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IMPACT OF MOTION SENSOR-ENHANCED PHYSICAL ACTIVITY PROGRAMS ON ADOLESCENTS' CARDIOMETABOLIC HEALTH – A SYSTEMATIC REVIEW

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ABSTRACT

Objective: *The purpose of this research was to thoroughly evaluate the impact of motion sensor-enhanced physical activity programs on adolescents' cardiometabolic health (whether they had access to mHealth technology). Methods: Using predetermined criteria for population (adolescents, youth), intervention (exercise, physical activity) and outcomes, electronic databases in PubMed, Scopus, Cochrane Library, Lilacs, Web of Science, and SPORT Discus were searched (smartphone, mobile applications, pedometer, step counter, motion sensor). Studies that used some kind of organized or unstructured physical activity intervention using motion sensors that provided feedback for self-monitoring in order to improve cardiometabolic health in teens were included (12-18 years). The risk of bias was evaluated using the Cochrane method. Using the program Review Manager 5.3, the meta-analysis was completed. There was a total of four randomized controlled trials in the meta-analysis. Results: A total of 12 papers satisfied the criteria for inclusion, and the meta-analysis looked at 6 of those articles. The review's findings showed that pedometers were the motion sensor most often used in intervention studies. The meta-analysis revealed that during physical activity treatments using motion sensors for self-monitoring and lasting longer than six months, body mass index, body mass index z-score, and body fat reduced for the intervention group compared to the control group. The pedometer was the motion sensor most often employed in intervention studies, according to this systematic review and meta-analysis. Additionally, the results for body composition were a summary of the results from the motion sensor-assisted physical activity interventions used in this analysis to address cardiometabolic risk factors.*

Keywords: step count; overweight; health promotion; youth; motor activity

1. INTRODUCTION

For children and adolescents, regular physical activity (PA) has been related to a number of health benefits, including improvements in the cardiometabolic profile, skeletal, physiological, and mental health (Hallel et al., 2006; WHO, 2010). According to estimates, just 19% of school-aged teenagers (ages 11 to 17) engage in the recommended amounts of physical exercise (WHO, 2010; Committee, 2018). Despite the fact that the guidelines encourage children and teenagers to do at least 60 minutes of moderate to vigorous PA each day, this is the case.

Longitudinal studies have shown that the teenage year is a pivotal period for the establishment and consolidation of life habits since variations in PA level during adolescence tend to carry over into adulthood (Van Dijk et al., 2016; Harding et al., 2015; Silva et al., 2018; Azevedo et al., 2007). In response to their greater access to technology, research has shown that utilising technologies like text messaging, social networks, sensors, wristbands, and smartphone applications influences young people's physical activity (Badawy et al., 2016; Badawy and Barrera, 2017; Gal et al., 2018).

The pedometer has shown potential as a tool of promoting PA in teens, according to systematic studies (Lubans et al., 2009) that looked at the influence of interventions on the quantity of habitual PA. Using smartphone applications and wearables, current advancements in mobile health (mHealth) technology make it feasible to assess physical activity quickly and precisely (Case et al., 2015). Although research indicates that employing motion sensors boosts PA in this population, studies that take into consideration cardiometabolic risk factors are still lacking (glycemic profile, lipid profile, inflammatory markers, and blood pressure). Physical activity (PA) is a significant modifiable determinant and those with high levels of PA exhibit a healthier cardiometabolic profile, according to epidemiological studies (Tarp et al., 2018; Ekelund et al., 2012). These studies have shown a relationship between PA and cardiometabolic risk factors.

The current study's goals are to (1) thoroughly evaluate PA treatments using motion sensors (with or without access to mHealth technology) to enhance cardiometabolic health in teenagers, and (2) statistically analyze intervention outcomes.

2. METHODS

This systematic review was elaborated according to the PRISMA recommendation (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher et al., 2009)

2.1 SEARCH STRATEGY

The Cochrane Library, PubMed, Scopus, Lilacs, Web of Science, and SPORT Discus were among the databases that were searched for this systematic review. All of these searches were carried out in addition to searches of the grey literature and clinical trials. The initial search was done without considering the language or the publication dates to make sure that all potentially relevant items were discovered.

The demography (young people, youth, boys, and girls), intervention (exercise, physical activity), and results were the MeSH search phrases or keywords used (smartphone, mobile applications, pedometer, step counter, motion sensor). The references list of the publications that were used in this research were also looked through for any pertinent studies.

2.2 ELIGIBILITY CRITERIA AND SELECTION OF STUDIES

Studies were included if they satisfied the following requirements: adolescents (12–18 years old); ii) study design: quasi-experimental or randomized controlled trial; iii) type of intervention: structured or unstructured physical activity intervention with motion sensors that provided feedback for self-monitoring (with or without access to mHealth technology); iv) primary outcomes: quantitative assessment of cardiometabolic risk factors (body mass index, waist circumference, glycemic and lipid profile, blood pressure, and blood sugar levels).

Articles were disqualified if they displayed any of the following traits: I observational studies; (ii) motion sensor-free physical activity treatments; (iii) adolescents in the control group received a systematized physical activity intervention (exercise, training); and (iv) a sample made up of children, adults, and/or older persons.

The duplicates were eliminated when the articles were identified. Following a title and abstract screening by two independent reviewers (G.C.S. and A.S.N.), papers that did not match the inclusion criteria were eliminated. Independent reviewers studied the complete texts of potentially qualifying papers in order to assess them (G.C.S and A.S.N). Article inclusion disputes were settled by consensus or by talking to a third reviewer (S.O.P).

2.3 DATA EXTRACTION

Two separate reviewers (G.C.S. and A.S.N.) independently extracted data from the included studies using an EXCEL form. Consensus was reached about the disagreements, or a third reviewer was consulted (S.O.P). The following factors were taken out of the study: author and year of the study, research design, sample size (participants' ages, sexes, and numbers), measurement of outcomes, description of the intervention, length of the intervention, and key findings.

2.4 RISK OF BIAS

Each included study's risk of bias was evaluated by two independent reviewers (G.C.S and A.S.N). According to Higgins and Green (2011), five Cochrane tool domains—sequence creation, allocation concealment, blinding, inadequate outcome data, and selective outcome reporting—were used to assess the study's quality. Each domain was given a risk of bias rating of low, uncertain, moderate, or high.

