Influence of exclusive resistance training on body composition and cardiovascular risk factors in overweight and obese children and adolescents: A systematic review update

Pavel Dietz[1,*], Michael Ornik[1], Estelle D. Watson[2] & Mireille N. M. van Poppel[1]

1 Institute of Sports Science, University of Graz, Graz, Austria

2 Centre for Exercise Science and Sports Medicine, School of Therapeutic Sciences, Faculty of Health Sciences, University of Witwatersrand, Johannesburg, South Africa

* Corresponding author: Institute of Sports Science, University of Graz, Mozartgasse 14, 8010 Graz, Austria
Tel: +43 3162321
Email: pavel.dietz@uni-graz.at

COMMENTARY

Article History:
Submitted 15th March 2018
Accepted 25th July 2018
Published 10th September 2018

Handling Editor:
Arno Schmidt-Trucksäss,
University of Basel, Switzerland

Editor-in-Chief:
Martin Kopp
University of Innsbruck, Austria

Reviewers:
Reviewer 1: Anonymous
Reviewer 2: Anonymous

ABSTRACT

Purpose: The aim of the present systematic review was to update a previous review investigating the effects of exclusive resistance training on body composition and cardiovascular risk factors for obese or overweight children and adolescents and to report the efficiency of whole-body strength training in weight management and obesity prevention during adolescence.

Method: Intervention studies that performed exclusive resistance training with overweight or obese children and adolescents under 18 years of age were systematically reviewed. Body composition and cardiovascular risk factors constituted as the outcome measurements.

Results: Five studies passed the inclusion criteria. All participants in treatment groups undertook supervised whole-body resistance training. The mean compliance was 87%. Four studies reported significant changes in body composition, with a decrease in mass, percentage body fat, waist circumference and waist-to-hip ratio as well as a significant increase in fat free mass. Three studies analysed the effects on cardiovascular risk factors and two reported significant changes with a decrease in systolic blood pressure and IL-6 as well as a significant increase in adiponectin.

Conclusion: A strength training intervention appears safe and tends to show positive effects for obese adolescents. Several significant changes were observed. A lack of studies and a small sample size of studies evaluating an exclusive strength training intervention does not provide strong evidence and does not allow a strong conclusion. Due to this, more studies are needed to analyse the role of exclusive resistance training in weight management for obese adolescents and its influence on cardiovascular risk factors.

Keywords:
adiposity – heart disease, prevention – youth – weight training – exercise – adolescents

Citation:
Dietz, P., Ornik, M., Watson, E. D. & van Poppel, M. N. M. (2018): Influence of exclusive resistance training on body composition and cardiovascular risk factors in overweight and obese children and adolescents: A systematic review update. *Current Issues in Sport Science, 3:012*. doi: 10.15203/CISS_2018.012

2018 | *innsbruck* university press, Innsbruck
Current Issues in Sport Science | ISSN 2414-6641 | http://www.ciss-journal.org/
Vol. 3 | DOI 10.15203/CISS_2018.012

Introduction

Definition and Epidemiology

Overweight and Obesity (OaO) is one of the major crises of our time. According to the World Health Organization (WHO, 2018) it is defined as abnormal or excessive fat accumulation that may impair health. Children aged between five and 19 years are defined as overweight if BMI-for-age is higher than 1 standard deviation above the WHO Growth Reference median and as obese if it is higher than 2 standard deviations. Worldwide the number of affected people is constantly rising. In recent decades, the number of children suffering from OaO has increased substantially. For example, Ng et al. (2014) showed that the proportion of children and adolescents with a BMI of 25 kg/m^2 or higher rose significantly between 1980 and 2013. The team indicated that 23.8% of boys and 22.6% of girls aged 18 years or younger were overweight or obese in 2013. The article of Lobstein and Jackson-Leach (2016) presents how this time trend may continue. They estimated that by 2025 the number of OaO children aged between five and 17 years may be 268 million, including 91 million obese if the necessary global interventions are not successful.

Risks associated with OaO

OaO goes along with numerous health issues starting in childhood. According to Papoutsakis et al. (2013), OaO has been suggested as a risk factor for developing asthma and other breathing problems. Flynn (2013) showed a profound impact of obesity on childhood hypertension. Moreover, skin problems have also been reported to be associated with it, according to the review of Mahé, Gnossike and Sigal (2014). A clinical review by Rosenfield (2013) confirms that there is a relationship between overweight and ovulatory dysfunction. Stolzman and Bement (2012) pointed out that obesity can play a major role in chronic inflammation and therefore can have a negative impact on an adolescent's life. Additionally, it should not be forgotten that there are long term health consequences, because the probability of children and adolescents staying obese into adulthood is high. In this context, Liang et al. (2015) showed that around half of obese children are likely to become adults suffering from obesity. These diseases can appear immediately or develop into chronic illnesses, because the chance of persistence into adolescence for those who are OaO is high.

Furthermore, OaO is accompanied by other diseases. One big risk is metabolic syndrome, according to Lloyd, Langley-Evans and McMullen (2012). It is linked to abdominal obesity, elevated blood pressure, insulin resistance and dyslipidaemia. Park, Falconer, Viner and Kinra (2012) observed that there is evidence for association between childhood BMI, hypertension as well as type 2 diabetes. Kavey (2015) reported an association for obesity and dyslipidaemia. He indicated that dyslipidaemia occurs almost only combined with obesity, which affects 40% of obese adolescents. Savino, Pelliccia, Chiarelli and Mohn (2010) showed a strong correlation between a higher BMI, the presence of type 2 diabetes, hypertension as well as reduced insulin sensitivity and risk factors for chronic kidney disease and end-stage renal disease. A previous review article by Reilly, Methven, McDowell, Hacking, Alexander, Stewar and Kelnar (2003) including 34 papers assessing the association between objectively defined indices of obesity (notably BMI), and/or central obesity (for example, waist circumference) and cardiovascular risk factors measured in childhood, showed that obesity was associated with most of the major cardiovascular risk factors: high blood pressure, dyslipidaemia, abnormalities in left ventricular mass and/or function, abnormalities in endothelial function, and hyperinsulinemia and/or insulin resistance.

Moreover, the mortality of obese people increases the higher the BMI gets. Zhou (2002) reported an elevation of all-cause mortality when the BMI is higher than 28 kg/m^2. He showed that a relative risk of coronary heart diseases might increase by 15.4%, total stroke by 6.1% and ischemic stroke by 18.8% for each increase of 2 kg/m^2 from baseline BMI. The origins of these diseases can be found in childhood obesity.

