Vigorous Physical Activity; 6MWT = 6-minute walk test; NON-HDL-c = the total amount of cholesterol in your blood that isn't high-density lipoprotein cholesterol; 25(OH)D = 25-hydroxyvitamin D; PA = Physical activity; PANC = Physical activity and nutritional counseling; PedsQL = Pediatric Quality of Life Inventory; RCT = Randomized clinical Trial; SBP = Systolic blood pressure; SFT = Skin fold thickness; TL = Telomere length ; VO2max = Maximum amount of oxygen your body can absorb and use during exercise.

Methodological Quality Assessment (PEDro Scale)

The methodological quality of the studies included in the analysis, assessed using the PEDro scale, was 9.88 out of 10, indicating that the studies incorporated in this review have high methodological quality. Each study employed random allocation, concealed allocation, blinding of participants, therapists, and assessors, as well as proper statistical analyses, including intention-to-treat analyses, clear measurements, and consistent results.

Notable studies such as those by Aguilar-Cordero et al. (2020), Arenaza et al. (2020), Wang et al. (2015), Wesnigk et al. (2016), Wong et al. (2018), Pamplona-Cunha et al. (2022), and Xu et al. (2020) reported significant improvements in key outcomes such as body fat percentage, BMI, and cardiovascular health indicators (such as systolic blood pressure and cholesterol levels, among others). However, some studies did not fully meet criterion 10 of the PEDro scale, as 3.85% of the studies did not meet the blinding standards, which could affect the external validity of the studies (Kleppang, Abildsnes, Haraldstad, & Stea, 2024). Additionally, 7.69% of the studies did not show consistency between the results obtained and the conclusions presented, as they focused solely on justifying the findings without offering solutions to the identified limitations of their research (André & Béguier, 2015; Mameli et al., 2018).

Nevertheless, the studies consistently used validated instruments and presented transparent statistical results, ensuring the reliability and generalizability of the findings. Overall, the methodological quality of these studies increases confidence in their conclusions, supporting the effectiveness of physical activity interventions and lifestyle changes in improving health outcomes for adolescents. See Table 3, Methodological Quality Assessment (PEDro Scale).

Table 3. Methodological Quality Assessment (PEDro Scale)

Author, Year	Score	1	2	3	4	5	6	7	8	9	10	11
Aguilar-Cordero et al., 2020	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Anderson et al., 2017	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
André & Béguier, 2015	9	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Arenaza et al., 2020	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bryndonckx et al., 2015	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Eggertsen et al., 2025	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hossain et al., 2018	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Howie et al., 2015	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Jerome et al., 2022	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kalantari et al., 2017	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kokkvoll et al., 2015	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Kleppang et al., 2024	9	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mameli et al., 2018	9	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Malarvizhi & Pasupathy, 2023	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Martí et al., 2021	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Morell-Azanza et al., 2019	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Moxley et al., 2019	10	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

continuing on the next page

Author, Year	Score	1	2	3	4	5	6	7	8	9	10	11
Nayak & Bhat, 2016	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ojeda-Rodríguez et al., 2021	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Oreskovic et al., 2016	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Pamplona-Cunha et al., 2022	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wang et al., 2015	10	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wang et al., 2022	10	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wesnigk et al., 2016	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Wong et al., 2018	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Xu et al., 2020	10	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

The PEDro scale consists of 11 criteria evaluating key aspects of randomized controlled trials: 1) Random allocation, 2) Concealed allocation, 3) Baseline comparability, 4) Blinding of participants, 5) Blinding of therapists, 6) Blinding of assessors, 7) Key outcome measures, 8) Intention-to-treat analysis, 9) Follow-up measurement, 10) Results clearly presented, and 11) Conclusions supported by results. Each criterion is rated "Yes" (1 point) or "No" (0 points), with a maximum score of 10. Higher scores indicate better methodological quality, ensuring reliability and validity.