2.5 STATISTICAL ANALYSIS

The measurements of body mass index (BMI), body fat percentage (percent BF), and waist circumference were altered between the pre- and post-intervention periods as a consequence (WC). The premise for assessing the intervention's effectiveness was the variation between the intervention and control groups. Using the inverse variance technique and the random effect model, the meta-analysis takes into consideration the duration of the intervention and the kind of outcome variable. Mean differences (MD) and 95 percent confidence intervals were calculated using the Review Manager application (RevMan 5.3). (RevMan, 2014). The effect sizes of the mean differences were calculated based on the Cohen16 classification. The degree of variability in the estimate of the impact that can be attributable to statistical heterogeneity rather than chance was measured using the Higgins inconsistency test, often known as I2. I2 may be translated into three different categories: low, tolerable heterogeneity (25%), moderate heterogeneity (25%), and excessive heterogeneity (> 50%). 2003 (Higgins JP).

3. RESULTS

A computerized search turned up 5,095 items, and 91 complete articles were selected for eligibility review (FIGURE 1). After full reading, 79 manuscripts were excluded, totaling 12 articles for the systematic review (Conwell et al., 2010; Ermetici et al., 2016; Kantanista et al., 2014; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Mameli et al., 2016; Manley et al., 2014; Martínez López, 2016; Schofield et al., 2005; Staiano et al., 2017; Isensee et al., 2018) and 6 of these were included in the meta-analysis.

We addressed the authors of the five randomized controlled trials that were included into the meta-analysis to inquire further about the data relevant to the results. Two of the writers remained silent.

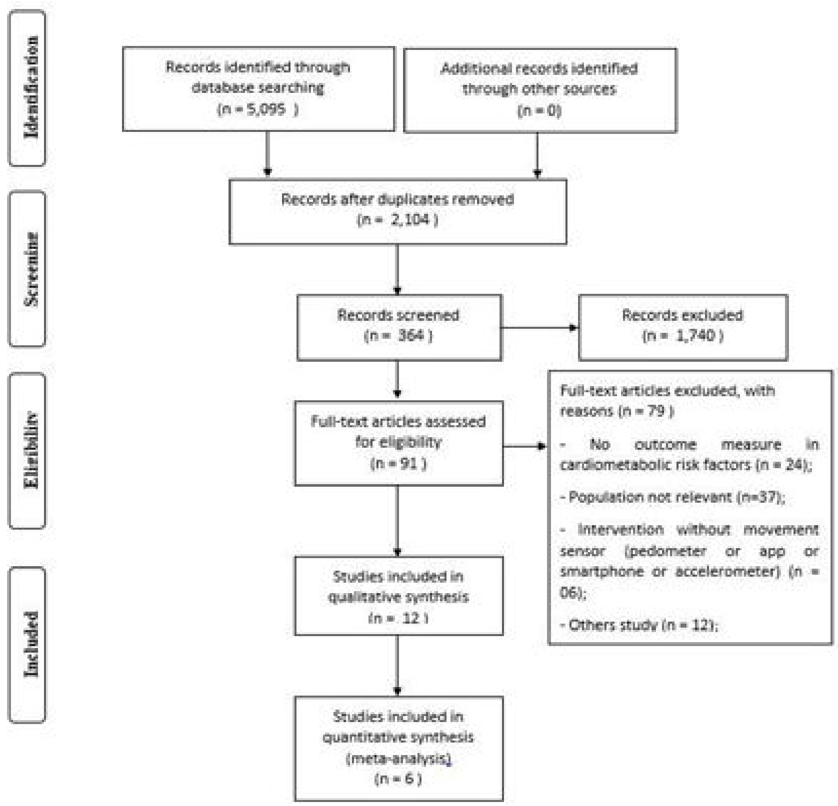

Figure 1: Flow diagram of trial selection, adapted from PRISMA. APP: application.

3.1 CHARACTERISTICS OF THE INCLUDED STUDIES

Additional details on the characteristics of the included studies are provided in TABLE 1. The systematic review included 12 trials with 2,850 teens in total, ranging in age from 8 - 18. Regarding the study designs, there were three quasi-experimental studies (Ermetici et al., 2016; Schofield, 2018; Isensee et al., 2018; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Mameli et al., 2016; Manley et al., 2014; Martnez López, 2016), seven randomised clinical trials (RCTs (Conwell et al., 2010; Kantanista et al., 2014). Participants from both sexes were present in eight investigations, including those by Conwell et al. (2010), Ermetici et al. (2016), Isensee et al. (2018), Mameli et al. (2016), Manley et al. (2014), Martnez López (2016), Schofield et al. (2005), and Staiano et al. (2017). All studies (Conwell et al., 2010, Ermetici et al., 2016, Isensee et al., 2018, Martnez López, 2016, Kantanista et al., 2014, Lubans et al., 2011, Lubans et al., 2012, Lubans et al., 2016, Manley et al., 2014, Schofield et al.) found that adding motion sensors boosted PA. While Lubans et al. (Lubans et al., 2016) utilised smartphone applications in addition to the pedometer to promote PA, Mameli et al. (Mameli et al., 2016) used a wristband as a motion sensor. Generic step objectives were used in two studies (Manley et al., 2014; Martnez López, 2016) to promote improvements in PA behaviour (for instance, attaining 12,000 and 15,000 steps per day for boys and girls, respectively). The school environment (teachers, counselling, and information) (Ermetici et al., 2016; Isensee et al., 2018; Lubans et al., 2011, 2012, 2016, and Manley et al., 2014); sessions and/or group meetings (Conwell et al., 2010, Schofield et al., 2005; Staiano et al., 2017); and text message (Ermetici) were additional components used in the interventions besides The duration of the treatments ranged from two months to two years. Eight studies (Ermetici et al., 2016; Isensee et al., 2018; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Manley et al., 2014; Martnez López, 2016; Schofield et al., 2005) did not perform any type of intervention for the control group, whereas in one study the control group received a diet intervention.

With respect to the main results found, 5 studies(Conwell et al., 2010; Ermetici et al., 2016; Isensee et al., 2018; Schofield et al., 2005; Staiano et al., 2017) found an increase in PA, 5 interventions observed a reduction in BMI (kg/m2)(Lubans et al., 2011; Lubans et al., 2012; Mameli et al., 2016; Martínez López, 2016; Staiano et al., 2017)and in BMI z-score(Ermetici et al., 2016; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Staiano et al., 2017) . Other studies (Mameli et al., 2016), Manley et al., 2014, Ermetici et al., 2016, and Conwell et al., 2010, reported decrease in body weight, waist-to-height ratio, relative body mass index, and insulin sensitivity. Two studies (Lubans et al., 2011; Lubans et al., 2012) reported a decrease in the percentage of body fat.