However, not only are physical systems affected, but also psychological risks exist. For example, Pizzi and Vroman (2013) observed an undeniable relationship between obesity and psychological disorders and psychological consequences such as a negative self-image, eating disorders or low self-esteem. These issues are especially difficult for children, and may create a vicious circle, which ends in a reduced health-related life quality. Their life is characterized by prejudice, mobbing and victimization at school or at work. Must and Strauss (1999) showed that children of normal weight describe overweight children of the same age as more likely to be lazy, dishonest, ugly and stupid. Out of this arises psychosocial strain, aggression or low self-confidence, sexual dissatisfaction and depression. As people tend to withdraw from their social environment, they tend to react by leading an unhealthy lifestyle. As a result, they gain bodyweight and get sick. According to Cornette (2008), 33% of overweight children and adolescents lose control of their eating habits, which results in an increase in body fat, depressive symptoms and dissatisfaction.

Treatment and prevention of OaO

Intervention programs are essential for the prevention of OaO in these populations. Primary prevention of childhood obesity has to be started at the latest at school age with school-based, home-based or community-based intervention programs. Oosterhoff, Joore and Ferreira (2016) showed a relationship between school-based lifestyle interventions and positive changes in children's BMI and blood pressure. General recommendations for an intervention programme are changes in lifestyle such as physical activity, free time and eating habits as well as psychological support. Flodmark, Marcus and Britton (2006) systematically reviewed that it is possible to prevent obesity in children and adolescents with school-based programs which involve physical activity and dietary habits. Physical activity constitutes a major part of these programs, according to Aguilar Cordero et al. (2014). His team reviewed the effectiveness of physical activity in reducing OaO in children and adolescents. They claimed that 180 minutes of exercise per week, in form of three 60-minute sessions of moderate intensity could be sufficient. They further stated that programs which combine aerobic and anaerobic exercises are claimed to be the most effective ones. Furthermore, it is generally accepted that a combination of aerobic exercises and resistance training could bring about large improvements. A randomised trial by Ho, Dhaliwal, Hills and Pal (2012) confirmed this. They proved that combination exercise training shows significant improvements in body weight, total body fat, percentage body fat, abdominal fat percentage and cardio-respiratory fitness compared to a non-exercising control group. Unfortunately, OaO children are hard to motivate for aerobic sports like walking, jogging, swimming, dancing or skating. Students with adiposity may not enjoy aerobic exercises and find it more difficult to keep up with students of normal weight. Inversely, with resistance training, due to their higher inherent body weight, it seems plausible that OaO children and adolescents have more powerful muscles than lean children and adolescents of the same age group. In this context, Ten Hoor, Plasqui, Schols and Kok (2014) showed that overweight children do not only have a higher fat mass, but also have a higher muscle mass compared to their normal weight counterpart. Thus, this may play a major part in exercise motivation. Resistance training may motivate them to start becoming more physically active as a first step to a healthier lifestyle.

Many studies include a form of resistance training in their physical activity exercise intervention, mostly in combination with endurance training. However, despite its motivational importance, studies investigating the role of exclusive resistance training in reducing obesity in childhood are rare. Within a previous systematic review, Dietz, Hoffmann, Lachtermann and Simon (2012) observed the influence of exclusive resistance training on body composition and cardiovascular risk factors in OaO children and adolescents. They pointed out that whole-body resistance training for children seems to be safe and tends to show positive effects on body composition. However, the effect on cardiovascular risk factors cannot be substantiated for resistance training only. They concluded that more RCT´s with an exercise intervention of resistance training only in OaO children or adolescents would be necessary to prove the effects. For that reason, the aim of the present study was to update the review from 2010 to examine whether the recommendations formulated by Dietz et al. (2012) were implemented. This would enable researchers to draw a more stable conclusion regarding the influence of exclusively resistance training on body composition and cardiovascular risk factors in overweight and obese children and adolescents.

Methods

Eligibility criteria

In this systematic review all studies had to pass the following inclusion criteria: (1) original research article; (2) published in English; (3) cohort had to be children or adolescents aged less than 18 years; (4) participants had to be defined as being overweight or obese (BMI ≥ 25kg/m^2 or BMI ≥ 85th percentile for age and sex) except for those being in a normal weight control group; (5) intervention had to be based exclusively on resistance training with free-weights (bodyweight, dumbbells, barbells, medicine balls), machines (weight-stacked, pneumatically controlled), resistance training equipment (e.g. Thera band) or a combination of these; (6) results had to relate to body composition (mass, BMI, percentage fat, total fat mass, fat free mass) and/or cardiovascular risk factors (blood pressure, waist circumference, waist-to-hip ratio, visceral fat, total cholesterol, LDL, HDL, leptin, adiponectin, IL-6, TNF-α). Any endurance-based training was only accepted as warm-up or cool-down periods and not as part of the main intervention. Due to the specific focus of this review, any intervention combining resistance training and diet was not accepted. This review included randomised controlled trials (RCTs), non-randomised controlled trials (NRCTs) and uncontrolled trials (UCTs).

Source and search protocol

Studies were located via electronic databases and the search was applied to PubMed. All Studies must have been published between December, 2010 and July, 2016. A comprehensive literature research for full-length manuscripts using the following subject headings and their logical combinations was conducted: 'resistance training', 'strength training', 'weight training', 'dumbbell training', 'child', 'children', 'childhood', 'adolescents', 'youth', 'obesity', 'obese', 'adiposity', 'overweight', 'BMI', 'body weight', 'body mass', 'body composition', 'risk factors', 'blood pressure', ' cholesterol', 'waist circumference', 'waist-to-hip ratio', 'lipids', 'lipoproteins', 'leptin', 'adiponectin', 'IL-6', 'TNF-α'. The search term was created as follows: ("resistance training" OR "strength training" OR "weight training" OR "dumbbell training") AND (child OR children OR childhood OR adolescents OR youth) AND (obesity OR obese OR adiposity OR overweight) AND (BMI OR "body weight" OR "body mass" OR "body composition" OR "risk factors" OR "blood pressure" OR cholesterol OR "waist circumference" OR "waist-to-hip ratio" OR lipids OR lipoproteins OR leptin OR adiponectin OR "IL-6" OR "TNF-α").