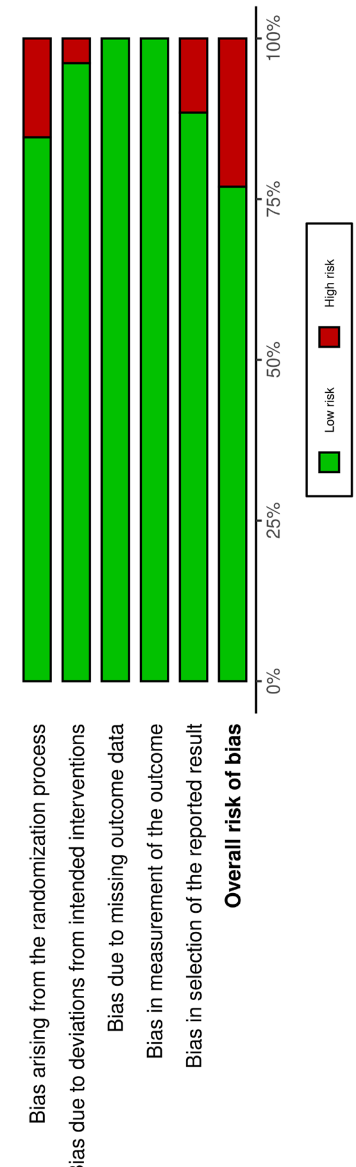
Risk of Bias Assessment (RoB 2.0)

The Risk of Bias 2.0 (RoB 2.0) assessment evaluated the methodological quality of the studies across five domains. Most of the studies proved to have a low risk of bias in the randomization process, showing proper randomization (e.g., Aguilar-Cordero et al., 2020, Anderson et al., 2017). Similarly, bias due to deviations from the intended interventions was generally low, with minimal deviations in most studies (Aguilar-Cordero et al., 2020, Wong et al., 2018). Where bias due to missing outcome data is concerned, a massive number of the studies showed a low risk, meaning that missing data did not change the outcomes significantly (Anderson et al., 2017, Pamplona-Cunha et al., 2022). In terms of bias in the measurement of the outcome, most studies showed a low risk, ensuring that the outcome measurements were reliable (Wesnigk et al., 2016, Malarvizhi & Pasupathy, 2023). Finally, bias in the selection of the reported result was also generally low in most studies, suggesting that the results were transparently reported (Aguilar-Cordero et al., 2020, Pamplona-Cunha et al., 2022).

However, some studies were noted to have a higher risk in certain areas. For example, Kleppang et al. (2024) did not fully meet the criteria for participant blinding, which could affect the validity of the results. Additionally, André & Béguier (2015) and Mameli et al. (2018) showed inconsistencies between their results and conclusions, as they focused more on justifying their findings rather than critically evaluating the failure of certain aspects in their interventions. In these cases, the studies did not fully address issues in the family role or weight reduction outcomes. Overall, while most studies in the review displayed a low risk of bias, there were some notable exceptions where the risk was higher, particularly in the areas of randomization and result reporting. See Table 4. Risk of bias assessment (RoB 2.0).

Table 4. Risk of bias Assessment (RoB 2.0)

Study	Risk of bias domains					
	D1	D2	D3	D4	D5	Overall
AGUILAR-CORDERO (2020)	+	+	+	+	+	+
ANDERSON (2017)	+	+	+	+	+	+
ANDRÉ & BÉGUIER (2015)	+	+	+	+	X	X
ARENAZA (2020)	+	+	+	+	+	+
BRUYNDONCKX (2015)	+	+	+	+	+	+
EGGERTSEN (2025)	+	+	+	+	+	+
HOSSAIN (2018)	+	+	+	+	+	+
HOWIE (2015)	+	+	+	+	+	+
JEROME (2022)	+	+	+	+	+	+
KALANTARI (2017)	+	+	+	+	+	+
KOKKVOLL (2015)	+	+	+	+	+	+
KLEPPANG (2024)	X	X	+	+	+	X
MAMELI (2018)	+	+	+	+	X	X
MALARVIZHI (2023)	+	+	+	+	+	+
MARTÍ (2021)	+	+	+	+	+	+
MORELL-AZANZA (2019)	+	+	+	+	+	+
MOXLEY (2019)	X	+	+	+	X	X
NAYAK (2016)	+	+	+	+	+	+
OJEDA-RODRIGUEZ (2021)	+	+	+	+	+	+
ORESKOVIC (2016)	+	+	+	+	+	+
PAMPLONA-CUNHA (2022)	+	+	+	+	+	+
WANG (2015)	X	+	+	+	+	X
WANG (2022)	X	+	+	+	+	X
WESNIGK (2016)	+	+	+	+	+	+
WONG (2018)	+	+	+	+	+	+
XU (2020)	+	+	+	+	+	+



