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Effects of different physical exercise programs on blood pressure in overweight children and adolescents: systematic review and meta-analysis

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Abstract

Aims The purpose of this meta-analysis was to systematically review studies in the literature that evaluated the effect of different exercise programs on blood pressure in overweight children and adolescents.

Data sources In September 2024, studies were searched in six electronic databases (PubMed, Web of Science, Scopus, Sportdiscus, Lilacs, and Scielo) and in reference lists.

Study eligibility criteria, participants, and interventions Randomized and non-randomized controlled trials with interventions involving physical exercise programs and assessment of systolic blood pressure (SBP) and diastolic blood pressure (DBP) in children and adolescents with overweight and/or obesity were considered for synthesis.

Study appraisal and synthesis methods The quality of studies was assessed using the PEDro scale for studies with randomized clinical trials. Meta-analysis was conducted using a random model in the Review Manager Software.

Results Seventeen studies were selected that involved 1,125 children and adolescents. The risk of bias score was considered moderate (five to eight points out of 11). The high-intensity interval training (HIIT) showed the largest effect, indicating a greater impact on BP reduction, while moderate-intensity continuous training (MICT) also had a significant effect, although with greater heterogeneity. No significant effects were found for the other types of exercise. For SBP, a summary effect of -0.44 (95% CI=-0.68; -0.20; $I^2=73\%$) was observed. For DBP, the metanalysis indicated −0.52 (95% CI=-0.73; -0.31; $I^2=63\%$).

Limitations There was a publication time limitation of ten years, and the search was restricted to articles published in journals indexed in databases, and there was also significant heterogeneity for the intervention subgroups, which can be explained by the moderate methodological quality of the studies.

Conclusions and implications of key findings Considering the significant effects of exercise interventions on blood pressure, we suggest the development of more interventions based on physical exercise practice for

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overweight and obese children and adolescents, which may also add environmental elements, lasting at least 12 weeks, with three 60-minute sessions per week, better control of exercise intensity, as HIIT and MICT were more effective in promoting a reduction in blood pressure when compared to other types of exercise. The implementation of these programs must be carried out in a multicomponent and multiprofessional approach to guarantee the adherence of participants and promote significant and sustainable changes in the cardiovascular health of children and adolescents.

Systematic review registration number PROSPERO no CRD42023469222.

Keywords Hypertension, Exercise, Obesity, Therapeutics

Introduction

Inappropriate lifestyles have increased in the child and adolescent population in recent decades, demonstrated by the tendency for greater use of electronic devices [1], a predominance of sedentary behaviors [2] and insufficient engagement in recommended levels of moderate to vigorous physical activity (MVPA) [3]. It should be noted that the World Health Organization recommends that children and adolescents practice at least 60 min of daily MVPA [4], with the aim of maintaining health and preventing and reducing overweight. However, a study monitoring Brazilian schoolchildren found a decreased in the practice of activities ≥ 420 min/week over 10 years, decreasing from 62.2 to 34.1% in boys, while girls maintained similar percentages from 34.0 to 30.8% [5]. In addition, sedentary Brazilian children and adolescents showed a progressive decline in physical fitness, while those who were active showed improvements [6]. The impact of these daily changes, such as being more overweight, an inadequate diet and excessive use of salt, sleep disorders and low participation in physical activities, leads to the onset of hypertension [7] and other cardiometabolic risk factors [8].

Therefore, the association of excess general adiposity and abdominal adiposity increased the risk of hypertension in adolescents threefold and sixfold, respectively [9], as well as a higher risk with lower physical fitness and a lower risk of hypertension with the practice of MVPA [10]. The implementation of physical exercise programs at an early stage is important and involves increasing physical fitness, reducing central adiposity and insulin resistance, as well as reducing the chronic inflammatory process associated with obesity [11]. In general, intervention programs use moderate-intensity continuous training (MICT) to reduce insulin resistance and the components of metabolic syndrome [12, 13], combined physical exercise to reduce insulin resistance [14], metabolic and inflammatory factors [15, 16], as well as higher intensity activities such as high-intensity interval training (HIIT), which has improved cardiorespiratory fitness [17] and reduced cardiometabolic factors [18–20].

In a recent study, the authors used MICT or HIIT programs as therapy for hypertensive adolescents and found a reduction in diastolic blood pressure (DBP) in boys, but did not evaluate the isolated effect of each of the exercises [21]. Meanwhile, a systematic review was inconclusive as to whether physical exercise reduces blood pressure (BP) in hypertensive individuals, but there was a greater reduction in BP with regular aerobic exercise compared to strength or combined training [22]. Another systematic review with meta-analysis [23], which looked at school-based interventions, found four studies in the six to 19 age group and concluded that there was a favorable effect on DBP in obese in the intervention groups compared to controls.

To date, despite the existence of various types of exercise and the benefits of regular practice, there is a scientific lacuna in relation to the effect of different exercise on BP in children and adolescents, including those with hypertension. Few studies have provided clinical outcomes when comparing different types of exercises on BP and there is little information [22, 23], as well as rare studies on the therapeutic importance of exercise in reducing BP in hypertensive in the child and adolescent population [21]. Thus, the objective was to systematically review studies that evaluated the effect of different exercises programs on BP in overweight children and adolescents.

Methods

This systematic review and meta-analysis were based on the items in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [24]. The study protocol was previously registered and is available on the International Prospective Register of Systematic Reviews (PROSPERO no. CRD42023469222). Inclusion criteria were based on the PICOS strategy for eligibility: Population (children and adolescents, aged 6–17 years, with overweight/obesity); Interventions (interventions that involved physical exercise programs, according to the type, frequency, volume, intensity and total duration of exercise); Comparators (inter-and intragroup comparisons of exercise and control group without intervention); Outcome (systolic and diastolic blood pressure); and Study Design (randomized and non-randomized controlled trials).