Study selection

With this procedure 116 potentially relevant articles were identified (Fig. 1). Thereafter, these studies were screened for relevance by title and abstract. 104 of the records were excluded as the studies did not include resistance training only or OaO children or adolescents. The remaining 12 studies were

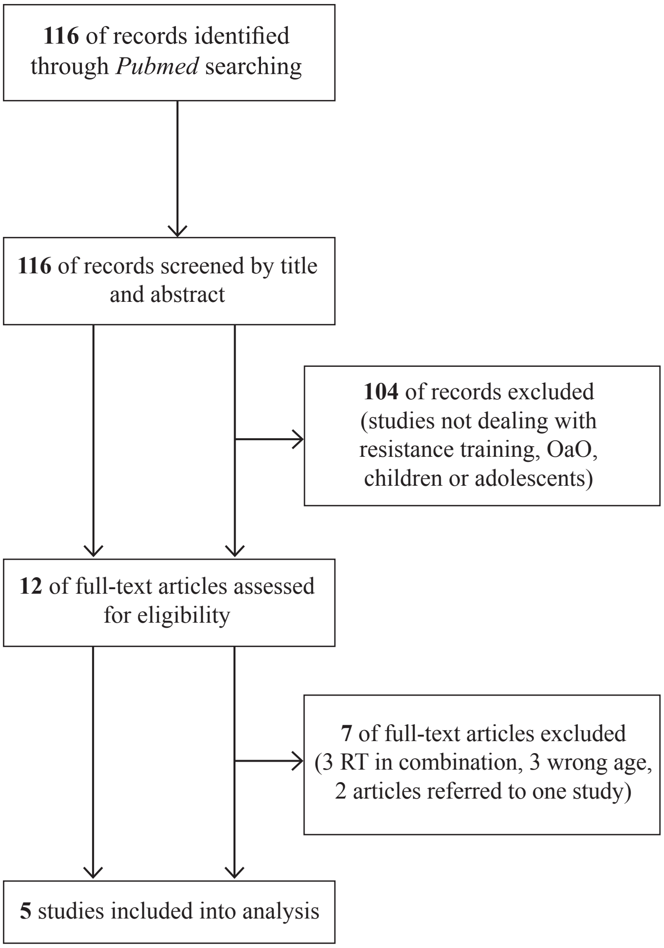

Figure 1: Flow chart of literature search

assessed for eligibility by full-length texts. Seven of full-length text articles were excluded because three used resistance training in combination with endurance training or diet, three articles referred to a wrong cohort and two studies referred to the same intervention study and only one of these were included in this review. Five studies passed the criteria and reported an intervention using resistance training only and investigated its effects on markers of body composition and/or cardiovascular risk factors in youths aged <18 years.

Quality Assessment

For assessing the quality of the reviewed articles, a standardized Quality Assessment Tool for Quantitative Studies (QATQS) in the field of public health research (Effective Public Health Practice Project, 2008), was used. The studies were evaluated on six criteria: (1) how likely the individuals selected to participate are representative of the target population (selection bias); (2) what kind of study design was used (study design); (3) the control of confounding factors (confounders); (4) the blinding of outcome assessors and participants (blinding); (5) the validity and reliability of the data-collection tools (data collection methods); (6) the number of and reasons for withdrawals and drop-outs (withdrawals and drop-outs). The component 'blinding' was not taken into consideration because of the fact that in studies with physical activity the assessors (i.e. researchers) and the participants are very likely to know the outcome of the randomization (Oja et al., 2011). Each article was rated on each component (1-6) as 'weak', 'moderate' or 'strong'. Moreover, the studies got a global rating on the basis of the individual assessments: a paper was rated 'weak', if there were two or more 'weak' ratings in components 1-6, 'moderate' if there was only one 'weak' rating and 'strong' if there was no 'weak' rating. An detailed description of the component ratings can be found online (Effective Public Health Practice Project, 2008).

Results

In the five included studies, three RCTs (Alberga, Farnesi, Lafleche, Legault, & Komorowski, 2013; Kelly et al., 2015; Schranz, Tomkinson, Parletta, Petkov, & Olds, 2014), one NRCT (Dias et al., 2015) and one UCT (Shultz et al., 2015) were identified.

Cohort and Intervention Characteristics

The sample sizes of the included studies reached from 14 (Shultz et al., 2015) to 56 (Schranz et al., 2014) participants, with a sum of 159 for all five studies. Three studies investigated a mixed cohort of boys and girls (Alberga et al., 2013; Dias et al., 2015; Shultz et al., 2015), two investigated only boys (Kelly et al., 2015; Schranz et al., 2014) and none investigated only girls. All studies focused on OaO children and adolescents except for a non-obese control group. Three studies defined obesity using the 95th BMI percentile (Alberga et al., 2013; Dias et al., 2015; Kelly et al., 2015) and two reported OaO children without giving any further specifications with regard to their definition of OaO (Schranz et al., 2014; Shultz et al., 2015). The age of the subjects ranged from eight to 17 years. The youngest cohorts were children aged between 8 and 12 years (Alberga et al., 2013), the oldest were participants aged between 13 to 17 years (Dias et al., 2015; Schranz et al., 2014).
Three studies were aimed at conducting supervised resistance training (Alberga et al., 2013; Kelly et al., 2015; Schranz et al., 2014), one study's participants undertook a circuit resistance training (Dias et al., 2015) and one study did not especially report which sort of resistance training was used (Shultz et al., 2015) (Table 1). All five studies used whole-body resistance training as an intervention with exercises for all major muscle groups (Table 2). Dias et al. (2015), required their participants to train 3 times per week, on non-consecutive days for 30 to 40 minutes per session. The intervention consisted of an increase of the sets from 1 set up to 3 sets, a decrease from 1-15 reps to 6-10 reps and an increase of the intensity from 50-70% of 10 RM to 70-85% 10 RM. The study by Shultz et al. (2015) reported

an exercise program consisting of 3 training sessions per week, on non-consecutive days, for 60 minutes per session. They used 1-2 sets of 15 exercises with an intensity of 60-85% 1 RM at the beginning and increasing up to 85% 1 RM for the last four weeks. Kelly et al. (2015), had the participants train twice per week, on non-consecutive days, for 60 minutes for each session. They split the exercise intervention into three parts. During weeks 1 to 4 they had to do 1 set, 10-15 reps with light to moderate intensity. Weeks 5 to 10 consisted of 2-3 sets, 13-15 reps with moderate intensity and weeks 11-16 was 3-4 sets, 8-12 reps with moderate to high intensity. Alberga et al. (2013), reported an exercise intervention of 2 days per week with 75 minutes per session. The session included a 20-minute warm up of endurance based training in groups or on machines, 45 minutes resistance training consisting of 13 exercises with 1 set, 8-12 reps and 65-85% 1 RM intensity as well as a cool down of 10 minutes light exercises and stretching. The participants by Schranz et al. (2014), undertook a resistance training of 10 multi- and single joint exercises including 10 minutes warm up and 5 minutes static stretching as a cool down activity. The training session consisted of 2 weeks with 1 set, 8-12 reps 10 RM and the rest of the 6months intervention included 3 sets, 8-12 reps at 10 RM.