Table 1. Characteristics of included studies.

Study	Design	Sample	Outcome measures	Reference standard	Intervention description	Duration Intervention	Main results
Conwell et al., (2010)	Pre-experimental (home-based)	*n*= 18 adolescents; Aged: 8-18 years.	PA= Pedometer; Anthropometry/body composition=Weight; Height; BMI; WC; Cardiovascular risk factors= Blood pressure; Lipids and lipoproteins (TG; TC; HDL; LDL; VLDL); SI- insulin sensitivity	BMI > 30 kg/m2 (Cole et al., 2000).	IG= counseling sessions (identify PA preferences and strategies to overcome barriers); pedometer goals of 10% increase from baseline levels); social support (family members).	10 weeks	Statistically significant increases in PA (10 800 ±919 to 13 667±1117) and insulin sensitivity (1.52±0.19 to 2.02* ±0.27) between the baseline and post-intervention. No significant differences in the weight, height, BMI, WC, BP, lipids and lipoproteins.
Ermetici et al., (2016)	non-randomized controlled (quasi experimental) school-based)	*n*= 487 adolescents; IG= 262; CG= 225. Aged = 11-15 years.	PA: questionnaire and pedometer; Anthropometry (weight; height; BMI-z score; Waist circumference-WHtR); Diet indicators: questionnaire;	BMI z-scores using CDC growth (Cole et al., 2000).	IG= Multicomponent intervention (school environment; Reinforcement tools such as textbook; text messages; pedometer-based self-monitoring, encouraging step increase. CG: No intervention	2 years	In adolescents with overweight/obesity, there was an increase in PA (from 9,399±211 to 12,268±4701 daily steps, P = 0.01). The intervention was associated with a significant difference in BMI z-score between groups (-0.18±0.03, P<0.01) and WHtR (-0.04±0.002, P<0.001). Subgroup analysis with overweight/obesity showed an association between the intervention and the difference in BMI z-score for girls (-0.39; 95% CI [-0.56 to -0.22]) and for boys (-0.22; 95%CI [-0.42 to -0.03]); WHtR for girls (-0.04; 95% [-0.06 to -0.03]) and boys (-0.05 [-0.06 to -0.04]).

Isensee et al., (2018)	RCT (based-school)	*n* = 1020 adolescents; IG= 649 CG = 371 Aged: 12-15 years.	PA = Question about MVPA (days/week), out-of-school sports activities (hours/week) and Active transport/commuting (minutes/day) BC = BMI (weight and height), WC, Body fat (bioelectrical impedance) and waist-to-height ratio.	BMI calculated (weight/height^2) and converted into the age- and sex-specific percentiles using Cole's (1990).	IG = multi-component intervention: - Individual (pedometer for self-monitoring and interactive user account on the "läuft." homepage - document their steps and experiences); - class (educational and practical lessons, and competitions means of steps/week and to collect creative ideas on how to increase PA in everyday school life and to keep records of these ideas.); - parents (parent-teacher conference to emphasize the importance of physical activity and to support their children in establishing a physically active lifestyle); - school (information material, activity promoting teaching methods, suggestions on how to improve the school environment to stimulate physical activity).	12-week 1-year Follow-up	A significant interaction effect between time and group for all 3 indicators of PA was observed: intervention group showed an increase spent with at least 1 hour of MVPA, while the control group decreased; active commuting and out-of-school sports activities increased significantly in the intervention but not in the control group. In relation to body composition: BMI percentile and body fat increased in both groups, but body fat increased nearly twice in the control; there were statistically significant increases in time*group effect on the waist-to-height in the control adolescents, while the intervention group remained stable.
Kantanista et al., (2014)	Pre-experimental	*n* = 56 girls; IG= 28; CG = 28 Aged: 16-18 years.	PA = Pedometer (Yamax Digi-Walker SW 701) for 7 weeks. BC = body fat (Bodystat 1500) and BMI;		IG and CG = Pedometer (individual goals pre-determined progressively, from the execution of an additional 10% (in the first week) to 25% (at week 8) in the number of steps.	8 weeks	There were no significant group-by-time interaction effects in biological variables and number of steps per day.
Lubans et al., (2011)	RCT (based school)	*n* = 100 boys; IG= 50; CG = 50; Aged: 14-15 years	PA = Pedometer (Yamax CW200) for 5 days (4 consecutive school days and 1 weekend day). BC = weight; height; BMI; WC; body fat (Imp™SFB7bioelectrical impedance).	BMI z-scores were calculated using reference centiles (Cole et al., 2000).	IG = multi-component intervention: -Enhanced school sport sessions (PA and nutrition recommendations; structured PA) – 10 x 90 min; -Interactive seminars 3 × 30 min; -Lunch-time physical activity sessions: 8 × 30 min; -Physical activity and nutrition handbooks - 9 weeks; -Physical activity leadership sessions 6 × 30 min; -Pedometers for self-monitoring (6 months) CG = not intervention.	6 months	There were significant group-by-time interaction effects for BMI with mean difference between groups: [−0.8 (−1.2, −0.3)] (p<0.001, d=0.7); and BMI z-score: mean difference between groups: [−0.2 (−0.3, −0.1)] (p<0.001, d=0.7); Significant beneficial effects were found from baseline 6 months for body fat% mean difference between groups: [−1.8 (−3.5, −0.2)] (p< 0.04, d= 0.5). Reduction in the number of participants classified as overweight (20% to 8%) or obese (10% to 8%) in the intervention group.
Lubans et al., (2012)	RCT (based school)	*n* = 357 girls IG= 178; CG = 179 Aged = 12-14 years.	PA = Actigraph accelerometers (MTI models 7164, GT1M, and GT3X) for 7 consecutive days. BC = weight; height; BMI; WC; body fat (Imp™ SFB7 bioelectrical impedance).	BMI categories were based on BMI z scores (Cole., 2000)	IG = multi-component intervention: -Enhanced school sport sessions (PA and nutrition recommendations; structured PA): 60-80 min; - 3 Interactive seminars; -Lunch-time physical activity sessions; -Physical activity and nutrition handbooks; -Pedometers for self-monitoring; - parent newsletters (4 periods); - Text messaging for social support. CG = no intervention	12 months	Changes in body composition were all in favor of the intervention group, but there were no statistically significant between-group differences. Difference in change: BMI (95% CI) −0.19 (−0.70 to 0.33); BMI z-score (95% CI): −0.08 (−0.20 to 0.04); Body fat%(95% CI): −1.09 (−2.88 to 0.70).