We performed a systematic search for publications using Medical Literature Analysis and Retrieval System Online (Medline) via PubMed, Web of Science, Scopus, SPORTDiscus, Latin American and Caribbean Literature in Health Sciences (LILACS), Scientific Electronic Library Online (SciELO) databases and manual searches in the reference lists of studies. The descriptors were selected based on the Medical Subject Headings (MESH) and were combined with the Boolean terms "AND" and "OR". Search strategies were conducted in September 2024, using subject headings and keywords in all databases: (("child" OR "adolescent" OR "youth" OR "teens") AND ("blood pressure" OR "hypertension") AND ("exercise" OR "physical training")). Searches were limited to the English, Portuguese and the Spanish language.

The work process of the review, related to the removal of duplicates, evaluation of titles, abstracts and full texts, extraction of original data and syntheses (descriptive and statistical) counted with the participation of three researchers, acting independently. The data extraction process was based on previous references, using an electronic spreadsheet, divided into three domains: descriptive (e.g., authors of the studies, place where they were carried out, sample size, sample profile); methodological (e.g., intervention time, protocol of exercise) and results.

Meta-analysis was conducted from the original data presented in the studies, using the software Review Manager (v.5.4.1). Given the heterogeneity of the data, we used the random model [25], inserting in the model the post-intervention and pre-intervention means of each group to identify the Δ value. To analyze heterogeneity, the I^2 statistic was used, taking as definitions moderate up to 50 and high ≥ 75%. The significance level of $p < 0.05$ and 95% confidence interval were considered.

The methodological quality of the studies was evaluated using the PEDro scale for studies with randomized clinical trials [26]. The scale is composed of 11 criteria relevant for quasi-experimental and experimental studies, for each criterion contemplated was attributed the value 1, while for the unmet criteria the value 0 was attributed. According to the total scores, the studies with scores: <6 (high), 6–7 (moderate), and > 7 (low) risk of bias.

Results

In total, the systematic searches in the electronic databases led to the identification of 2,069 potentially relevant references, from the following: PubMed ($n = 370$), Web of Science ($n = 939$), Scopus ($n = 80$), SPORTDiscus ($n = 340$), LILACS ($n = 318$), and SciELO ($n = 22$). After identification and removal of duplicates ($n = 555$), 1,514 studies were evaluated by their titles, and subsequently 63 of them remained for evaluation by their full texts. Of these, 46 did not meet the eligibility criteria, the most frequent reasons being: studies with an acute effect of exercise ($n = 14$); studies only with eutrophic children and adolescents ($n = 12$); studies without blood pressure analysis ($n = 11$); and studies based on interventions other than exercise programs ($n = 09$). Thus, seventeen articles were referred to the synthesis of this review (Fig. 1).

Per location, the studies were conducted in Brazil [8, 11, 13, 21, 27–30], Korea [31–33], United States of America [34, 35], Spain [36], Italy [37], Iran [38] and Tunisia [39], comprising an average age between 11.2 and 16.3 years old. It was observed that a great variation among the criteria adopted for the inclusion of children and adolescents, and the interventions had overweight/obesity as their primary outcome. Three studies had other variables as the primary outcome for the inclusion of children and adolescents in the proposed interventions: adolescents diagnosed with pre-hypertensive, hyperinsulinemia and obesity [31], adolescents diagnosed with overweight, and hypertension [21] and adolescents diagnosed with pre-hypertensive and obesity [33] (Table 1).

The methodological evaluation indicated that the quality of the studies was moderate risk of bias (mean score: 6.7 ± 1.0; variation from five to eight; Table 1). Among the studies, two were classified as high risk of bias, 11 were classified as moderate risk of bias and four were classified as low risk of bias. Common limitations were related to the allocation, therapists, evaluator, and blind subjects to the intervention. Less than half of the studies (41.2%) randomly allocated individuals. Only five studies had a dropout rate of more than 15%.

The interventions used in the studies showed similarity. Most of the interventions had a frequency of three times per week that lasted four [35] and nine months [36]. Among the types of exercise training, studies were identified that conduct an intervention with moderate-intensity continuous training (MICT) [8, 11, 13, 21, 29, 31, 33, 34, 36, 38], high-intensity interval training (HIIT) [11, 21, 29, 35, 38, 39], moderate-intensity interval training (MIIT) [39], resistance training (RT) [28, 34, 37], functional training (FT) [28, 32], combined training (CT) [27, 37], recreational soccer program (RSP) [30] and who presented a control group without exercise [8, 11, 13, 21, 29, 30, 32–34, 36, 39]. The training protocols are detailed in Tables 2 and 3.

The metanalysis was carried out based on data from 1,125 participants in the different studies. In Fig. 2, the results for systolic blood pressure (SPB) after the interventions with different physical exercise we observed a summary effect of -0.44 (95% CI: -0.68; -0.20, $I^2 = 73\%$) (Fig. 2). In Fig. 3, the results of diastolic blood pressure (DBP) resulted in a summary effect of -0.52 (95% CI: -0.73; -0.31, $I^2 = 63\%$). In Fig. 4, the results of the control group without exercise for SPB and DBP resulted in a summary effect of -0.01 (95% CI: -0.19; 0.16, $I^2 = 8\%$) and effect of -0.01 (95% CI: -0.23; 0.20, $I^2 = 19\%$), respectively.

