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Review. Effects of Pediatric Resistance Training on health parameters in children: a systematic review. Vol. 8, n.º 2; p. 283-308, may 2022. https://doi.org/10.17979/sportis.2022.8.2.8955

Effects of Pediatric Resistance Training on health parameters in children: a systematic review

Efectos del Entrenamiento de Fuerza Pediátrico sobre parámetros de salud en niños: una revisión sistemática

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Abstract

Physical inactivity, increasingly common among children, is associated with different health problems, including pediatric dynapenia, characterized by low levels of muscle fitness. This raises the need to implement Pediatric Resistance Training (PRT) programs to improve health in this population. The main objective of this work is to investigate the efficacy of PRT-based interventions on different health parameters in boys and girls aged 6 to 13 years. The PRISMA protocol has been followed, using a total of 5 databases (Web of Science, Scopus, Sportdiscus, PubMed and ERIC). The results obtained a total of 587 articles were obtained, of which 13 met the inclusion and exclusion criteria. Following the analysis of the 13 articles, the results show that the effect of PRT interventions in children showed substantial improvements in different anthropometric parameters (body composition, BMI, waist circumference and bone mineral density), and to a lesser extent in physiological (blood pressure and lipid profile) and psychological (self-concept and self-esteem) variables. It is concluded that PRT programs seem to be established as a suitable non-pharmacological treatment to improve certain anthropometric health parameters, with further research needed to determine the effect on physiological and psychological variables.

Keywords

Resistance training; pediatric dynapenia; health; physical inactivity; children.

Resumen

La inactividad física, cada vez más frecuente entre los niños y las niñas, está asociada a diferentes problemas de salud, entre ellos, la dinapenia pediátrica, caracterizada por bajos niveles de aptitud muscular. Esto suscita la necesidad de implantar programas de Entrenamiento de Fuerza Pediátrico (EFP) para mejorar la salud en esta población. Este trabajo tiene como principal objetivo realizar una revisión sistemática sobre las principales investigaciones que abordaron los efectos de un programa de EFP sobre diferentes parámetros de salud en niños y niñas de 6 a 13 años. Se ha seguido el protocolo PRISMA utilizándose 5 bases de datos (Web of Science, Scopus, Sportdiscus, PubMed y ERIC). Los resultados obtuvieron un total de 587 artículos, de los cuales 13 cumplieron los criterios de inclusión y exclusión. Tras el análisis de los 13 artículos, los resultados muestran que el efecto de las intervenciones de EFP en niños mostró mejoras sustanciales en diferentes parámetros antropométricos (composición corporal, IMC, circunferencia de la cintura y densidad mineral ósea), y en menor medida en variables fisiológicas (presión arterial y perfil lipídico) y psicológicas (autoconcepto y autoestima). Se concluye que los programas de EFP parecen establecerse como un tratamiento no farmacológico adecuado para mejorar determinados parámetros de salud antropométricos, precisando más investigación para determinar el efecto sobre variables fisiológicas y psicológicas.

Palabras clave

Entrenamiento de fuerza; dinapenia pediátrica; salud; inactividad física; niños.

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1. Introduction

Physical inactivity in the child and youth population is increasing worldwide and currently, according to a study by Aubert et al. (2018) that assessed the level of physical activity (PA) in children and youth (5-17 years) in a total of 49 countries with different levels of development, only 34%-46% of children and youth meet the World Health Organization (WHO) recommendations of at least 60 minutes of moderate-vigorous physical activity (MVPA) per day. More recently, Guthold et al. (2020), in a study of 1.6 million children and young people (11-17 years), found that more than 80% do not meet these recommendations. These low levels of PA are associated with different health problems, such as an increased risk of cardiovascular disease, metabolic dysfunction and increased obesity (DeFina et al., 2015; Faigenbaum & Geisler, 2021; Suder & Chrzanowska, 2013).

Moreover, linked to this decline in PA, recent studies indicate that muscular fitness (MF) in today's children and youth is lower than in previous generations (Chulvi-Medrano et al., 2020; Faigenbaum et al., 2019; Sandercock et Cohen, 2019; Tomkinson et al., 2021). These low levels of MF are associated with poor motor competence, functional limitations and adverse health outcomes (Garcia-Hermoso et al., 2019; Smith et al., 2014).