Lubans et al., (2016)	RCT (based school)	*n* = 361 boys; IG = 181; CG = 180 Aged = 12-14 years.	PA = actigraph accelerometers (model GT3X); BC = BMI; BMI z score and WC.	BMI-z scores were determined using reference centiles (Cole et al., 2000).	IG = ATLAS intervention: -Teachers (workshops and fitness instructor session); -Parent (newsletters- 4 ×); - Students (Researcher-led seminars 3 × 20 min); - Enhanced school sport sessions (PA and nutrition recommendations; structured PA): 20 x 90 min; -Lunch-time physical activity sessions; -Smartphone application and website for physical activity monitoring and motivational messaging (15 weeks); - Pedometers for self-monitoring to set goals to increase their daily steps (17 weeks). CG = received the intervention following the 18-month assessments.	8 months Follow-up = 10 months post-intervention	There was some support for a positive effect among participants who were overweight or obese at baseline (*n*=129), as demonstrated by a reduction in BMI z-score (mean[95% CI]): - 0.13 [−0.23 to −0.03, p = 0.013], in the intervention group, compared to a smaller reduction among those in the control group -0.06 [-0.16 to 0.05, p = 0.292).
Mameli et al., (2016)	RCT	n = 43 adolescents IG = 16 CG = 14 Aged = 10 – 17 years.	BC = SDS of BMI (standard deviation scores): calculated using Italian reference data (Cacciari, 2006).	BMI ≥95th percentile (Cacciari, 2006)	IG = Mediterranean diet and instruction to practice PA and minimize sedentary activity; wristband (motion sensor) to measure EE; APP (real-time recording of food consumption); SMS (feedback on the diet and PA); CG = Mediterranean diet and instruction to practice PA and minimize sedentary activity.	3 months	Changes in weight and BMI (SDS) were - 0.06 kg (95%CI: 3.29 to 3.14, p = 0.96) for the IG vs. CG. Difference was in fact 0.07 kg (95%CI: 2.81 to 2.96, p = 0.96) and BMI (SDS) 0.01 kg (95%CI: 0.15 to 0.18, p = 0.87) for intervention.
Manley et al., (2014)	RCT	n = 116 adolescents; IG = 55; CG = 61; Aged: 11-13 years.	PA: Pedometer (Yamax Digiwalker 200) for 4 days; BC = BMI; BMI percentile; and relative body mass index (RBMI).	Overweight was defined as a BMI percentile between 85 and 94% (overweight) and BMI ≥95% (obese) (CDC,2000). RBMI =[BMI/(50th percentile BMI on CDC age-gender specific growth chart × 100].	IG = Pedometer (girls to achieve at least 12,000 and boys 15,000 steps each at school). Teachers (encourage the students and educate regarding the benefits of physical activity) CG = no intervention	12 week	Intervention group 8.71 reduction in RBMI compared to a 1.78 reduction in the control group.
MartínezLópez, (2016)	RCT	n = 102 adolescents; IG1 = 31; IG2 = 37; CG = 34; Aged=13.70± 1.47 years	PA = pedometer (Omron HJ-152-E); BC = BMI (weight and height);	BMI reference (Sobradillo, 2004).	IG 1 and 2 = girls to achieve at least 10,000 and boys 12,000 steps per day. CG = no intervention	6 weeks	Statistically significant reduction in BMI (27.95 ± 2.86 to 27.58 ± 2.91 kg/m^2, P= 0.000) in the IG and increase in the CG (27.83 ± 3.91 to 28.18 ± 3.76, P= 0.000) between the baseline and post-intervention.
Schofield et al., (2005)	quasi-experimental	*n* = 85 girls; IGP = 27; IGM = 28; CG = 30; Aged= 15 – 18 years.	PA = 4-days of pedometer seald (SW700 Yamax Digiwalker) and PA questionnaire. BC = BMI (weight and height) and WC; Blood pressure: Omron monitor.	BMI was determined using age-specific cut points for overweight and obesity (Cole, 2000).	Intervention (IGP and IGM) involving goal setting and self-monitoring using either time-based PA goals or step based PA goals. Weekly meetings to discuss PA, goals and barriers. Weekly meetings to discuss PA, goals and barriers. CG = no intervention.	12 weeks	Step-based intervention group significantly increased PA from baseline. There were no significant changes in any group for BMI.
Staiano et al., (2017)	quasi-experimental (family-based)	*n* = 105 adolescents; IGP = 25; IGP+G = 56; CG = 24 Aged = 8-17 years.	PA = Pedometer (Omron HJ-324U); BC = BMI (weight and height).	BMI z-score was calculated from the CDC (2016).	The groups received 10 sessions of 90 min. (PA, nutrition, and behavioral modification); IGP = session + pedometer for self-monitoring; IGP +G = session + pedometer with individualized step goals (500 steps/day).	10 weeks	IGP +G had a significantly greater reduction in weight (p = 0.045), BMI (p = 0.017), and BMI z-score (p = 0.012), compared with the CG. IGP+G increased on average 1185 (425) daily steps and IGP reduced by 162 (620) daily steps from baseline.

BC: body composition; BMI: body mass index; EE.: energy expenditure; CG: control group; IG: intervention group; IGP+G: pedometer intervention group with goals; IGP: pedometer intervention group; MVPA: moderate to vigorous physical activity; PA: physical activity; RBMI: ; RTC: WC: waist circumference.