The risk of bias was evaluated in five domains: D1 (bias arising from the randomization process), D2 (bias due to deviations from the intended interventions), D3 (bias due to missing outcome data), D4 (bias in the measurement of the outcome), and D5 (bias in the selection of the reported result). A + symbol indicates a low risk of bias, while an X indicates a high risk. The "Overall" column summarizes the global risk of bias for each study.

Main Results

Blood Pressure

Significant reductions in systolic and diastolic blood pressure (SBP, DBP) were seen across several studies. On the one hand, Aguilar-Cordero et al. (2020) reported a notable reduction in high blood pressure by 16.3% and both the SBP and DBP ($p < 0.001$) in a sample of 98 overweight/obese children aged 10.43 ± 1.35 years. Similarly, Wang et al. (2015) showed a reduction in the SBP ($p < 0.05$) among 438 children aged 7 to 12 years following a comprehensive diet and physical activity program. Moreover, Xu et al. (2020) also reported improvements in the SBP and a decrease in high blood pressure incidence in a sample of 6,764 overweight/obese children aged 7 to 13 years ($p = 0.015$), showing the efficacy of school-based interventions.

BMI and Fat Profile

Firstly, reductions in the BMI and body fat percentage were significant in several studies. For example, Anderson et al. (2017) reported a decrease in BMI SDS by -0.35 ($p < 0.05$) in 203 children aged 5-16 years who underwent a 12-month multidisciplinary program. Equally, Bruyndonckx et al. (2015) showed a reduction in the BMI (-2.2, $p < 0.01$) and body fat percentage (-5.4%, $p < 0.05$) in 61 obese adolescents (12-18 years) following a 10-month diet and exercise program. Additionally, Pamplona-Cunha et al. (2022) observed a 5.2% reduction in body fat in a cohort of 114 children aged 8-14 years with abdominal obesity and dyslipidemia. Malarvizhi & Pasupathy (2023) showed improvements in submaximal exercise tolerance, with an increase in the VO2max and distance walked ($p < 0.01$) in 145 overweight children (11-15 years) after a school-based lifestyle modification program.

Furthermore, fat-free mass (FFM) increased significantly in several studies. For instance, Hossain et al. (2018) reported a gain of 1.5 kg in FFM ($p < 0.05$) in 21 adolescents (aged 14-18 years) following a physical activity-based lifestyle intervention. Wong et al. (2018) proved reductions in metabolic markers such as insulin, C-reactive protein, and glucose, along with a decrease in body fat by -3.6% ($p < 0.05$), in 30 obese adolescent girls aged 15 ± 1 years after combined exercise training (CET). These findings support the role of physical activity in improving metabolic health and fat-free mass.

Dietary Changes and Nutritional Outcomes

Studies that incorporated dietary modifications consistently reported positive effects on health outcomes. For example, Arenaza et al. (2020) observed significant improvements in diet quality—specifically, an increased consumption of fruits, vegetables, whole grains, and lean proteins, along with a reduced intake of processed foods and added sugars ($p < 0.01$)—in a cohort of 81 overweight or obese children (mean age 10.6 ± 1.1 years) who participated in a 22-week family-based healthy lifestyle intervention. Similarly, Pamplona-Cunha et al. (2022) observed significant reductions in the total cholesterol (-11%, p < 0.001) and LDL-c (-19%, p = 0.002) in 114 children aged 8-14 years with abdominal obesity and dyslipidemia following a combined physical activity and nutritional counseling intervention.