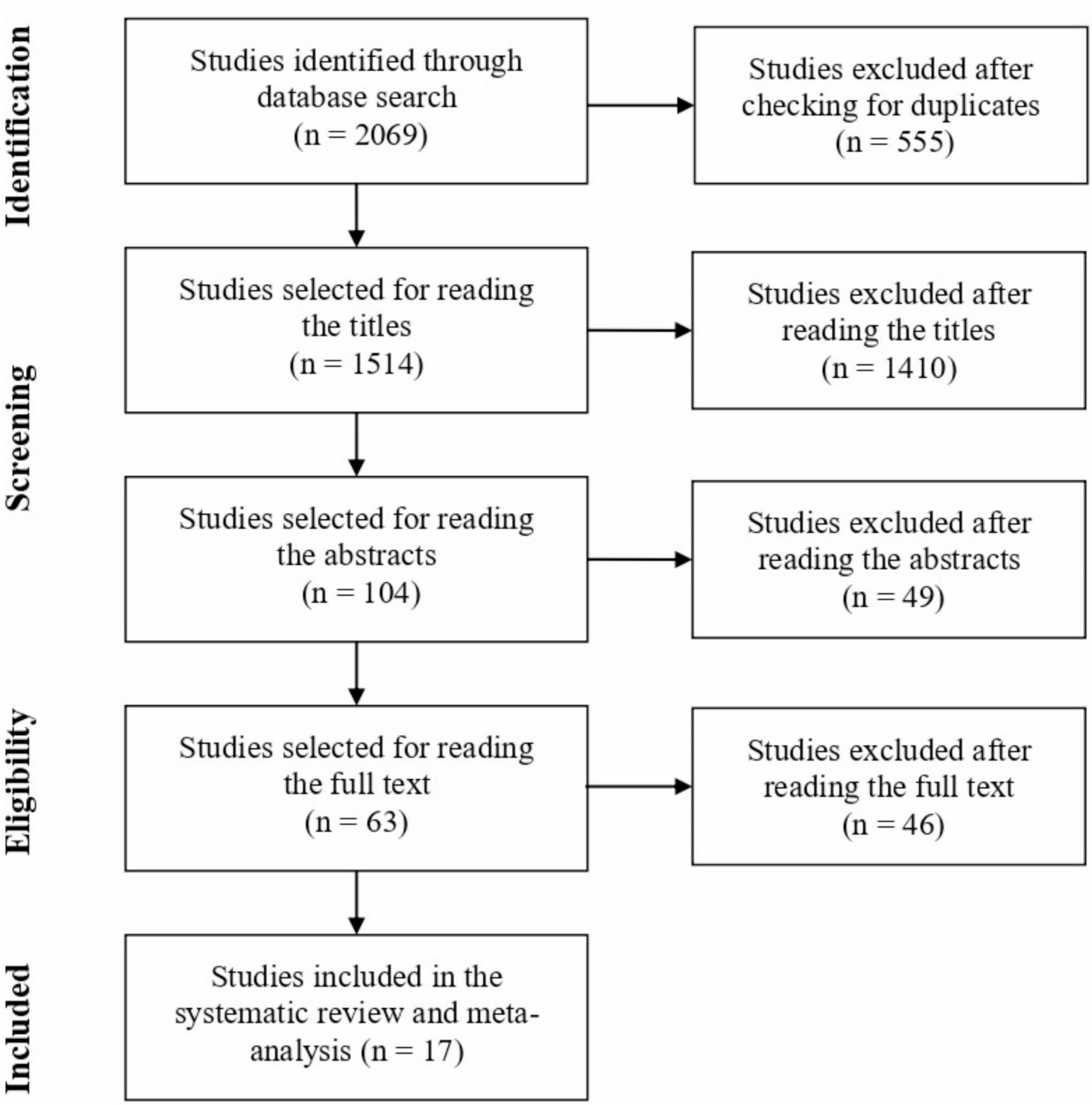

Fig. 1 Flow of information the phases of the systematic review and meta-analysis

A significant relative risk was observed to decrease the PAS for the general effect of the MICT (SMD=-0.65; 95%CI=-1.09; -0.21; $p=0.004$; $I^2=84\%$) and for the HIIT (SMD=-0.71; 95%CI=-1.33; -0.09; $p=0.02$; $I^2=71\%$). However, no significant relative risk effects were observed for the CT (SMD=-0.05; 95%CI=-0.38; 0.29; $p=0.79$; $I^2=0\%$) and other types of exercise (SMD=-0.08; 95%CI=-0.33; 0.17; $p=0.53$; $I^2=0\%$), with significant differences between the subgroups (Chi^2=8.46; $p=0.04$; I^2=64.5%) (Fig. 2).

A significant relative risk was observed to decrease the PAD for the general effect of the MICT (SMD=-0.62; 95%CI=-0.93; -0.32; $p<0.001$; $I^2=65\%$) and for the HIIT (SMD=-0.88; 95%CI=-1.50; -0.25; $p=0.006$; $I^2=70\%$). However, no significant relative risk effects were observed for the CT (SMD=-0.32; 95%CI=-0.68; 0.04; $p=0.08$; $I^2=13\%$) and other types of exercise (SMD=-0.18; 95%CI=-0.61; 0.26; $p=0.42$; $I^2=60\%$), no significant differences between the subgroups (Chi^2=4.99; $p=0.17$; I^2=39.9%) (Fig. 3).

Table 1 Descriptive information on the studies included in the systematic review and meta-analysis