3.2 RISK OF BIAS

The evaluation of the bias risk for the 12 included studies is shown in Figures 2 and 3. In the randomization area, five research showed a significant risk of bias (Conwell et al., 2010; Ermetici et al., 2016; Kantanista et al., 2014; Schofield et al., 2005; Staiano et al., 2017). It was determined that three research (Lubans et al., 2011, Martnez López, 2016, and Schofield et al., 2005) had an unknown risk of bias since they did not specify how concealment of allocation was carried out. Five studies (Isensee et al., 2018; Lubans et al., 2012; Lubans et al., 2016; Mameli et al., 2016; Manley et al., 2014) showed minimal risk of bias in the allocation since concealment was carried out using concealed envelopes, a researcher who was not participating in the study, or using software. In the blinding area, two studies—Lubans et al. (2012) and Lubans et al. (2016)—were assessed as having low risk of bias, and five—Isensee et al. (2018), Mameli et al. (2016), Manley et al. (2014), Schofield et al. (2005), and Staiano et al. (2017)—were classified as having uncertain risk of bias.

In relation to the domain incomplete findings, 9 research were categorised as having low bias risk (Kantanista et al., 2014; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Mameli et al., 2016; Manley et al., 2014; Schofield et al., 2005; Isensee et al., 2018). Given that data from four investigations (Ermetici et al.,2016, Kantanista et al.,2014, Schofield et al.,2005, and Staiano et al.,2017) were not described in depth in the manuscript, the risk of bias for presenting selected outcomes was determined to be uncertain. One research had an unknown risk (Lubans et al., 2011), six studies had a high risk of bias (Conwell et al., 2010; Ermetici et al., 2016; Kantanista et al., 2014; Martnez López, 2016; Schofield et al., 2005; Staiano et al., 2017), and five studies had a low risk of bias (Lubans et al).

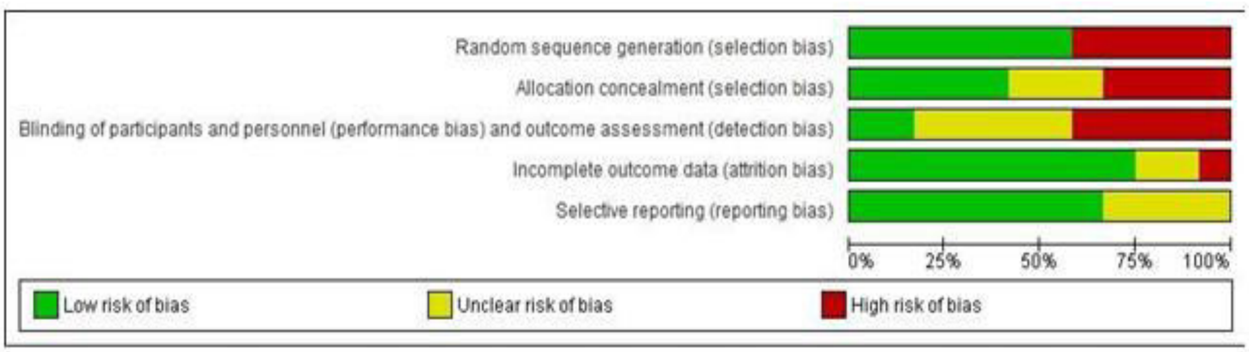

Figure2: Risk of bias graph: review authors' judgments on each risk of bias item presented as percentages across all included studies.

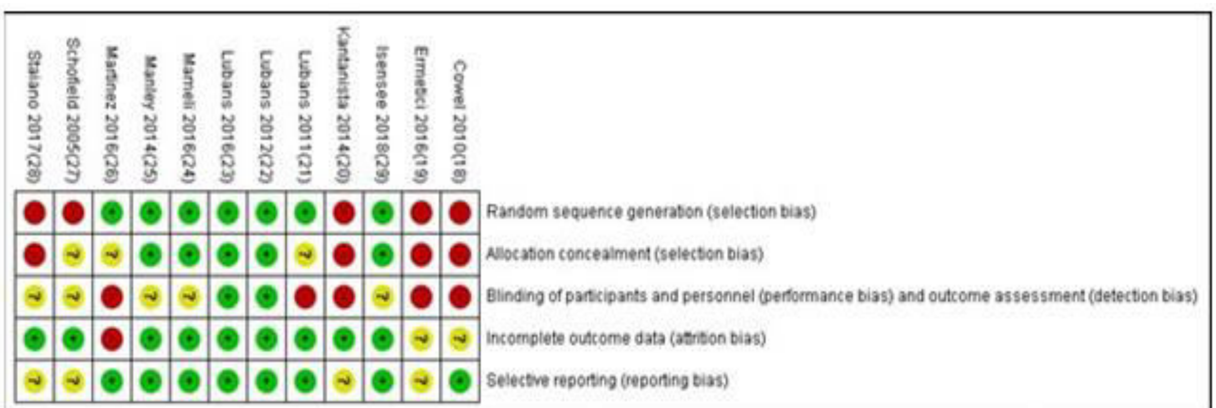

Figure 3: Risk of bias summary: review authors' judgments on each risk of bias item for each included study. Green symbols represent a low risk of bias, yellow symbols represent an unclear risk of bias, and red symbols a high risk of bias.

3.3 EFFECTS OF INTERVENTIONS

3.3.1 Effects on body mass index (BMI)

All included studies: 3 to 12 months of intervention

The meta-analysis included all clinical studies (Isensee et al., 2018; Lubans et al., 2011, 2012, and 2016) that assessed BMI (kg/m2) and reported changes between baseline and post-intervention. With strong evidence of heterogeneity (I2 =79%), the meta-analysis of random effects failed to show a statistically significant difference in the mean of the difference (MD) in BMI between the intervention and control groups (1878 individuals; 4 trials).

According to the Cohen effect size categorization (Cohen, 1988), the size of the difference (- 0.63) may be regarded as a "moderate" impact.

Studies: three months of treatment

After 3 months of intervention, BMI was evaluated in two studies (Lubans et al., 2011; Isensee et al., 2018); no significant difference between the intervention group and the control group was found (MD= - 0.08, 95 percent CI= -0.19 to 0.02, P= 0.11; 1160 participants; 2 studies; no evidence of heterogeneity (I2 = 0%)). (FIGURE 4).

Studies: six- to twelve-month intervention

According to the studies (Lubans et al., 2011, Lubans et al., 2012, and Lubans et al., 2016) that carried out interventions lasting more than six months, the differences in BMI means were statistically significant (MD= - 0.96, 95 percent CI= -1.65 to -0.27, P= 0.006; 818 participants; 3 studies), with evidence of mild heterogeneity (I2 =19 percent). This suggests that motion sensor-based PA treatments have a somewhat substantial impact on teenage BMI. In every randomized controlled experiment, the intervention group's BMI fell below that of the control group.