Another of the consequences of physical inactivity in the child and youth population is what is known as the pediatric inactivity triad (Faigenbaum, et al., 2020), consisting of three distinct but interrelated components: paediatric dynapenia, a condition characterised by low levels of muscle strength and power, and consequent functional limitations not caused by neurologic or muscular disease; physical iliteracy, referring to the lack of confidence, competence, and motivation to engage in meaningful physical activities with interest and enthusiasm; and exercise deficit disorder, which describes a condition of reduced levels of MVPA (<60 minutes of MVPA daily).

In contrast, regular practice of MVPA in children and youth is associated with improvements in cardiometabolic health, body composition, academic performance and health-related quality of life (Piercy et al., 2018). In addition, recent findings indicate that resistance training (RT) has also been associated with positive physical and mental health

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benefits in young people (Collins et al., 2019; Drenowatz & Greier, 2018; Padilla-Molero et al., 2012 & Santos et al., 2012).

To counteract the harms of physical inactivity and maximise the benefits of MVPA practice, the International Consensus on Youth Resistance Training (Lloyd et al., 2014) states that both the WHO (2010) and other Public Health Agencies, such as the United States Department of Health and Human Services (Piercy et al., 2018) or the Department of Health, Physical Activity, Health Improvement and Protection (2011recommend the performance of 60 minutes or more of MVPA daily for children and young people in the age range 5-17 years. In addition to vigorous activities that strengthen muscles and bones at least three times per week (Bull et al., 2020).

In the last decade, particular interest has been shown in RT among the child and youth population and its relationship to various health parameters, showing that programmes of paediatric resistance training (PRT) are a safe and effective method for increasing cardiovascular fitness, body composition, bone mineral density, blood lipid profiles, insulin resistance and mental health (Faigenbaum et al., 2015; Smith et al., 2014 and Stricker et al., 2020), as well as for improving muscle fitness and motor performance in children and adolescents (Benson et al., 2007; Casas et al., 2018; Lesinski et al.; Lloyd et al., 2014; Stricker et al., 2020). However, most studies include the adolescent period and there are few studies that focus only on PRT in children <13 (Villa-González, et al., 2022).

For this reason, the aim of this systematic review was to investigate the efficacy of PRT programmes on certain anthropometric (body composition, BMI, waist circumference and bone mineral density), physiological (blood pressure and lipid profile) and psychological (self-concept and self-efficacy) health parameters in children aged 6-13 years.

2. Method

A systematic review was carried out in accordance with the recommendations and criteria of the PRISMA statement for the development and guidance of systematic reviews and meta-analyses (Moher et al, 2009).

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Search procedure

The search procedures were based on the keywords and Boolean Operators: (“resistance training” OR “strength training” OR “weight training” OR “resistance exercise”) AND (“child” OR “children” OR “schooler” OR “preadolescent” OR “kid” OR “childhood” OR “schoolchildren”) AND (“BMI” OR “waist circumference” OR “body composition” OR “blood pressure” OR “hypertension” OR “hdl” OR “ldl” OR “cholesterol” OR “bone density” OR “bone mineral density” OR “psychosocial” OR “psychological”) established by the authors and consulted through the thesauri of these databases.

The combination of these keywords were inserted into the electronic databases of Web of Science, Scopus, Sportdiscus, PubMed, and ERIC, and manual searches in ResearchGate. A time limit was set from 2005 to December 2021, and studies beyond this period were not included. Databases were searched from 24 January to 28 December 2021.

Eligibility Criteria

The inclusion criteria were established following the PICOs strategy set out in the PRISMA statement: P (Population): boys and girls aged between 6 and 13 years. The selection of this age limit is mainly due to the fact that this age criterion is recommended by the International Consensus on Youth Resistance Training (Lloyd et al., 2014); I (Intervention): resistance training programme for health improvement longer than 2 weeks in school or sports settings; C (Comparison): experimental group that received the treatment with or without control group; O (Outcome): assessment of at least one health parameter after completion of the intervention; S (Type of study): randomised controlled trials and quasi-experimental trials.