Reference	Place of study (year)	Sex / Age	Groups	Primary outcome	Risk of bias
Aguilar-Cordero et al. [36]	Spain (2019)	♀♂ 10–15 yrs	MICT (n = 49), CG (n = 49)	Overweight/obesity	Moderate
Antunes et al. [27]	Brazil (2020)	♀♂ 12–15 yrs	CT (RT + MICT): ♀/10w (n = 12) – 20w (n = 12), ♂/10w (n = 13) – 20w (n = 13)	Obesity	Moderate
Branco et al. [28]	Brazil (2018)	♂ 11–16 yrs	RT (n = 09), FT (n = 09)	Obesity	Moderate
Fanelli et al. [37]	Italy (2021)	♀♂ 14–20 yrs	RT (n = 10), CT (RT + MICT, n = 10)	Overweight/obesity	Low
Horner et al. [34]	United States (2015)	♀♂ 12–18 yrs	MICT (n = 30), RT (n = 27), GC (n = 24)	Obesity	Low
Kargarfard et al. [38]	Iran (2016)	♀♂ 10–14 yrs	MICT (n = 10), HIIT (n = 10), CG (n = 10)	Obesity	Low
Kim et al. [31]	Korea (2020)	♀♂ 14–16 yrs	MICT (n = 24), CG (n = 24)	Pre-hypertensive, hyperinsulinemia, obesity	High
Lee; Spector; Reilly [35]	United States (2016)	♀♂ 11–17 yrs	HIIT (n = 12)	Overweight/obesity	Moderate
Leite et al. [29]	Brazil (2022)	♂ 10–17 yrs	MICT (n = 20), HIIT (n = 20), GC (n = 16)	Obesity	Moderate
Leite et al. [8]	Brazil (2023)	♀♂ 10–16 yrs	MICT 12w (n = 55), MICT 24w (n = 27), GC (n = 17)	Overweight/obesity	Moderate
Leite et al. [21]	Brazil (2024)	♂ 10–17 yrs	GEN (n = 55), GEH (n = 26), GCN (n = 14), GCH (n = 12)	Overweight, hypertensive	Moderate
Racil et al. [39]	Tunisia (2016)	♀ 13–15 yrs	MIIT (n = 17), HIIT (n = 16), CG (n = 14)	Obesity	Low
Seo et al. [32]	Korea (2019)	♀♂ 6–16 yrs	MICT (n = 26), Usual care group (n = 44)	Overweight/obesity	Moderate
Sung et al. [33]	Korea (2019)	♀♂ 14–16 yrs	MICT (n = 20), CG (n = 20)	Pre-hypertensive, obesity	High
Tadiotto et al. [11]	Brazil (2023)	♀♂ 11–16 yrs	HIIT (n = 13), MICT (n = 15), CG (n = 24)	Overweight/obesity	Moderate
Tornquist et al. [13]	Brazil (2020)	♀♂ 11–17 yrs	MICT (n = 23), CG (n = 23)	Overweight/obesity	Moderate
Vasconcellos et al. [30]	Brazil (2015)	♀♂ 12–17 yrs	RSP (n = 10), CG (n = 10)	Obesity	Moderate

♀ = girls; ♂ = boys; n = sample; RT = resistance training; CT = combined training; MICT = moderate-intensity continuous training; HIIT = high-intensity interval training; CG = control group; FT = functional training, MIIT = moderate-intensity interval training; RSP = recreational soccer program; GEN = group exercise non-hypertensive; GEH = group exercise hypertensive; GCN = group control non-hypertensive; GCH = group control hypertensive

Discussion

The purpose of this systematic review was to see what evidence is available on the effects of different exercise programs on blood pressure in overweight and/or obese children and adolescents. It should be noted that metabolic alterations are associated with greater body mass and are linked to increased blood pressure [9, 40, 41]. Clinical interventions to reduce blood pressure are essential in adults [40, 41] and in children and adolescents as primary [7] and secondary health prevention in hypertensive patients [21]. In the population of children and adolescents, the effects of exercise on blood pressure and hypertensive measures are relevant and have some scientific lacunae, since several studies have been found approaching cardiometabolic risk factors in this population [21, 42], but there is a scarcity in relation to the responses of different interventions and exercise programs on blood pressure.

In our review of the literature, considering publications from the last ten years, only 17 articles were analyzed in full because they met the inclusion criteria, all of which were carried out on overweight children and adolescents and evaluated the effect of different exercise programs on systolic and diastolic blood pressure. However, the studies selected were heterogeneous in their methods in terms of the characteristics of the exercises, i.e. in relation to the type and intensity, duration of the session, weekly frequency and intervention time of the exercises, known as FITT (frequency, intensity, time and type) [43]. In the specific articles in this review, the total sample size was 458 and ranged from nine [28] to fifty-five participants [21]. In addition, for this review we chose to select interventions with an age range of between six and 17 years, with only one study including children aged six and over [32], the rest were equal to or older than 10 years.

Among the intervention protocols applied, the studies involved controlled exercise, which included frequency, duration and intensity, and although they were different protocols, positive changes were observed in the variables studied. Heart rate was used as a criterion for monitoring the intensity of physical exercise in most of the articles evaluated, given its importance as an indicator of the intensity of physical activity in children and adolescents [44]. Furthermore, it is important to note that among the training protocols, MICT was the most frequently used exercise protocol (53%) and was used in nine studies [8, 11, 13, 21, 29, 31, 33, 34, 38], standing out in the prevention of cardiometabolic diseases. MICT has been considered the most suitable type of exercise for overweight and/or obese individuals in children, adults and the elderly, and localized exercise has been included as a complement [43].

Table 2 Descriptive information on the types of physical exercise in the studies included in the systematic review and meta-analysis