Research: Follow-up

Three studies (Isensee et al., 2018, Lubans et al., 2012, and Lubans et al., 2016) carried out a follow-up of the intervention. The magnitude of the difference was -1.12, but it was not statistically significant (MD= - 1.12, 95 percent CI= -3.13 to 0.88, P= 0.27; 1647 participants; 3 studies), with high heterogeneity (I2 = 77 percent).

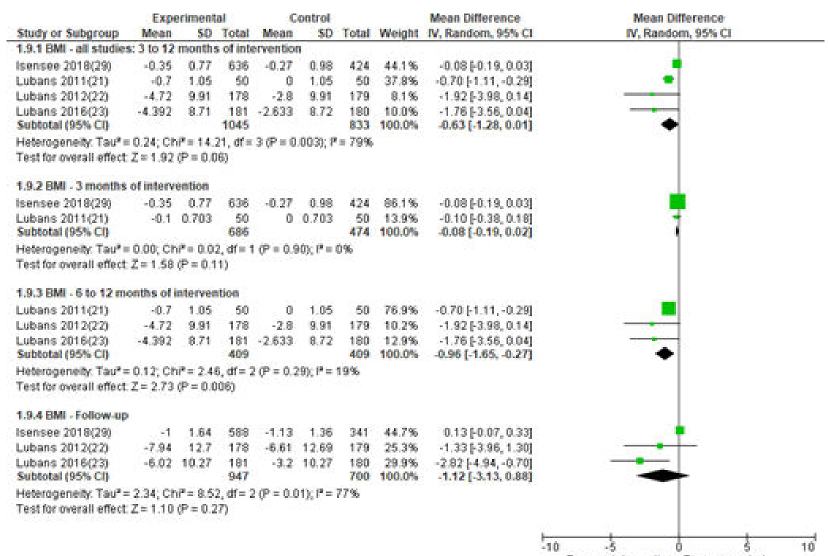

Figure 4: Forest plot of the effect of motion sensors – determined physical activity interventions versus control on body mass index (kg/m2). CI: confidence interval, IV: inverse variance, SD: standard deviation.

3.3.2 EFFECTS ON BODY FAT

All included studies: 3 to 12 months of intervention

Body fat was analyzed in all studies(Lubans et al., 2011; Isensee et al., 2018; Lubans et al., 2012; Lubans et al., 2016) included in the meta-analysis of random effects, showing that there were no statistically significant differences between the means of BF (MD= -1.51, 95 percent CI= -3.17 to 0.15, P= 0.08; 1808 participants; 4 studies; certainty of evidence very low), with high heterogeneity (I2 = 79 percent). Due to the danger of participant blinding, the large confidence intervals, and worries about the data's heterogeneity, the certainty of the evidence was rated as extremely poor.

Studies: three months of treatment

After a 3-month intervention, two studies that verified body fat reported no significant change in BF (MD= -0.79, 95 percent CI= -2.69 to 1.10, P= 0.41; 1090 individuals; 2 studies), despite considerable heterogeneity (I2 = 85%).

Studies: six- to twelve-month intervention

A meta-analysis of interventions for reducing body fat over a six-month period was conducted, with three studies (Lubans et al., 2012; Lubans et al., 2016; Lubans et al., 2011) included. The results showed that adolescents in the intervention group experienced a significant reduction in BF (MD= -2.11, 95 percent CI= -3.26 to -0.96, P= 0.0003; 818 participants; 3 studies), with no (FIGURE 5).

Research: follow-up

At the follow-up (10–12 months after the intervention), three studies evaluated the BF. The meta-analysis of random effects revealed a strong impact (-1.13) with considerable heterogeneity (I2=81%), despite the fact that it was not statistically significant (MD= -1.13, 95 percent CI= -3.90 to 1.64, P=0.42).

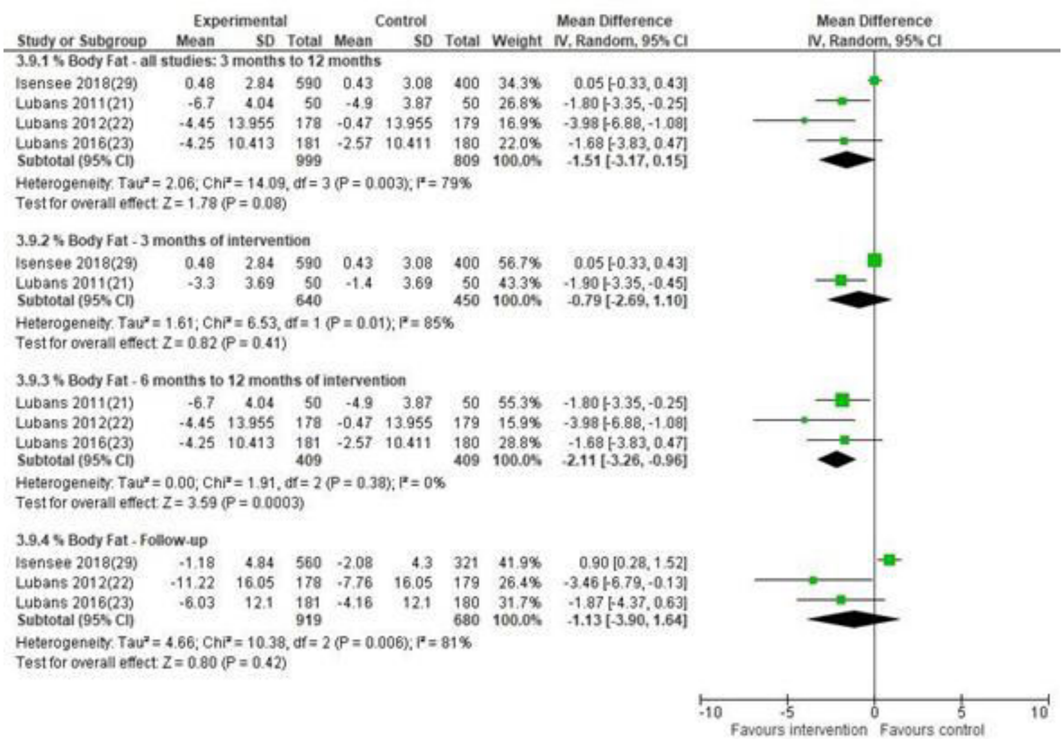

Figure 5: Forest plot of the effect of motion sensors – determined physical activity interventions versus control on body fat (%). CI: confidence interval, IV: inverse variance, SD: standard deviation.