Exclusion criteria taken into account in this review were: 1) review articles (meta-analyses, systematic reviews and narrative reviews), 2) sample types (scientific papers addressing healthy parameters in PRT, but not children aged 6-13 years) and 3) types of training protocols (such as concurrent training combining strength and endurance in the same training schedule) 4) duplicate articles.

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Selection process

The search was conducted independently by two authors, with the search strategy presented through the databases mentioned above. Articles whose title and/or abstract met the eligibility criteria were selected. Inclusion and exclusion criteria were rigorously applied to the selected articles in their full text and, finally, those that were relevant were included for final review and synthesis.

After the final selection, the most relevant information from these studies was recorded in table 1, where the following data were extracted from each article selected for review: 1) relevant authors of each study, 2) design of the research conducted, whether it was a randomised controlled trial or quasi-experimental study, 3) sample drawn from the participants of each study 4) age of the subjects, 5) the duration of the training programme, with a minimum of 2 weeks, 6) training programme where the frequency, intensity and volume of training were recorded, 7) description of the training in terms of the type of training, material and exercises used, 8) results of the variables studied and 9) PEDro scale.

Study risk of bias assessment

The quality of the individual studies was assessed using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale scores the existence of quality indicators presented as 1 point and the absence of such indicators as 0 points, up to a maximum score of 11 points. A score of > 6 will represent studies with low risk of bias.

3. Results

In the first stage of the search strategy, a total of (n = 587) articles were identified. In the second stage, after removal of duplicates, a total of (n = 476) articles were screened by title and abstract, and 437 articles were excluded. In the third stage, 39 full-text articles were reviewed in depth and (n = 28) studies were excluded for different justified reasons. Finally, after application of the PRISMA methodology standards, a total of 13 studies on RT in children met the inclusion criteria (Figure 1).

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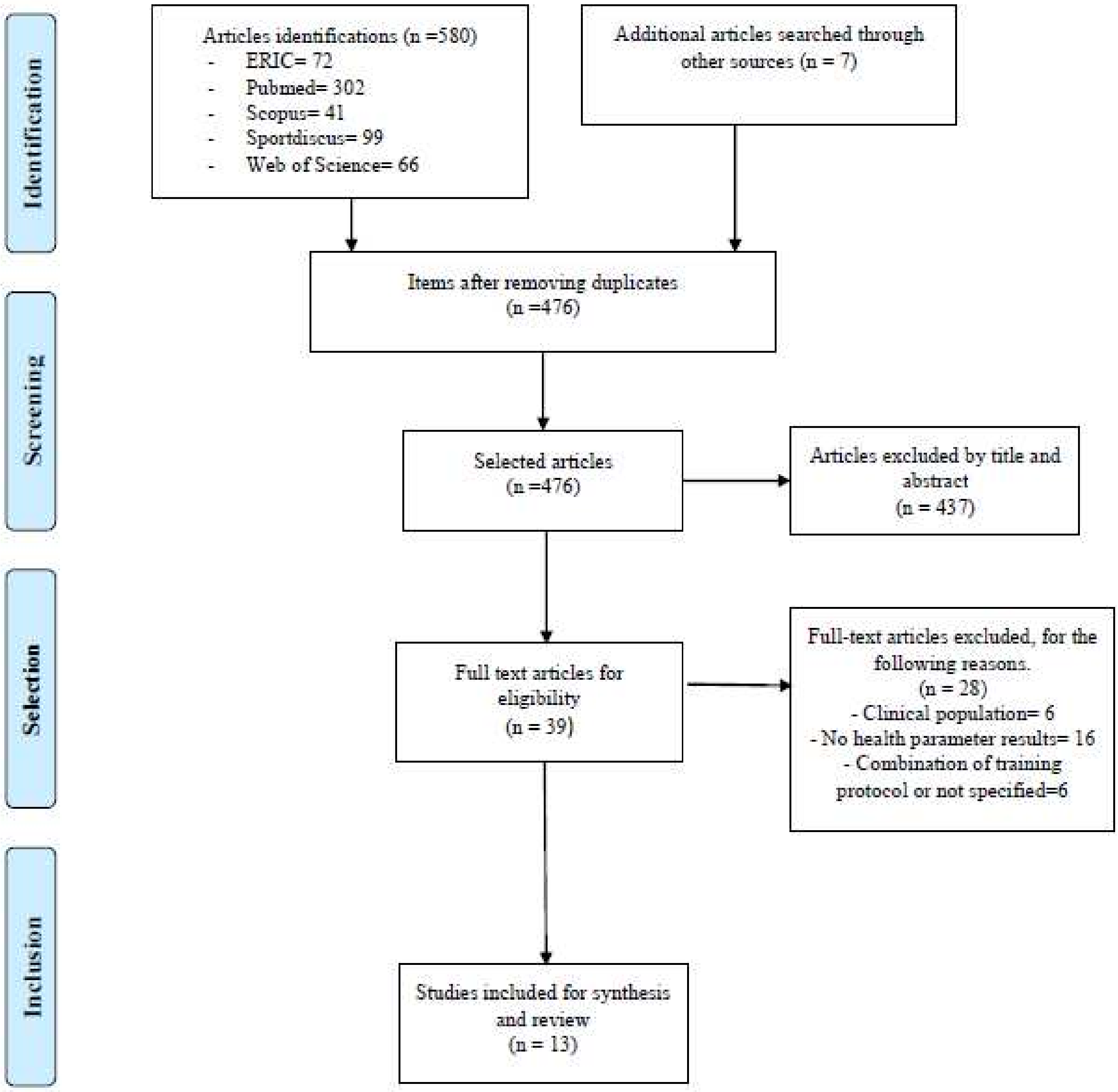