Reference	Intensity	Volume (week) + session (min)	Protocol exercise	Duration
Aguilar-Cordero et al. [36]	No info available	4 sessions (90′)	Games and sports appropriate to capacities, with a largely aerobic component and involving little jumping, structured as a warm-up, main activity and cool down	39wks
Antunes et al. [27]	RT = 40–55% of 10RM + MICT = 65–85% HR_{max}	CT = 3 sessions (30′ RT + 30′ MICT)	RT = 8 exercises, 1 set, 15–20 reps, 1–2′ rest + MICT = walk/running	10wks 20wks
Branco et al. [28]	RT = 12–14 RPE; FT = 12–14 RPE;	3 sessions (alternating in trainings A and B)	1st to 6th week, moderate-intensity resistance exercises; 7th to 12th week, high-intensity resistance exercises were used in an "all-out" mode (3 sets, passive rest interval)	12wks
Fanelli et al. [37]	RT = weight / (1.0278–0.0278 × rep) CT = 50–60% HR_{max}	RT = 2 sessions (30–35′) CT = 2 sessions (30–35′)	RT = 8 exercises, 3 set, constant load CT = (RT + 30′ MICT - stationary bicycle or elliptical machine)	24wks
Horner et al. [34]	MICT = 60–75% VO_{2peak} RT = ?	MICT = 3 sessions (60′) RT = 3 sessions (60′)	MICT = treadmill, elliptical or stationary bike RT = 10 exercises, 2 sets, 8–12 reps	12wks
Kargarfard et al. [38]	MICT = 60–95% HR_{res} HIIT = 60–90% HR_{res}	MICT = 3 sessions (50–60′) HIIT = (50–60′)	MICT = running on a treadmill HIIT = 4′ (60–70% HR_{res}) + 2′ (40–50% HR_{res})	8wks
Kim et al. [31]	MICT = 40–70% HR_{res} / 11–16 RPE	MICT = 5 sessions (50′)	7 rope jumping exercises	12wks
Lee; Spector; Reilly [35]	HIIT = 80–90% HR_{max}	HIIT = 3 sessions (30′)	HIIT = 10 sets, 60″ cycling, 90″ 40–50% HR_{max}	4wks
Leite et al. [29]	MICT = 35–75% HR_{res} HIIT = 100% MAS	MICT = 3 sessions (110′) HIIT = 3 sessions (45–48′)	MICT = 45′ indoor cycling, 45′ walking, 20′ stretching HIIT = 2 sets, 8 rep 30″ maximum effort, 30–60″ active recovery, 4′ passive rest between sets - running	12wks

′ = minutes; ″ = seconds; rep = repetitions; RT = resistance training; MICT = moderate-intensity continuous training; 10RM = 10 repetition maximum; HR_{max} = maximum heart rate; CT = combined training; FT = functional training; RPE = rating of perceived exertion; VO_{2peak} = peak oxygen uptake; HIIT = high-intensity interval training; HR_{res} = reserve heart rate

However, in recent years HIIT has been the subject of several studies as an alternative to health promotion [45–47], and one study using HIIT was selected in this review [35]. Four studies (27%) chose to compare interventions with MICT and HIIT in the same study [11, 29, 38, 39], as a way of comparing the interventions, or in the same group, but at different times, as an alternative to evolving the training method [28]. Finally, two studies [30, 36] proposed sports-related training protocols for overweight children and adolescents.

In general, it is suggested that a longer period of intervention provides greater benefits [48], as well as greater adherence to physical activity in everyday life [49]. However, a period of four to 12 weeks has been indicated as the period in which the greatest benefits appear [48], and at 24 weeks there is a tendency to maintain the effects achieved in the first 12 weeks [8]. However, another review reported better results in body composition, metabolic and inflammatory parameters after 24 weeks [50]. It should be noted that intervention time is one of the components in the FITT prescription, and the frequency of exercises has been indicated as three times a week, in sessions of around 60 min, and the favorable results are more evident after 1500 min of practice in different programs [48].

In the current review, most of the studies were conducted over 12 weeks, while one study was conducted over four weeks [35] and three studies were conducted over a longer period, with exercise over six months [13, 37] and nine months [36]. Most of the selected studies (94%) reached the minimum time of 12 weeks, the time cited to achieve the effectiveness of the interventions. It should be emphasized that studies lasting longer than 24 weeks obtained similar results to those lasting 12 weeks. Therefore, there were no major effects and no significant

Table 3 Descriptive information on the types of physical exercise in the studies included in the systematic review and meta-analysis (continued)

Reference	Intensity	Volume (week) + session (min)	Protocol exercise	Duration
Leite et al. [8]	MICT = 35–75% HR_{res}	MICT = 3 sessions (110′)	MICT = 45′ indoor cycling, 45′ walking, 20′ stretching	12wks 24wks
Leite et al. [21]	MICT = 35–75% HR_{res} HIIT = 85–100% HR_{res}	MICT = 3 sessions (60′) HIIT = 3 sessions (35–45′)	MICT = indoor cycling or aquatic environment HIIT = 2 sets, 4 rep 30″ maximum effort, 60″ active recovery (50% HR_{res}), 4′ passive rest between sets–aquatic/stationary bicycle/running	12wks
Racil et al. [39]	MIIT = 80% MAS HIIT = 100% MAS	MIIT = 3 sessions (40–50′) HIIT = 3 sessions (40–50′)	MICT = 3 sets, 15′ at 80% MAS, 15′ at 50% MAS HIIT = 3 sets, 15′ at 80% MAS, 15″ at 50% MAS	12wks
Seo et al. [32]	FT– 60–90% HR_{max} + MICT	3 sessions (one group exercise session and two home-based exercise sessions)	FT – 60′, 6 exercises, 1′ duration, 30–60″ recovery) (Home: FT + 30′ running/cycling	12wks
Sung et al. [33]	MICT = 40–70% HR_{res} / 11–16 RPE	MICT = 5 sessions (50′)	7 rope jumping exercises	12wks
Tadiotto et al. [11]	HIIT = 80–100% HR_{res} MICT = 35–75% HR_{res}	HIIT = 3 sessions (35′ stationary bicycle) MICT = 3 sessions (60′ stationary bicycle)	HIIT = 3 sets, 4 rep 30″ maximum effort, 60″ active recovery, 4′ passive rest between sets	12wks
Tornquist et al. [13]	MICT = 50–70% HR_{max}	MICT = 3 sessions (40′)	(1st: sports activity; 2nd: walking and resistance exercises; 3rd: aquatic activities)	24wks
Vasconcellos et al. [30]	RSP = 80–88% HR_{max}	RSP = 3 sessions (60′)	Recreational soccer program	12wks

′ = minutes; ″ = seconds; rep = repetitions; MICT = moderate-intensity continuous training; HIIT = high-intensity interval training; HR_{res} = reserve heart rate; MAS = maximal aerobic speed; MIIT = moderate-intensity interval training; FT = functional training; RPE = rating of perceived exertion; HR_{max} = maximum heart rate; RSP = recreational soccer program

differences in duration between the exercises. However, some studies showed less significant effects than others, which may be directly related to the training protocol and not to the duration of the intervention, as observed in studies in which adolescents participated in sports and walking sessions [13] and recreational soccer programs [30]. This may show that some of the activities proposed in the protocols may be more difficult to control the intensity of, as they depend largely on the physical capacity, assimilation and adaptation, as well as the final performance of the participant. On the other hand, the study by Lee et al. [35], which took the shortest time to conduct (4 weeks), showed a significantly positive result, which may demonstrate the rapid effect of interrupting a sedentary routine in overweight children and adolescents.