3.3.3 EFFECTS ON WAIST CIRCUMFERENCE

All included studies: 6 to 12 months of intervention

A meta-analysis of random effects including two randomized controlled trials (Lubans et al., 2011; Lubans et al., 2016) did not demonstrate a statistically significant difference in waist circumference (MD= -1.62, 95% CI= -7.94 to 4.69, *P*= 0.61; 461 participants; 2 studies), with high evidence of heterogeneity (*I2* =73%) (FIGURE 6).

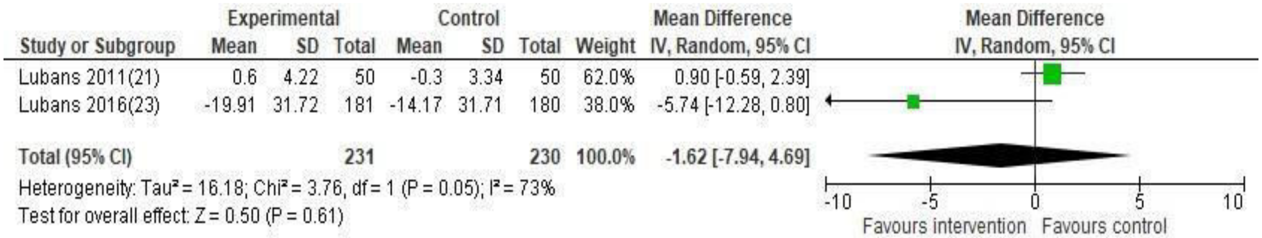

Figure 6: Forest plot of the effect of motion sensors – determined physical activity interventions versus control on waist circumference (cm). CI: confidence interval, IV: inverse variance, SD: standard deviation.

4. DISCUSSION

The goal of this review was to assemble data on motion sensor-based physical activity treatments to improve cardiometabolic health in adolescents. The review's findings demonstrate that (1) pedometers were the most often used motion sensors, (2) the majority of research included several components in their intervention protocols, and (3) body composition was the main result of these studies. Our meta-analysis revealed that treatments lasting six to twelve months significantly promoted a decrease in BMI and body fat percentage.

We discovered that BMI decrease (Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Martnez López, 2016), BMI z-score (Ermetici et al., 2016; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016), and BMI were employed in the majority of research (SDS)

Only one of the studies that were included looked at cardiovascular risk variables, and the results showed that insulin sensitivity had increased after 10 weeks of goal-setting, pedometer use for self-monitoring, and family support (Conwell et al., 2010).

The current systematic review found that one research used motion sensors to promote an active lifestyle. Physical activity is still seen as a crucial component in cardiometabolic health, despite the fact that youth and more than half of the world's population are believed to be insufficiently active (Kohl et al., 2012; Hallal et al., 2012). Ekelund et al. (2012) and Tarp et al. (2018) found a correlation between higher levels of physical exercise and worse cardiometabolic health. Because of the changes in the cardiometabolic profile caused by self-monitoring, utilising motion sensors that provide feedback has become an effective way to increase physical activity.

While there were methodological differences in the goal-setting and motion sensor use times across all treatments, the studies of Conwell (Conwell et al., 2010), Kantanista (Kantanista et al., 2014), and Manley (Manley et al., 2016), as opposed to six other studies (Ermetici et al., 2016; Isensee et al., 2018; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016) Teenagers needed input from motion sensors, such as pedometers, wristbands, and smartphone applications, in order to become aware of their habitual behaviour and, as a result, enhance their PA (Salawi et al., 2014; Zolotarjova et al., 2018).

The pedometer was the motion sensor that was utilised the most in the trials, both as a tool for self-monitoring and to assess physical activity. Although the brands, types, and internal mechanisms (piezoelectric and spring-levered) of the pedometers used in the research included in this study differ, they are nonetheless recognised for their good accuracy and are confirmed as appropriate instruments for step monitoring.

The majority of the studies' intervention protocols included PA in addition to school-related components (teachers, school environment) (Ermetici et al., 2016; Lubans et al., 2011; Isensee et al., 2018; Lubans et al., 2012; Lubans et al., 2016; Manley et al., 2014), counselling sessions on healthy habits (Conwell et al., 2010; Schofield et al., 2016 (Isensee et al., 2018; Conwell et al., 2010; Lubans et al., 2012; Lubans et al., 2016). Programs and therapies for adolescent behaviour modification, especially those for overweight or obese kids, are largely considered as effective and crucial.

Four of the seven RCTs included in the current review were included in the meta-analysis regarding the outcomes since Martinez's study (Martnez López, 2016) presented a high risk of bias and two authors (Mameli et al., 2016; Manley et al., 2014) did not send the necessary information regarding the results so that they could be included in the meta-analysis. Most of the randomised clinical studies were conducted in educational settings. The four trials (Lubans et al., 2011, Lubans et al., 2012, Lubans et al., 2016, and Isensee et al., 2018) had statistical heterogeneity that was considerable; however, the heterogeneity was reduced when studies with equivalent methodological aspects were analysed.

In the intervention group, there was a significant reduction in BMI and percent body fat compared to the control group, with mean differences of, respectively, -0.96, -0.27, and -2.11 in the intervention group compared to the control group, according to the findings of the meta-analysis of these studies (FIGURE 3, 4).

In addition to improved school sports programmes, interactive seminars, nutrition workshops, lunchtime physical activity sessions, handbooks and pedometers for self-monitoring, parent newsletters, and text messaging for social support, these randomised controlled trials were built on the social cognitive theory.

When the 3-month treatments were analysed, the magnitudes of mild and moderate effects were verified for the BMI and % BF, respectively, even though there were no statistically significant changes. Both programmes included a variety of school-based strategies, such as goal setting, pedometer use for self-monitoring, and peer and parental social support. These findings suggest that longer-term physical activity programs are required to change body composition and prevent obesity in this group of people.

Only the Conwell pre-experimental study (Conwell et al., 2010) examined additional markers besides body composition, such as lipid profile, blood pressure, and insulin sensitivity. Body composition outcomes (BMI, body fat, and waist circumference) were used to summarize the results of the physical activity interventions using motion sensors on cardiometabolic risk factors. This limitation on metabolic variables was also seen in a recent review of research on children and adolescents with morbid obesity (Zolotarjova et al., 2018), where cardiovascular risk factors were only assessed in three of the included studies that addressed a specific demographic (obese adolescents).