Only two studies included a warm up and cool down as part of the session (Alberga et al., 2013; Schranz et al., 2014). The tempo of the exercises performed was only reported by Schranz et al. (2014), rest between exercises and sets was only reported by Dias et al. (2015) (no rest between sets and exercises) and by Schranz et al. (2014) (1 minute rest per set and 1 minute rest per exercise (Table 2)). In all studies except for the UCT (Shultz et al., 2015), the control groups had no exercise intervention (Alberga et al., 2013; Dias et al., 2015; Kelly et al., 2015; Schranz et al., 2014). The specific strength for the exercise intervention was tested with a 1 RM-test in four of the five studies (Alberga et al., 2013; Kelly et al., 2015; Schranz et al., 2014; Shultz et al., 2015), only one study used a 10 RM-test (Dias et al., 2015).

One of these studies used a 1 RM-test to identify the strength for measurements and a 10 RM-test for the training intensity (Schranz et al., 2014). Three studies combined free-weights and machines as training equipment (Alberga et al., 2013; Dias et al., 2015; Schranz et al., 2014), one used pneumatically controlled machines only (Shultz et al., 2015) and one did not report about equipment (Kelly et al., 2015).

The duration was 12 weeks (Alberga et al., 2013; Dias et al., 2015), 16 weeks (Kelly et al., 2015; Shultz et al., 2015) or 6 months (Schranz et al., 2014). The compliance ranged from 74% (Schranz et al., 2014) to 100% (Shultz et al., 2015) with a mean for all five studies of 87.2%. The data for cohort and intervention characteristics is shown in Table 1 and Table 2.

Outcome measurements

The results of measurements for body composition referring to the parameters described above are shown in Table 3. The results for cardiovascular risk factors also refer to the parameters described above and are shown in Table 4. All data are reported by pre- to post-intervention changes and the group outcomes are shown separately. Time effects from baseline to post-intervention for treatment and control groups and group differences between two groups after exercise intervention are presented with the respective p-values or as not statistically significant. All data is expressed as mean and standard deviation or as medians and 1st to 3rd quartiles.

One study (Dias et al., 2015) focused on results of the treatment group only, because the control group was tested at baseline, the other studies show findings of the treatment group and, if existing, the control group. All five studies determined body composition by using dual energy x-ray absorptiometry. Dias et al. (2015) observed a significant decrease in percentage body fat as well as a significant decrease in waist circumference and waist-to-hip ratio in the treatment group. Furthermore, a significant decrease in systolic blood pressure was an outcome of the exercise intervention. An insignificant change was found in the remaining measurements. Shultz et al. (2015) did not publish a post-intervention score for BMI. A statistically significant decrease in percentage body fat and fat free mass was reported. Moreover, IL-6 and adiponectin showed a significant change from pre to post-intervention in the treatment group. A change of Leptin and TNF-α was defined as not significant. Kelly et al. (2015) reported insignificant time effect changes in the entire outcome measurements by body composition and cardiovascular risk factor regarded in this systematic review, in both the treatment group, and in the control group. Alberga et al. (2013) observed a significant decrease of weight only in the treatment group and a significant increase of total lean mass in treatment and control group. Insignificant changes were reported in both groups for BMI, percentage fat and total fat mass. Schranz et al. (2014) recorded a statistically significant decrease in mass and percentage fat as well as a significant increase in fat free mass for the treatment group.

No significant group differences are reported for all measurements regarded in this review. All five studies researched outcome measurements concerning body composition but only three studies reported investigations for cardiovascular risk factors (Dias et al., 2015; Kelly et al., 2015; Shultz et al., 2015). None of the studies reviewed observed scores in visceral fat. To summarize, only two of five studies dealing with exclusive resistance training in OaO children and adolescents reported a significant time effect in the treatment group for mass (Alberga et al., 2013; Schranz et al., 2014), three studies observed a significant decrease in percentage fat in the treatment group (Dias et al., 2015; Schranz et al., 2014; Shultz et al., 2015) and three studies showed a significant increase in fat free mass in the treatment group (Alberga et al., 2013; Schranz et al., 2014; Shultz et al., 2015). Only one study measured a significant change in waist circumference and waist-to-hip ratio in the exercise intervention group (Dias et al., 2015). Concerning cardiovascular risk factors, only one study reported a statistically significant decrease of systolic blood pressure in the treatment group (Dias et al., 2015) and two studies observed statistically significant time effects in IL-6 and adiponectin. One study showed a significant increase in total lean mass in the control group. The remaining outcome measurements reported in this systematic review showed no significant time effects or group differences between the treatment and control group after an exercise intervention in OaO children and adolescents. A summary of the study results is given within Table 6.

Quality Assessment

Using the standardized QATQS, the global rating of the study of Kelly et al. (2015), and Schranz et al. (2014) were assessed as strong. The articles of Dias et al. (2015), Shultz et al. (2015) and Alberga et al. (2013) were assessed as moderate because of a lack of representativeness (Table 5).

Discussion

The aim of this systematic review was to clarify the role of resistance training in an intervention program to prevent obesity in children and adolescents and to examine whether the recommendations formulated by Dietz et al. (2012) were implemented. An intervention program for OaO children and adolescents has to be fun and needs to motivate the children to continue. However, aerobic exercise in particular, might often be difficult for them since it may be too exhausting or uncomfortable leading to reduced compliance. Exclusive resistance training could be a solution to this problem, because OaO children and adolescents may be motivated by the strength advantages they have compared to normal weight children. The five studies reviewed in this paper undertook a resistance exercise programme including 2 to 3 training sessions a week with 30 to 75 minutes per session, performing mostly 2 to 3 sets and 8 to 12 repetitions. A significant decrease of the body fat was reported in three studies (Dias et al., 2015; Schranz et al., 2014; Shultz et al., 2015) as well as a significant increase in fat free mass (Alberga et al., 2013; Schranz et al., 2014; Shultz et al., 2015). The insignificant changes in BMI may result from the increase of lean mass. Only two studies showed a statistically significant change in cardiovascular risk factors (Dias et al., 2015; Shultz et al., 2015). The biggest success was achieved by Dias et al. (2015). In this study, the participants undertook a 12 weeks intervention of exclusive resistance training, the measurements for systolic blood pressure decreased significantly and were similar to the score of normal weight participants in the control group after the intervention. Shultz et al. (2015) reported a significant decrease in IL-6 and increase in adiponectin.

Resistance training is a major, yet mostly underestimated, part of weight management. For example, Ten Hoor et al. (2015) reported that parents are more likely to indicate that their child was not allowed to participate in strength exercises (29.6%) than in aerobic exercises (4.0%). Dietz et al. (2012) reported that a reason against the usage of exclusive resistance training for weight management may be due to no or little weight loss of trainees which will most likely abate their training enthusiasm. The interventions of the five studies reviewed show a trend to improvements which could minimize cardiovascular risk factors and may be an important step to a healthier life.