Figure 1: PRISMA flow chart

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In the table I, the 13 selected articles on health parameters in RT in children from 6 to 13 years of age are listed.

Table 1. Description of the main articles selected for the elaboration of the review.

Authors	Design	Sample	Ages	Duration	Training program (frequency, intensity and volume)	Program description	Results of the variables studied	EDro
(Yu et al., 2005)	RCT (intergroup and intragroup)	N= 82 BMI ≥85 CG: n= 41 EG: n= 41 T: I y II	8-11 years old (10,4 years old)	6	3 sessions per week (75') 75% 10 MR increased progressively 90% MR 1x20 MR (9 exercises) 1 agility exercise and 1 aerobic exercise.	CRT: Exercises for all muscle groups with own body weight, dumbbells and weight machines.	Intergroup: *BMD (p<0.05) Intragroup: *BF (p<0.05) ***LBM (p<0.001) n.s.BMI (p>0.05) *** BMD (p<0.001)	
(Yu et al., 2008)	RCT (intergroup)	N=82 (54 boys y 28 girls) BMI≥ 85 CG: N=41 EG: N=41	8-11 years old (10,5 years old)	6	3 sessions per week (75') 75% 10 MR increased progressively 1x20 MR (8 exercises) 1 agility exercise and 1 aerobic exercise.	CRT: Exercises for all muscle groups with own body weight, dumbbells and weight machines.	**BMI (p<0.01) n.s. BMF (p>0.05) *** LBM (p<0.001) * BF (p<0.05) ** Strengh confidence ** Resistance confidence	

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		T: I y II				n.s. Global self-concept (p>0.05)
(Naylor et al., 2008)	QT (intragroup)	N= 23 BMI >30kg/m2 CG:10 EG:13	12, years old	2 8	3 days a week (60') α 75 MR progressive increase α 90% MR 2x8 (10 exercises) 1' rest between exercises	CRT: weight machines with a total of 10 exercises with all muscle groups.	* SBP (p< 0.05) n.s. DBP (p> 0.05) n.s. BMI (p>0.05) * BC (p< 0.05) *LBM (p< 0.05) ** BF (p< 0.01)

RCT: Randomized Controlled Trial; QT: Quasi-experimental trial; CG: control group; EG: experimental group; RT: resistance training; MR: maximum repetition: BMI; Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BC: Body Composition; BMF: Body Mass Fat; LBM: Lean Body Mass; BMD: Bone Mineral Density; BF: Body Fat; CRT: Circuit Resistance Training; T: Tanner.
*** p>0.001 **p>0.01 *p>0.05 n.s.: not significant.

Table 1.