Because paediatric obesity is on the increase and weight loss and body fat reduction are essential to reduce both short- and long-term hazards, future research must assess additional outcomes than anthropometry that are connected to cardiometabolic risk factors (changes in metabolic profile, diabetes mellitus, insulin resistance, and cardiovascular diseases).

One of the review's strong aspects is the meta-analysis of the effect of the motion sensor-based physical activity intervention on adolescent cardiometabolic health. Despite the benefits of the present research, there are some disadvantages. The lack of scientific publications that were considered eligible for inclusion was the review's largest flaw. Second, the influence of the therapies is the result of the interaction of many variables. However, research has shown that multi-component therapy is more effective.

5. CONCLUSION

The goal of this review was to gather data on motion sensor-based physical activity treatments for improving adolescent cardiometabolic health. The review's findings indicate that (1) pedometers were the most often used motion sensors, (2) most studies included a variety of intervention components, and (3) body composition was the main outcome of these research. The results of our meta-analysis showed that treatments lasting six to twelve months significantly reduced BMI and body fat percentage.

The majority of studies, according to our research, employed BMI reduction (Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Martnez López, 2016), BMI z-score (Ermetici et al., 2016; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016), and BMI (SDS) (Mameli et al., 2016).

Only one of the studies that were included looked at cardiovascular risk variables, and the results showed that after 10 weeks of goal setting, pedometer use for self-monitoring, and family support, insulin sensitivity had increased (Conwell et al., 2010).

One researcher used motion sensors to promote an active lifestyle, according to the current systematic review. Despite the fact that youth and more than half of the world's population are believed to be insufficiently active, physical activity is still recognized as a crucial component in cardiometabolic health (Kohl et al., 2012; Hallal et al., 2012). Greater levels of physical activity are associated with worse cardiometabolic health, according to epidemiological studies (Ekelund et al., 2012; Tarp et al., 2018). Due to modifications in the cardiometabolic profile brought on by self-monitoring, the use of motion sensors that offer feedback has thus become an effective strategy for enhancing physical activity.

The studies of Conwell (Conwell et al., 2010), Kantanista (Kantanista et al., 2014), and Manley (Manley et al., 2016), in contrast to six other studies (Ermetici et al., 2016; Isensee et al., 2018; Lubans et al., 2011; Lubans et al., 2012; Lubans et al., 2016; Mameli et al., 2016) teenagers needed feedback in order to become aware of their habitual behaviour and, as a result, enhance their PA. Motion sensors, such as pedometers, wristbands, and smartphone applications, gave this feedback (Salawi et al., 2014; Zolotarjova et al., 2018).

The pedometer was the motion sensor that was most often used in the trials to assess physical activity and as a self-monitoring tool. Despite the fact that the pedometers used in the research included in this review have different brands, models, and internal mechanisms (piezoelectric and spring-levered), they are nonetheless praised for their great accuracy and are confirmed as reliable instruments for measuring steps.

Along with PA, the majority of the studies' intervention protocols also included aspects of school (school environment, teachers) (Ermetici et al., 2016; Lubans et al., 2011; Isensee et al., 2018; Lubans et al., 2012; Lubans et al., 2016; Manley et al., 2014), counselling sessions on healthy habits (Conwell et al., 2010; Schofield et al (Isensee et al., 2018; Conwell et al., 2010; Lubans et al., 2012; Lubans et al., 2016). Adolescent behavioural modification programmes and therapies, especially for overweight or obese kids, are largely considered as effective and crucial.

Four of the seven RCTs included in the current review were included in the meta-analysis regarding the outcomes because Martinez's study (Martnez López, 2016) had a high risk of bias and two authors (Mameli et al., 2016; Manley et al., 2014) failed to send the information regarding the results necessary for them to be included in the meta-analysis. The bulk of the randomised clinical trials happened at educational institutions. The four trials (Lubans et al., 2011, Lubans et al., 2012, Lubans et al., 2016, and Isensee et al., 2018) had significant statistical heterogeneity; however, the heterogeneity was reduced when studies with similar methodological aspects were analysed.

The meta-analysis of these studies' findings demonstrated that interventions lasting 6 to 12 months significantly decreased BMI and percent body fat in the intervention group compared to the control group, with mean differences of, respectively, -0.96, -0.27, and -2.11 in the intervention group compared to the control group (FIGURE 3, 4).

These randomised controlled trials were based on social cognitive theory, and other components included enhanced school sports programmes, interactive seminars, nutrition workshops, lunchtime physical activity sessions, handbooks and pedometers for self-monitoring, parent newsletters, and text messaging for social support.

When the 3-month treatments were analysed, there were no statistically significant changes, although the magnitudes of small and moderate effects were verified for the BMI and % BF, respectively. Goal setting, pedometer use for self-monitoring, and peer and parental social support were all elements of both programmes' multidimensional, school-based strategies. These findings suggest that in order to change body composition and prevent obesity in this population, physical activity programmes must last longer than six months.

While only the Conwell pre-experimental study (Conwell et al., 2010) examined additional markers besides body composition, such as lipid profile, blood pressure, and insulin sensitivity, body composition outcomes (BMI, body fat, and waist circumference) were used to summarise the results of the physical activity interventions using motion sensors on cardiometabolic risk factors. This limitation on metabolic parameters was also seen in a recent review of research on children and adolescents with morbid obesity (Zolotarjova et al., 2018), where cardiovascular risk variables were only assessed in three of the included studies that addressed a specific demographic (obese adolescents).

Given that paediatric obesity is on the increase and that losing weight and body fat is essential to reducing both short- and long-term hazards, future research must include outcomes other than anthropometry that are connected to cardiometabolic risk factors (changes in metabolic profile, diabetes mellitus, insulin resistance, and cardiovascular diseases).

One of the review's key strengths is the meta-analysis of the motion sensor-based physical activity intervention's effects on adolescent cardiometabolic health. There are several disadvantages to the present research, despite its benefits. The absence of scientific publications considered suitable for inclusion was the review's main flaw. Second, the effects of the therapies are the result of many elements coming together. Despite this, studies have shown that multi-component therapy is more effective.

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