An important risk factor for cardiovascular diseases is visceral fat. Referring to Després (2007), visceral abdominal tissue is in close relation to metabolic syndrome by increasing blood pressure and reducing high density lipoprotein (HDL) and therefore it is an interesting measurement in obese interventions. At the beginning visceral fat was a component in the body composition outcome measurements but none of the studies reviewed had reported data concerning visceral fat.

There have been some improvements following on from the article of Dietz et al. (2012). In their review, Dietz and his team criticized some of the studies for using bioelectrical impedance analysis (BIA) instead of dual-energy x-ray absorptiometry (DXA). The latter one is a more precise way to analyse body composition of the participants. Encouragingly, it is important to recognise that after some years, DXA is now the main method used. Furthermore, in this review more physiological outcomes compared to Dietz et al. (2012) were measured. Based on the researched influence the hormones Leptin, IL-6, TNF-α and Adiponectin were included in the outcome protocol. Shultz et al. (2015) reported significant changes in IL-6 and Adiponectin after a 16-week resistance training in obese youth. Importantly, two major factors of exercise program design were insufficiently reported in the reviewed articles. The tempo in which the exercise was performed was only described in the study of Schranz et al. (2014). Additionally, the rest between sets and/or between exercises was reported by Dias et al. (2015) and Schranz et al. (2014), but not by any of the others. Fiqueiredo et al. (2016) depicted different effects after different rest interval lengths between sets after strength training. Therefore, this is crucial information that could be improved in future studies.

The original review by Dietz et al. (2012) reported positive changes in body composition and cardiovascular health after resistance training but the lack of controlled trials and randomization, made interpretation difficult. An analysis of studies including a treatment group with exclusive resistance training and a treatment group with resistance training combined with dietary modifications was recommended to better understand the role of strength training in relation to obesity intervention programs. As in the original review by Dietz et al. (2012), the present systematic review found positive changes of an exclusive resistance training intervention on body composition markers and cardiovascular risk factor, but the small sample size of studies does provide strong evidence and thus, does not allow a strong conclusion.

In conclusion, recommendations for future studies given by Dietz et al. (2012) were mostly implemented but the total number of studies is still low but percentage number of RCTs increased. The quantity of outcome measurements increased to include data such as systolic blood pressure, total cholesterol, waist-to-hip ratio, waist circumference, Leptin, Adiponectin, IL-6 and TNF-α. Visceral fat was recommended but none of the five studies included it, although it is an important outcome to control effects of an intervention with OaO children. However, significant changes were still found for exclusive strength training on obese children and adolescents. Alberga et al. (2013) and Schranz et al. (2014) found a significant increase in mass which can be explained by a significant increase in fat free mass. Muscle growth and a decrease in percentage fat are the outcomes of resistance training interventions.

Conclusion

This systematic review showed the effect of exclusive resistance training on body composition and cardiovascular risk factors in OaO children or adolescents. A strength training intervention seems to be safe and tends to show positive effects in OaO youth. Some significant changes were observed. However, a lack of studies and a small sample size of participants conducting an exclusive strength training intervention make reliable interpretation difficult. Consequently, more studies are needed to analyse the role of exclusive resistance training in weight management in obese youth.

Funding

The authors have no funding or support to report.

Competing Interests

The authors have declared that no competing interests exist.

Data Availability Statement

All relevant data are within the paper.

References

Aguilar Cordero, M. J., Ortegón Piñero, A., Mur Vilar, N., Sánchez García, J. C., García Verazaluce, J. J., García García, I., & Sánchez López, A. M. (2014). Programas de actividad física para reducir sobrepeso y obesidad en niños y adolescentes; revisión sistemática [Physical activity programmes to reduce overweight and obesity in children and adolescents; a systematic review]. *Nutricion hospitalaria*, *30*(4), 727–740. doi: 10.3305/nh.2014.30.4.7680

Alberga, A. S., Farnesi, B.-C., Lafleche, A., Legault, L., & Komorowski, J. (2013). The effects of resistance exercise training on body composition and strength in obese prepubertal children. *The Physician and sportsmedicine*, *41*(3), 103–109. doi: 10.3810/psm.2013.09.2028

Cornette, R. (2008). The emotional impact of obesity on children. *Worldviews on evidence-based nursing*, *5*(3), 136–141. doi: 10.1111/j.1741-6787.2008.00127.x

Després, J.-P. (2007). Cardiovascular disease under the influence of excess visceral fat. *Critical pathways in cardiology*, *6*(2), 51–59. doi: 10.1097/HPC.0b013e318057d4c9

Dias, I., Farinatti, P., Souza, M. G. C. de, Manhanini, D. P., Balthazar, E., Dantas, D. L. S.,. . . Kraemer-Aguiar, L. G. (2015). Effects of Resistance Training on Obese Adolescents. *Medicine and science in sports and exercise*, *47*(12), 2636–2644. doi: 10.1249/MSS.0000000000000705

Dietz, P., Hoffmann, S., Lachtermann, E., & Simon, P. (2012). Influence of exclusive resistance training on body composition and cardiovascular risk factors in overweight or obese children: A systematic review. *Obesity facts*, *5*(4), 546–560. doi: 10.1159/000341560

Effective Public Health Practice Project. (2008). Quality Assessment Tool for Quantitative Studies. Retrieved from http://www.ephpp.ca/tools.html

Figueiredo, T., Willardson, J. M., Miranda, H., Bentes, C. M., Machado Reis, V., Freitas de Salles, B., & Simão, R. (2016). Influence of Rest Interval Length Between Sets on Blood Pressure and Heart Rate Variability After a Strength Training Session Performed By Prehypertensive Men. *Journal of strength and conditioning research*, *30*(7), 1813–1824. doi: 10.1519/JSC.0000000000001302

Flodmark, C.-E., Marcus, C., & Britton, M. (2006). Interventions to prevent obesity in children and adolescents: A systematic literature review. *International journal of obesity (2005)*, *30*(4), 579–589. doi: 10.1038/sj.ijo.0803290

Flynn, J. (2013). The changing face of pediatric hypertension in the era of the childhood obesity epidemic. *Pediatric nephrology (Berlin, Germany)*, *28*(7), 1059–1066. doi: 10.1007/s00467-012-2344-0

Ho, S. S., Dhaliwal, S. S., Hills, A. P., & Pal, S. (2012). The effect of 12 weeks of aerobic, resistance or combination exercise training on cardiovascular risk factors in the overweight and obese in a randomized trial. *BMC public health*, *12*, 704. doi: 10.1186/1471-2458-12-704