Regarding the results of the physical exercise programs in this review, the majority showed an improvement in blood pressure values in SBP (SMD=-0.44; 95% CI=-0.68; -0.20; $p = 0.04$; $I^2 = 73\%$) and DPB (SMD=-0.52; 95% CI=-0.73; -0.31; $p = 0{,}17$; $I^2 = 63\%$), which confirms the importance of physical activity as a crucial factor in improving health parameters. Four interventions resulted in a significant and statistically significant reduction in SBP [31, 33, 38, 39], while eight studies in DBP [11, 31, 33, 37–39]. The studies that used a protocol of progression of the intensity of exercise over the course of weeks stand out, and in the end, obtained notably positive results [31, 38]. However, some studies have not shown a significant reduction in SBP [11, 27, 34], despite being well protocoled and with uniformity among the participants, probably due to the variety of factors that can influence SBP, such as white coat hypertension, a factor well described and studied in medicine [41], which is difficult to control in children and adolescents [51].

Most of the studies showed a significant reduction in DBP in the population studied, an effect that may be related to a reduction in peripheral vascular resistance, closely linked to the DBP value, as a result of the adaptive action provided by regular physical exercise, especially in its action on the sympathetic nervous system, through a reduction in noradrenaline and an increase in prostaglandins in the peripheral blood [52, 53]. The deleterious effect of not practicing regular physical exercise is noteworthy, since SBP and DBP values remained the same in the control group, whose children and adolescents were instructed not to take part in weight loss programs or assisted physical training.

The results found reinforce the positive impact of structured exercise programs on blood pressure in overweight and obese children and adolescents. It is important to note that the effectiveness of these interventions seems to be directly related to the duration, intensity and type of exercise proposed. Although longer interventions did not demonstrate greater benefits than the 12-week

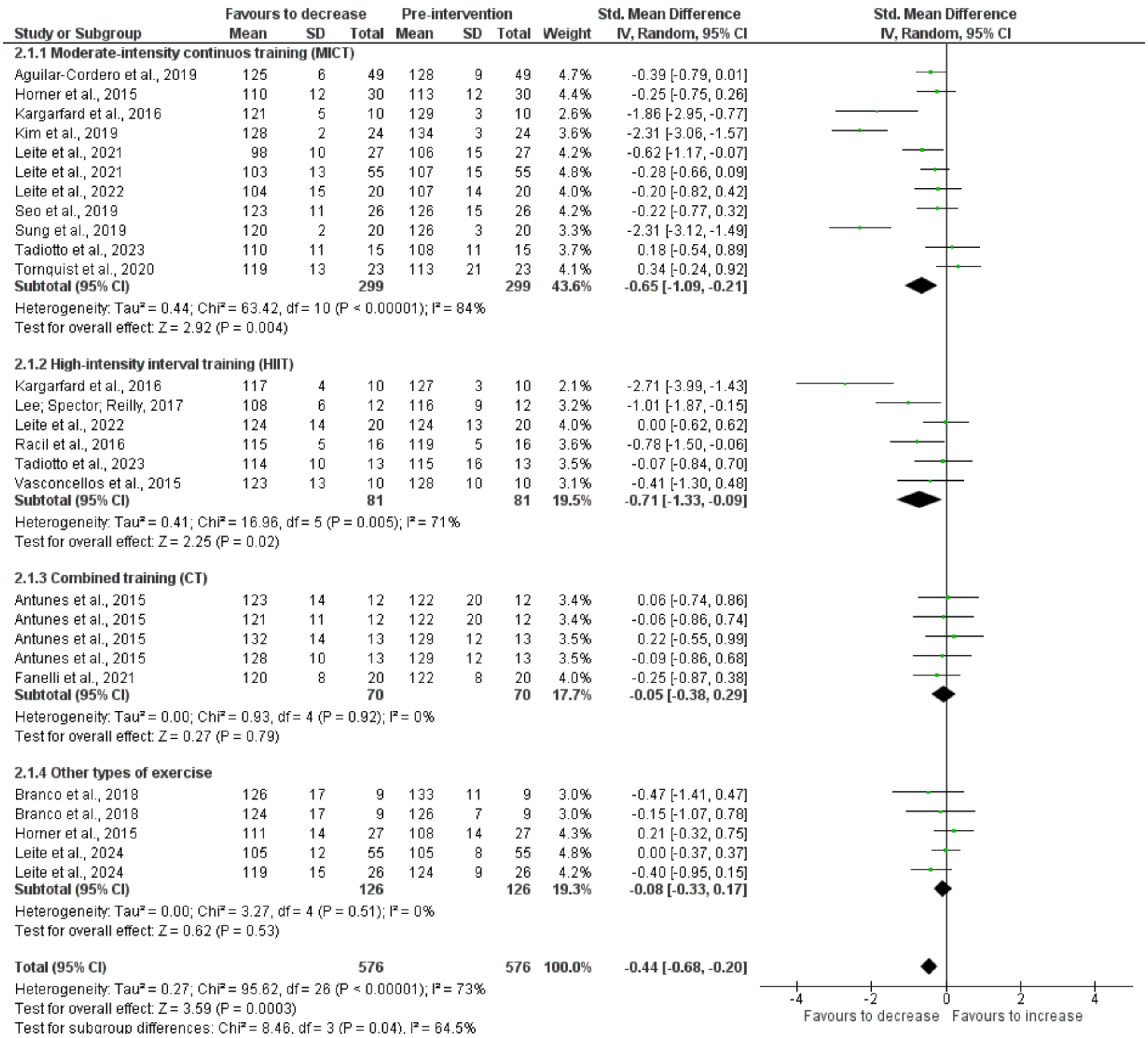

Fig. 2 Forest graph with comparison of the effect of exercise interventions intra- and inter-subgroups on systolic blood pressure in children and adolescents

programs, adherence and appropriate intensity control were crucial factors for better results. Therefore, these findings highlight the need for well-structured exercise programs to maximize cardiometabolic health benefits in this population.