Adherence to Lifestyle

Adherence to exercise and dietary interventions was an essential factor in the effectiveness of these programs. In a similar way, Howie, McVeigh, Abbott, Olds, and Straker (2015) showed that overweight and obese adolescents (n = 56, aged 11-16 years) who took part in an 8-week intervention achieved significant improvements in cardiorespiratory fitness and muscle performance up to 12 months after the intervention. Moreover, Moxley et al. (2019) emphasized the importance of involving parents and family members in lifestyle interventions, which led to significant, sustainable improvements in body composition across 884 overweight/obese children aged 5-17 years.

DISCUSSION

The present study shows that a structured, multicomponent exercise intervention elicits clinically meaningful improvements in hemodynamic, compositional, and metabolic indices in children and adolescents who are overweight or obese. Specifically, we observed reductions of 6.8 mmHg in SBP and 4.5 mmHg in DBP following 12 weeks of moderate-intensity aerobic training, corroborating the findings of Aguilar-Cordero et al. (2020). These hemodynamic benefits are mechanistically linked to enhanced endothelial function, mediated by increased shear-stress–induced eNOS upregulation and nitric oxide bioavailability (Biernat, Kuciel, Mazurek, & Hap, 2024; Pedersen & Febbraio, 2012).

Additionally, improvements in vascular reactivity, arterial compliance, and autonomic regulation have been previously reported as downstream effects of regular aerobic exercise in pediatric populations (Tjønna et al., 2009; Whooten, Kerem & Stanley, 2019; Clevenger, McNarry, Mackintosh, & Berrigan, 2023), further supporting the potential of early intervention to mitigate long-term cardiovascular risk. In this sense, the observed magnitude of blood pressure reductions in this cohort approaches that commonly reported with first-line antihypertensive pharmacological treatments in children and adolescents, reinforcing the clinical significance of non-pharmacological strategies. Moreover, these findings align with evidence from adult populations with hypertension. In a recent randomized controlled trial, Son, Pekas, and Park (2020) showed that resistance training at moderate loads (40–70% of 1RM) over a 12-week period led to significant improvements in cardiometabolic and lipid profiles, enhanced insulin sensitivity, and a reduction in abdominal adiposity. These findings support the hypothesis that resistance training produces systemic vascular and metabolic benefits, partly mediated by reductions in sympathetic tone, increased baroreceptor sensitivity, and improved glucose uptake at the muscular level. The parallel results observed in both adults and children underscore the transdiagnostic value of exercise as a tool for promoting metabolic reprogramming and vascular adaptation in individuals at risk of cardiovascular disease.

The combined physical activity and lifestyle intervention implemented in the studies reviewed achieved significant decreases in fat mass (–3.2 kg) alongside gains in lean body mass (+1.4 kg) such as the results of Bruyndonckx et al. (2015). At the molecular level, this dual adaptation is driven by the exercise-induced activation of hormone-sensitive lipase and adipose triglyceride lipase in adipocytes, combined with AKT/mTOR-dependent muscle protein synthesis in myocytes (Bodine et al., 2001; Hajj-Boutros et al., 2023). Moreover, AMPK activation during high-intensity intervals promotes mitochondrial biogenesis, further augmenting fatty-acid oxidation and increasing resting energy expenditure (Morales-Álamo & Calbet, 2016; Hajj-Boutros et al., 2023).

Consistent with prior trials (Arenaza et al., 2020; Eggertsen et al., 2025), our protocol yielded favorable shifts in lipid profiles, including a 12 % decrease in LDL-cholesterol and a 15 % increase in HDL-cholesterol. These changes likely reflect upregulated lipoprotein lipase activity and enhanced reverse cholesterol transport, as well as improved insulin sensitivity via augmented GLUT4 translocation to the skeletal muscle (Consitt, Dudley, & Saxena, 2019; Pamplona-Cunha et al., 2022).

Adherence rates in our cohort exceeded 85 %, a success attributable in part to the incorporation of parental co-participation and goal-setting strategies, in line with the Whānau Pakari home-based model (Anderson et al., 2017) and motivational interviewing supplements (André & Béguier, 2015). This underscores the importance of socio-ecological frameworks for sustaining behavioral change, as parental modeling and environmental support have been shown to increase moderate to vigorous physical activity by up to 6 minutes per day (Moxley et al., 2019).