Kavey, R.-E. W. (2015). Combined dyslipidemia in childhood. *Journal of clinical lipidology*, *9*(5 Suppl), S41-56. doi: 10.1016/j.jacl.2015.06.008

Kelly, L. A., Loza, A., Lin, X., Schroeder, E. T., Hughes, A., Kirk, A., & Knowles, A.-M. (2015). The effect of a home-based strength training program on type 2 diabetes risk in obese Latino boys. *Journal of pediatric endocrinology & metabolism : JPEM*, *28*(3-4), 315–322. doi: 10.1515/jpem-2014-0470

Liang, Y., Hou, D., Zhao, X., Wang, L., Hu, Y., Liu, J.,. . . Mi, J. (2015). Childhood obesity affects adult metabolic syndrome and diabetes. *Endocrine*, *50*(1), 87–92. doi: 10.1007/s12020-015-0560-7

Lloyd, L. J., Langley-Evans, S. C., & McMullen, S. (2012). Childhood obesity and risk of the adult metabolic syndrome: A systematic review. *International journal of obesity (2005)*, *36*(1), 1–11. doi: 10.1038/ijo.2011.186

Lobstein, T., & Jackson-Leach, R. (2016). Planning for the worst: Estimates of obesity and comorbidities in school-age children in 2025. *Pediatric obesity*, *11*(5), 321–325. doi: 10.1111/ijpo.12185

Mahé, E., Gnossike, P., & Sigal, M.-L. (2014). Le psoriasis de l'enfant [Childhood psoriasis]. *Archives de pediatrie : organe officiel de la Societe francaise de pediatrie*, *21*(7), 778–786. doi : 10.1016/j.arcped.2014.04.018

Must, A., & Strauss, R. S. (1999). Risks and consequences of childhood and adolescent obesity. *International journal of obesity and related metabolic disorders : journal of the International Association for the Study of Obesity*, *23 Suppl 2*, S2-11.

Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., . . . Gakidou, E. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: A systematic analysis for the Global Burden of Disease Study 2013. *The Lancet*, *384*(9945), 766–781. doi: 10.1016/S0140-6736(14)60460-8

Oja, P., Titze, S., Bauman, A., Geus, B. de, Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: a systematic review. *Scandinavian journal of medicine & science in sports*, *21*(4), 496–509. doi: 10.1111/j.1600-0838.2011.01299.x.

Oosterhoff, M., Joore, M., & Ferreira, I. (2016). The effects of school-based lifestyle interventions on body mass index and blood pressure: A multivariate multilevel meta-analysis of randomized controlled trials. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, *17*(11), 1131–1153. doi: 10.1111/obr.12446

Papoutsakis, C., Priftis, K. N., Drakouli, M., Prifti, S., Konstantaki, E., Chondronikola, M.,. . . Matziou, V. (2013). Childhood overweight/obesity and asthma: Is there a link? A systematic review of recent epidemiologic evidence. *Journal of the Academy of Nutrition and Dietetics*, *113*(1), 77–105. doi: 10.1016/j.jand.2012.08.025

Park, M. H., Falconer, C., Viner, R. M., & Kinra, S. (2012). The impact of childhood obesity on morbidity and mortality in adulthood: A systematic review. *Obesity reviews: an official journal of the International Association for the Study of Obesity*, *13*(11), 985–1000. doi: 10.1111/j.1467-789X.2012.01015.x

Pizzi, M. A., & Vroman, K. (2013). Childhood obesity: Effects on children's participation, mental health, and psychosocial development. *Occupational therapy in health care*, *27*(2), 99–112. doi: 10.3109/07380577.2013.784839

Reilly, J. J., Methven, E., McDowell, Z. C., Hacking, B., Alexander, D., Stewart, L., & Kelnar, C. J. H. (2003). Health consequences of obesity. *Archives of disease in childhood, 88*(9), 748-752. doi: 10.1136/adc.88.9.748

Rosenfield, R. L. (2013). Clinical review: Adolescent anovulation: maturational mechanisms and implications. *The Journal of clinical endocrinology and metabolism*, *98*(9), 3572–3583. doi: 10.1210/jc.2013-1770

Savino, A., Pelliccia, P., Chiarelli, F., & Mohn, A. (2010). Obesity-related renal injury in childhood. *Hormone research in paediatrics*, *73*(5), 303–311. doi: 10.1159/000308161

Schranz, N., Tomkinson, G., Parletta, N., Petkov, J., & Olds, T. (2014). Can resistance training change the strength, body composition and self-concept of overweight and obese adolescent males? A randomised controlled trial. *British journal of sports medicine*, *48*(20), 1482–1488. doi: 10.1136/bjsports-2013-092209

Shultz, S. P., Dahiya, R., Leong, G. M., Rowlands, D. S., Hills, A. P., & Byrne, N. M. (2015). Muscular strength, aerobic capacity, and adipocytokines in obese youth after resistance training: A pilot study. *The Australasian medical journal*, *8*(4), 113–120. doi: 10.4066/AMJ.2015.2293

Stolzman, S., & Bement, M. H. (2012). Inflammatory Markers in Pediatric Obesity. *ICAN: Infant, Child, & Adolescent Nutrition*, *4*(5), 297–302. doi: 10.1177/1941406412459344

Ten Hoor, G. A. ten, Plasqui, G., Schols, A. M. W. J., & Kok, G. (2014). Combating adolescent obesity: An integrated physiological and psychological perspective. *Current opinion in clinical nutrition and metabolic care*, *17*(6), 521–524. doi: 10.1097/MCO.0000000000000099

Ten Hoor, G. A. ten, Sleddens, E. F. C., Kremers, S. P. J., Schols, A. M. W. J., Kok, G., & Plasqui, G. (2015). Aerobic and strength exercises for youngsters aged 12 to 15: What do parents think? *BMC public health*, *15*, 994. doi: 10.1186/s12889-015-2328-7

World Health Organization (2018). *Obesity and overweight – Fact sheet*. Retrieved from http://www.who.int/mediacentre/factsheets/fs311/en/

Zhou, B.-F. (2002). Effect of body mass index on all-cause mortality and incidence of cardiovascular diseases--report for meta-analysis of prospective studies open optimal cut-off points of body mass index in Chinese adults. *Biomedical and environmental sciences : BES*, *15*(3), 245–252.