Strengths and limitations

The present study also presents some limitations to be observed. First, there was a 10-yr publication time limitation. Secondly, the research was conducted and limited to articles published in journals indexed in the electronic bases PubMed, Web of Science, Scopus, SPORTDiscus, LILACS, and SciELO. It may be that some studies published before 2014 that address this issue were not included in this review. Furthermore, during the search strategy, we did not include the term physical activity. As a result, it is possible that studies investigating the effects of physical activity (when not described as exercise or physical training) on blood pressure were excluded from the analysis.

Moreover, limitations in the analysis should also be highlighted. There was significant heterogeneity for the intervention subgroups that can be explained by the moderate methodological quality of the studies of which approximately 76.5% of the studies presented moderate or high risk of bias while only four presented low risk of bias. Therefore, the findings of the present study should be interpreted with caution. Another important point

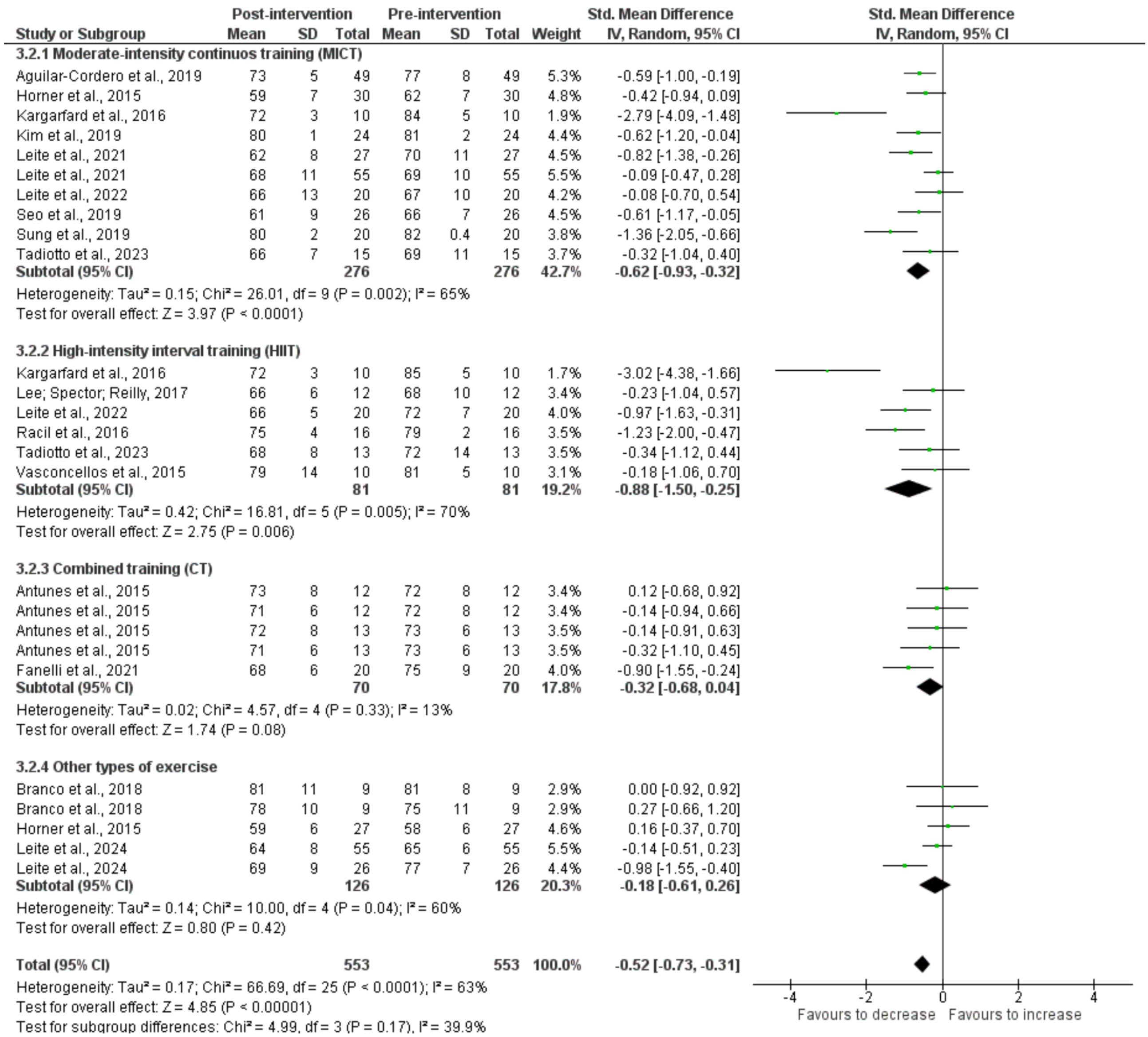

Fig. 3 Forest graph with comparison of the effect of exercise interventions intra- and inter-subgroups on diastolic blood pressure in children and adolescents

observed was the lack of investigations with well-controlled methodologies on the effects of exercises on pre-hypertension and hypertension. Therefore, it is important that more studies are conducted with more methodological control and a more detailed description of the exercise protocols.