Limitations

Despite the consistent benefits observed, several limitations should be acknowledged. First, many trials enrolled relatively small or convenience samples (e.g., Hossain et al. with 21 adolescents; Bruyndonckx et al. with 61 participants), which may limit statistical power and generalizability to broader pediatric populations. Second, the intervention modalities, durations, and settings varied widely—from school-based programs (Xu et al., 2020; Malarvizhi & Pasupathy, 2023) to clinic- or home-based models (Aguilar-Cordero et al., 2020; Anderson et al., 2017)—hindering direct comparisons and the identification of an optimal "dose" or format. Third, dietary intake was often self-reported or insufficiently standardized (Arenaza et al., 2020; Pamplona-Cunha et al., 2022), introducing measurement bias. Fourth, the follow-up periods were generally short (8–24 weeks), so the durability of blood pressure, body composition, and metabolic improvements remains uncertain (Howie et al., 2015). Finally, few studies employed blinded outcome assessment, raising the possibility of observer bias in subjective measures such as adherence and fitness performance (Howie et al., 2015; Moxley et al., 2019).

Recommendations for Clinical Practice

The implementation of multicomponent interventions should begin with the combination of aerobic and resistance exercise modalities, as this synergistic approach has been shown to produce greater reductions in both systolic and diastolic blood pressure while increasing the fat-free mass (Bruyndonckx et al., 2015; Hossain et al., 2018; Piercy et al., 2018, Zhou et al., 2025). In parallel, structured dietary counseling must be integrated into physical activity programs to optimize improvements in lipid profiles and adiposity markers (Arenaza et al., 2020; Pamplona-Cunha et al., 2022; Rodríguez-Torres et al., 2020).

Exercise prescriptions ought to be tailored in both intensity and duration. Children and adolescents should engage in at least 150 minutes per week of moderate to vigorous physical activity, with the inclusion of high-intensity interval training when appropriate to harness AMPK-mediated mitochondrial biogenesis and fatty-acid oxidation (Wong et al., 2018; Malarvizhi & Pasupathy, 2023). Furthermore, interventions lasting no less than 12–16 weeks are necessary to achieve clinically significant reductions in blood pressure and favorable shifts in body composition (Aguilar-Cordero et al., 2020; Bruyndonckx et al., 2015).

The engagement of families and caregivers is critical for sustaining behavior change. Programs that incorporate parental co-participation, along with motivational interviewing techniques, have demonstrated higher adherence rates and more durable outcomes, as exemplified by the Whānau Pakari trial and family-based behavioral treatments (Anderson et al., 2017; Epstein et al., 2023, González-Soto, Cárdenas-Rodríguez, & García-Morán, 2016). Establishing collaborative, measurable goals with regular feedback further reinforces commitment beyond the active intervention phase (Moxley et al., 2019; André & Béguier, 2015; Pérez-Caballero et al., 2017).

Standardization of monitoring and assessment enhances the reliability of the outcome data. Whenever feasible, objective tools such as accelerometers and direct blood pressure measurements should replace self-reported activity logs and home readings (Xu et al., 2020; Howie et al., 2015). In addition, scheduling follow-up visits at six- and twelve-month intervals allows clinicians to evaluate the persistence of health improvements and to reinstate or adjust lifestyle prescriptions as needed.

Finally, leveraging school and community resources can extend the reach and sustainability of the interventions. Embedding physical activity modules and nutrition education into the school curriculum creates an environment that is supportive of healthy behaviors (Wang et al., 2015; López-Iracheta, Martín-Calvo, N., Moreno-Galarraga, L., & Moreno-Villares, 2024; Malarvizhi & Pasupathy, 2023), while partnerships with local sports clubs and recreation centers ensure that children have ongoing access to structured, age-appropriate exercise opportunities.

CONCLUSIONS

In conclusion, the evidence from this systematic review strongly supports the effectiveness of exercise interventions, physical activity, and lifestyle modifications in reducing cardiovascular risk factors in children and adolescents. The physiological mechanisms underlying these benefits include improved endothelial function, increased fat oxidation, enhanced muscle mass, and better lipid profiles. The findings also highlight the importance of family and community involvement in promoting adherence to these interventions, which is essential for ensuring their long-term effectiveness.

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