Table 1: Cohort and intervention characteristics

Author, year	Study design	Sample	Age [mean±SD]	Exercise mode, intervention	Strength test method	Resistance training equipment	Duration	Compliance
Dias, 2015	NRCT	n=44 T: 17 girls 7 boys ≥95th percentile BMI: 32.1±3.6 kg/m² C: 7 girls 13 boys <85th percentile BMI: 20.6±2.4 kg/m² C: only tested at baseline	T: 14.1±1.0 years C: 14.7±1.4 years	T: Circuit resistance training for all major muscle groups 3-times/week, non-consecutive days, 30-40min Week 1-2: 1 set, 10-15 reps, 50-70% 10RM Week 3-6: 2 sets, 8-12 reps, 60-80% 10RM Week 7-12: 3 sets, 6-10 reps, 70-85% 10RM C: no exercise intervention	10 RM	machines, free-weight exercises	12 weeks	Not reported
Shultz, 2015	UCT	n=14 8 girls 6 boys BMI: 32.3±3.9 kg/m²	16.1±1.6 years	3 times/week, non-consecutive days, 60 min session Weeks 1-12: 1-2, 15 exercises, 60-85% 1 RM Weeks 13-16: 1-2 sets, 15 exercises, 85% 1 RM	1 RM	pneumatically controlled machines	16 weeks	100%
Kelly, 2015	RCT	n=26 T: 13 C: 13 BMI: 33.36±5.68 kg/m² Percentile: 97.58±2.03%	T: 15.4±0.9 years C: 15.6±0.96 years	T: home based, supervised, periodized strength resistance training 2 non-consecutive days/week, 60min session Weeks 1-4: 1 set, 10-15 reps, light moderate intensity Weeks 5-10: 2-3 sets, 13-15 reps, moderate intensity Weeks 11-16: 3-4 sets, 8-12 reps, moderate – high intensity C: no exercise intervention	1 RM	not reported	16 weeks	89%
Alberga, 2013	RCT	n=19 T: 5 girls 7 boys C: 1 girl 6 boys ≥95th percentile	T: 10±1 years C: 10±2 years	Supervised resistance training 2 days/week, 75min session Warm up: 20min, 65-70% MHR Resistance training: 45min, 1set, 8-12 reps, 65-85% 1 RM, 13 exercises Cool down: 10min, light exercises & stretching	1 RM	dumbbells, medicine balls, machines	12 weeks	98%
Schranz, 2013	RCT	n=56 T: 30 BMI: 32.2±4.3 C: 26 BMI: 32.6±5.0	T: 14.9±1.4 years C: 15.1±1.6 years	Supervised resistance training 10 multijoint & singlejoint exercises Warm up: 10min Week 1: 1 set, 8-12 reps 10 RM Week 2: 1 set, 8-12 reps 10 RM Weeks 3-26: 3 sets, 8-12 reps 10 RM Cool down: 5min, static stretching	1 RM	weight-stacked machines, free-weight exercises	6 months	74%

T= treatment-group; C= control-group; RCT= randomised controlled trial; NRCT= not randomised controlled trial; UCT= uncontrolled trial; BMI= body mass index; RM= repetition maximum; MHR= maximum heart rate; Reps= repetitions.

Table 2: Resistance training program of each study

Author, year	Day	Order	Exercises	Sets	Reps	Tempo	Rest
Dias, 2015	3 times/ week	1 2 3 4 5 6 7 8 9 10 11 12	Chest press Leg press Low row Leg extension Seated bilateral cable Row Leg curls Arm curls Leg adduction Triceps extension Leg abduction Plantar flexion Push-up	Weeks 1-2: 1 Weeks 3-6: 2 Weeks 7-12: 3	Weeks 1-2: 10-15 Weeks 3-6: 8-12 Weeks 7-12: 6-10	Not reported	No rest between sets and exercises
Shultz, 2015	3 times/ week	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	Chest press Chest curls Biceps curls Triceps curls Push-up Curl down Deltoid press Pull-down Latissimus dorsi curl Leg press Quadriceps extension Hamstring curl Hip abduction Hip adduction Abdominal curl	Number of sets alternated weekly	Not reported	Not reported	Not reported
Kelly, 2015	2 times/ week	1 2	Compound lower body exercises & isolated upper body exercises Compound upper body exercises & isolated lower body exercises	Weeks 1-4: 1 Weeks 5-10: 2-3 Weeks 11-16: 3-4	Weeks 1-4: 10-15 Weeks 5-10: 13-15 Weeks 11-16: 8-12	Not reported	Not reported
Alberga, 2013	2 times/ week	1 2 3	Warm up: treadmill, cycle ergometer, StairMaster, elliptical machines, group aerobic exercises Resistance training: 13 single & multi-joint exercises using all major muscle groups Cool down: whole body dynamic stretching exercises	Warm up: 20min Resistance training: 1 Cool down: 10min	Resistance training: 8-12	Not reported	Not reported

Author, year	Day	Order	Exercises	Sets	Reps	Tempo	Rest
Schranz, 2013	3 times/ week	1	Bench press	Week 1: 1	8-12	2:2	1min/set
		2	Leg press	Week 2: 2	8-12		1min/ exercise
		3	Lat pull-down	Weeks 3-26: 3	8-12		
		4	Leg curl (lying or seated)		8-12		
		5	Shoulder press		8-12		
		6	Seated row		8-12		
		7	Biceps curl		8-12		
		8	Triceps pressdown		8-12		
		9	Abdominal crunch		8-12		