Authors	Design	Sample	Ages	Duration	Training program (frequency, intensity and volume)	Program description	Results of the variables studied	E D r

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(Sgro, McGuigan, Pettigrew et Newton, 2009)	RCT (intragroup)	N=31 (15 boys and 16 girls) BMI ≥ 85 G8S: n=6 (4 boys and 2 girls) G16S: n=9 (3 boys and 6 girls) G24S: n=16 (8 boys and 8 girls) T: I y II	7 -12 years old	8-24	3 days a week (45-60') 1-8 s:3x6-8 MR 9-16 s:3x4-6 MR 17-24 s: 3x3-5 MR .	TST: exercises with all muscle groups of own body weight, elastic bands, medicine balls and heavy bags.	G8S: n.s. BMI n.s. BMD n.s. LBM *BMF (p<0.021) G16S: n.s. BMI *** BMD (p<0.001) **LBM (p<0.002) **BMF (p<0.012) G24S: n.s. BMI ** BMD (p<0.004) ***LMB (p<0.001) ***BMF (p<0.001)
(McGuigan, Tatasciore, Newton et Pettigrew, 2009)	QT (intragroup)	N= 48 (n=26 girls y 22 boys) BMI ≥85 T: I y II	7-12 years old (9,7 years old)	8	3 days a week Day 1: 3x8-10MR (8 exercises and 90" rest between exercise) Day 2: 3x10-12MR (8 exercises and 60" rest between exercises) Day 3: 3x3-5 MR (8 exercises	TST: exercises for all muscle groups with dumbbells, elastic bands, medicine balls and weight machines.	**BMF (p< 0.003) *LMB (p<0.05) n.s. BMI (p>0.05) n.s. BMD (p>0.05)

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					and 3" rest between exercises)			
(Lau et al., 2010)	QT (intragroup)	N= 18 (5 girls, 13 boys) BMI >85	12,45 years old	6	3 days a week (60') 75-85% 1-MR 3x5-8 (10 exercises) Rest between sets 3-5'.	TST: exercises for all muscle groups with weight machines.	n.s. BMF (p>0.05) d=0.01 n.s. LMB (p>0.05) d= 0.02 n.s. BMI (p>0.05) d= 0.02 ***BMD (p<0.001) d= 0.14 *WC (p< 0.05) d=0.05	6

RCT: Randomized Controlled Trial; QT: Quasi-experimental trial; CG: control group; G8S: 8-week group; G16S: 16-week group; G24S: 24-week group; RT: resistance training; MR: maximum repetition: BMI; Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BC: Body Composition; BMF: Body Mass Fat; LBM: Lean Body Mass; BMD: Bone Mineral Density; BF: Body Fat; WC: waist circumference: CRT: Circuit Resistance Training; TST: traditional strength training T: Tanner. *** p>0.001 **p>0.01 *p>0.05 n.s.: not significant.

Table 1.

Authors	**Design**	**Sample**	**Ages**	**Duration**	**Training program (frequency, intensity and volume)**	**Program description**	**Results of the variables studied**	**PEDro**

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(Vasquez et al., 2013)	QT (intra and inter group)	N=120 BMI≥ 95 EG1: N=60 (with 0-3 months of training) EG2: N=60 (with 3-6 months of training) T: I y II	8-13 years old	16	3 times a week (45') 1-2-3: 1' of work - 2' of rest - repeated 3 times.	TST: dumbbells and own body weight for all muscle groups.	(0-3 months: EG1 vs EG2) Intergroup ***BMI (p<0.001) ***WC (p<0.001) ***BF in boys (p<0.001) ***BF in girls (p<0.001) Intragroup *WC (p<0.02) *TG (p<0.04) ***HDL (p<0.001) n.s. SBP (p>0.05) (3-6 months: EG1 vs EG2) Intergroup *BMI (p<0.04)
(Alberga, Farnesi, Lafleche, Legault et Komorowski, 2013)	RCT (intragroup and entergroup)	N=19 BMI: ≥ 85 EG: 12 (7 boys and 5 girls) CG: 7 (6 boys and 1 girl) T: I	8-12 years old	12	2 times a week (75´) 65-85% MR 1x8-15 MR	TST: exercises for all muscle groups with dumbbells, medicine balls and weight machines.	Intragroup: *LMB legs (p<0.05) *LMB trunk (p<0.05) *LMB arms (p<0.05) *LMB total (p<0.05) *BMF (p<0.05) n.s BMI (p>0.05) Intergroup: *LMB legs (p<0.05)