Conclusion

In this systematic review and meta-analysis, the regular practice of physical exercise was relevant in reducing systolic and diastolic blood pressure, a factor that lends credence to the importance of physical activity in overweight and obese children and adolescents in the prevention and treatment of hypertension and cardiometabolic risk factors. Regarding the types of exercise, we highlight the results found in exercise programs involving moderate-intensity continuous training or high-intensity interval training, while the lack of exercise led to unfavorable changes in blood pressure.

Considering the significant effects on blood pressure, we suggest the development of interventions based on physical exercise practice lasting at least 12 weeks, with three 60-minute sessions per week, and including control of exercise intensity, preferably monitored by heart rate and intensity progression over time, considering that other types of exercise do not have a significant effect. The implementation of these programs should be multicomponent and multiprofessional, with the participation

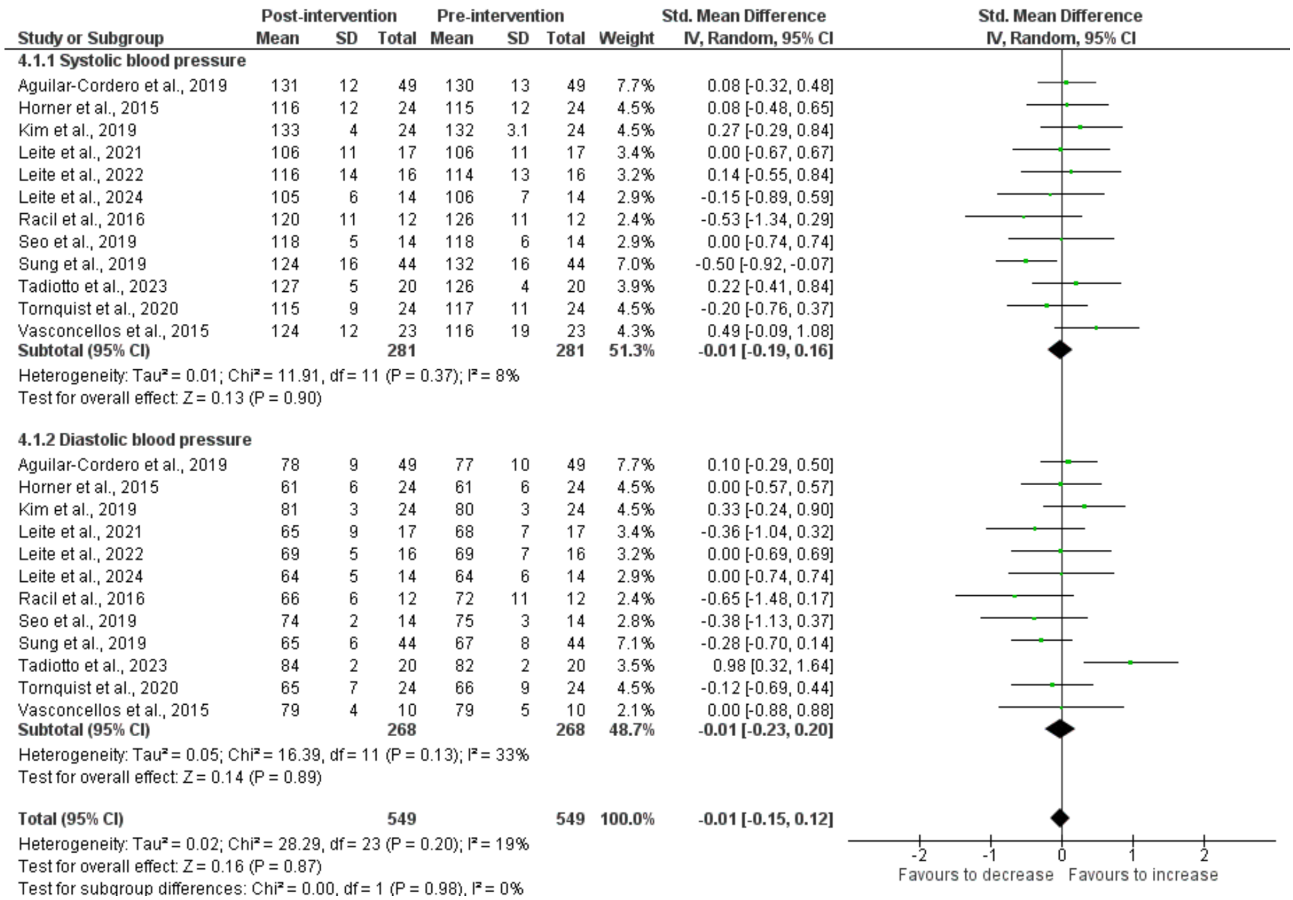

Fig. 4 Forest graph with comparison of the effect of interventions in the control group on systolic blood pressure and diastolic blood pressure in children and adolescents

of different health professionals, and should take place in accessible environments and with continuous social support. These strategies aim to guarantee adherence and promote significant and sustainable changes in the cardiovascular health of overweight and obese children and adolescents.

Abbreviations

BP	Blood pressure
DBP	Diastolic blood pressure
HIIT	High-intensity interval training
LILACS	Latin American and Caribbean Literature in Health Sciences
MICT	Moderate-intensity continuous training
MVPA	Moderate to vigorous physical activity
SBP	Systolic blood pressure
SciELO	Scientific Electronic Library Online
SMD	Standardized mean difference

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Author contributions
The manuscript was written by JVAT, MCT, TAAT, and NL, as well as revised by FJMJ, JM, BOP, and RR. Conceptualization: MCT, FJMJ, and NL. Methodology: MCT, FJMJ, and NL. Literature search: JVAT, and TAAT. Data extraction: JVAT, MCT, and TAAT. Data analysis and interpretation: JVAT, MCT, TAAT, and NL. Supervision: NL, JM, BOP, and RR. All approved the final version submitted.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Conflict of interest
The authors declare no conflicts of interest and they do not have professional relationships with companies that will benefit from the results of this study.

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