Table 3: Body composition outcome measurements

Author, year	Type of change	Mass, kg	BMI, kg/m²	% fat method	% fat	Total fat mass, kg	Fat free mass, kg	WC	WHR
Dias, 2015	pre:post								
	T	87.8 (11.3)	32.1 (3.6)	DXA	44.6 (4.3)	37.4 (6.4)	46.9 (7.3)	103.9 (8.9)	0.93 (0.06)
		87.2 (11.5)	31.7 (3.7)		43.9 (4.1)	36.9 (6.7)	46.6 (7.3)	100.9 (9.4)	0.90 (0.07)
	C	56.1 (10.0)	20.6 (2.4)		24.3 (7.6)	13.2 (5.2)	40.5 (7.4)	72.4 (7.9)	0.83 (0.07)
	time effect								
	T	NS	NS		P<0.05	NS	NS	P<0.001	P<0.001
	C was only tested at baseline	-	-		-	-	-	-	-
Shultz, 2015	pre:post								
		-	32.3 (3.9)	DXA	41.9 (6.5)	-	50.8 (10.9)	-	-
					40.7 (6.7)		52.5 (11.3)		
	time effect				P=0.006		P=0.011		
Kelly, 2015	pre:post								
	T	97.8 (17.2)	33.1 (4.3)	DXA	31.5 (6.5)	31.0 (89.1)	63.9 (11.4)	103.5	-
		103.7 (22.0)	34.4 (6.7)		33.2 (3.9)	33.9 (65.6)	65.6 (99.3)	(11.1)	
	C	100.1 (20.6)	34.2 (7.5)		32.5 (5.7)	33.2 (13.7)	63.6 (79.5)	108.7	
		93.0 (9.3)	30.6 (2.1)		33.2 (5.4)	29.4 (46.6)	61.5 (45.6)	(13.0)	
	time effect							105.8	
	T	NS	NS		NS	NS	NS	(14.1)	
	C	NS	NS		NS	NS	NS	101.4 (8.4)	
								NS	
								NS	
Alberga, 2013	pre:post								
	T	57.6 (13.5)	27.1 (4.5)	DXA	39.3 (7.0)	23.1 (8.2)	32.6 (6.8)	-	-
		59.6 (14.1)	27.4 (4.7)		38.7 (7.0)	23.5 (8.5)	34.0 (7.0)		
	C	61.6 (11.6)	27.7 (3.2)		41.2 (4.0)	25.6 (6.5)	33.9 (5.3)		
		62.5 (11.9)	27.4 (3.3)		40.7 (4.5)	25.8 (7.0)	34.7 (5.2)		
	time effect								
	T	P<0.05	NS		NS	NS	P<0.05		
	C	NS	NS		NS	NS	P<0.05		
Schranz, 2013	pre:post								
	T	96.0 (15.9)	31.8 (3.7)	DXA	42.5 (5.8)	-	53.8 (8.7)	-	-
		100.5 (18.6)	32.1 (4.3)		41.0 (6.0)		56.2 (8.3)		
	C	97.0 (21.5)	32.3 (4.8)		41.4 (6.5)		53.5 (10.1)		
		100.5 (26.3)	32.5 (5.7)		39.5 (7.6)		56.0 (10.1)		
	time effect	P<0.01	NS		P<0.01		P<0.01		
	group difference	NS	NS		NS		NS		

Data are mean (SD). T= treatment-group; C= control-group; DXA= dual energy x-ray absorptiometry; BMI= body mass index; WC= waist circumference; WHR= waist-to-hip ratio; NS= not significant.

Table 4: Cardiovascular outcome measurements

Author, year	Type of change	SBP, mmHg	TC, mg/dl	LDL, mg/dl	HDL, mg/dl	Leptin, ng/ml	IL-6, pg/ml	TNF-α, pg/ml	Adiponectin, ng/ml
Dias, 2015	pre:post								
	T	122.4 (9.1)	159.5[139.3-181.3]	95.2 (22.0)	41.5[35.2-50.2]	39.010 [22.710-50.060]	1.4 [0.9-2.3]	1.8 [1.2-2.7]	5.119 [3.110-7.763]
		110.1 (8.3)	152.0[136.8-185.5]	94.5 (25.7)	42.0[32.7-52.7]	35.400 [18.780-52.320]	1.6 [1.2-2.4]	1.8 [1.2-2.7]	5.125 [3.025-7.167]
	C	109.7 (11.5)	138.5[124.5-178.8]	85.8 (26.1)	49.0[45.2-57.0]	3.858 [1.297-9.239]	0.6 [0.5-1.0]	1.8 [1.2-2.7]	10.150 [4.848-13.840]
	time effect								
	T	P<0.001	NS	NS	NS	NS	NS	NS	NS
	C was only tested at baseline								
Shultz, 2015	pre:post								
	T	-	-	-	-	30.4 (17.9)	7.1 (5.1)	5.3 (3.0)	5.8 (4.0)
						24.2 (13.8)	1.9 (0.8)	3.5 (1.8)	7.3 (3.8)
	time effect					NS	P=0.011	NS	P=0.047
Kelly, 2015	pre:post								
	T	129.4 (10.1)	-	-	-	-	-	-	-
		125.6 (11.2)							
	C	125.8 (7.5)							
		120.7 (8.3)							
	time effect								
	T	NS							
	C	NS							
Alberga, 2013	pre:post								
	T	-	-	-	-	-	-	-	-
	C								
	time effect								
	T								
	C								
Schranz, 2013	pre:post								
	T	-	-	-	-	-	-	-	-
	C								
	time effect								
	group difference								

Data are mean (SD) or medians [1st-3rd]. T= treatment-group; C= control-group; SBP= systolic blood pressure; TC= total cholesterol; LDL= low-density lipoprotein; HDL= high-density lipoprotein; IL-6= Interleukin-6; TNF-α= tumoral necrosis factor-α; -= not reported; NS= not significant.

Table 5: Quality assessment of the included articles according to the EPHPP tool

Author	Representativeness	Design	Confounders	Blinding[b]	Methods	Drop-out's	Global rating[a]
Dias	Weak	Strong	Strong	NA	Strong	Strong	Moderate
Shultz	Weak	Moderate	Strong	NA	Strong	Strong	Moderate
Kelly	Moderate	Strong	Strong	NA	Strong	Strong	Strong
Alberga	Weak	Strong	Moderate	NA	Moderate	Moderate	Moderate
Schranz	Moderate	Strong	Strong	NA	Strong	Moderate	Strong

EPHPP= Effective Public Health Practice Project; n.a.= not applicable.
[a] Strong= no weak component rating; moderate= one weak component rating; weak= two or more weak component ratings.
[b] The component 'blinding of outcome assessors and participants' has been considered not applicable for observational and interventional studies. The reason for considering blinding not applicable for intervention studies in this case is that in studies with physical activity intervention the assessors (i.e. researchers) and the participants are very likely to know the outcome of the randomization.

Table 6: Summary of study results

Author	Mass	BMI	%Fat	Total fat mass	Fat free mass	WC	WHR	SBP	TC	LDL	HDL	Leptin	IL-6	TNF-α	Adipo-nectin
Dias	n.s.	n.s.	↑	n.s.	n.s.	↑	↑	↑	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Shultz	-	-	↑	-	↑	-	-	-	-	-	-	n.s.	↑	n.s.	↑
Kelly	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-	n.s.	-	-	-	-	-	-	-
Alberga	↑	n.s.	n.s.	n.s.	↑	-	-	-	-	-	-	-	-	-	-
Schranz	↑	n.s.	↑	-	↑	-	-	-	-	-	-	-	-	-	-

BMI= Body Mass Index; TFM= total fat mass; FFM= fat free mass; WC= waist circumference; WHR= waist-to-hip ratio; SBP= systolic blood pressure; TC= total cholesterol; LDL= low-density lipoprotein; HDL= high-density lipoprotein; L= leptin; I= IL-6; T= TNF-α; A= adiponectin.
↑= significant improvement; ↓= significant decline; n.s.= not significant; - = not assessed.