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RCT: Randomized Controlled Trial; QT: Quasi-experimental trial; CG: control group; EG1: experimental group 1; EG2: experimental group 2; RT: resistance training; MR: maximum repetition: BMI; Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; LDL: Low Density Lipoproteins; TG: Triglycerides; HDL: High Density Lipoproteins; BC: Body Composition; BMF: Body Mass Fat; LBM: Lean Body Mass; BMD: Bone Mineral Density; BF: Body Fat; WC: waist circumference: CRT: Circuit Resistance Training; TST: traditional strength training T: Tanner. *** p>0.001 **p>0.01 *p>0.05 n.s.: not significant

Table 1.

Authors	**Design**	**Sample**	**Ages**	**Duration**	**Training program (frequency, intensity and volume)**	**Program description**	**Results of the variables studied**	**E D r o**
(Cunha et al., 2015)	RCT (intragroup)	N=18 BMI: <85 CG: N=9 EG: N=9 T: I	10-12 years old	12	3 days a week (α60') 60-80% MR Rest between series of 60-90 seconds. 1-4: 3x15 (60%MR) 5-8: 3x10-12 (70%MR) 9-12: 3x6-8 (80%MR) .	TST: exercises for all muscle groups with weight machines and your own body weight.	Intragroup: * BMF (p<0.05) d=0.14 *LBM (p<0.05) d=0.35 ** BMD (p<0.05) d=0.31 n.s. BF (p>0.05) d=-0.08	
(Yu et al., 2016)	RCT (intragroup)	N=38 (25 boys y 13 girls) BMI: > 40 y <60	11-13 years old	10	2 days a week (α60´) 1-4:3x12 MR (13 exercises and 16" rest between each set)	TST: exercises for all muscle groups with weight machines, own body weight, sandbags, elastic bands and fitness balls.	Intragroup *BMI (p<0.048) n.s. BF (p>0.05)	

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		(normal weight) CG: N=19 (6 girls y 13 boys) EG: N= 19 (7 girls y 12 boys) BMI: ≥ 40 y ≤60 T: II			4-10: 4x12 MR		***LBM ($p<0.001$) n.s.SBP ($p> 0.05$) n.s. DBP ($p> 0.05$) *TC ($p< 0.025$) n.s.HDL($p>0.05$) ***LDL ($p< 0.001$) n.s TG ($p> 0.05$)
(Ramezani, Gaeini, Hosseini, Mohammadi y Mohammadi, 2017)	RCT (intergroup)	N=60 CG: N= 15 EG1: N=15 (aerobic work) EG2: N= 15 (resistance training) EG3: N= 15 (concurrent training)	8-12 years old	8	4 days a week (α60´) 50-75% MR 3x8 MR (5 exercises) 1' rest between sets	TST: exercises for all muscle groups with dumbbells and weight machines.	EG2 vs CG ***BMI ($p>0.001$) ***TC($p>0.001$) ***TG ($p>0.001$) ***HDL($p>0.001$) ***LDL($p>0.001$)

RCT: Randomized Controlled Trial; QT: Quasi-experimental trial; CG: control group; EG1: experimental group 1; EG2: experimental group 2; EG3: experimental group 3; RT: resistance training; MR: maximum repetition: BMI; Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; LDL: Low Density Lipoproteins; TG: Triglycerides; HDL: High Density Lipoproteins; BC: Body Composition; BMF: Body Mass Fat; LBM: Lean Body Mass; BMD: Bone Mineral Density; BF: Body Fat; WC: waist circumference: CRT: Circuit Resistance Training; TST: traditional strength training T: Tanner. *** $p>0.001$ ** $p>0.01$ * $p>0.05$ n.s.: not significant

Table 1.

Authors	Design	Sample	Ages	Duration	Training program (frequency, intensity and volume)	Program description	Results of the variables studied E

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(Thompson et al., 2017)	QT (intergroup)	N=25 BMI: <85 EG: N=16 (TST+PT) CG: N=9 T: I y II	EG:11,8 years old CG: 12, 1 years old	16	2 days a week (90') Plyometrics: 3 sets of exercises rotated weekly (Block 1: week 1,4,7...rest 60" between sets) TST: 3x 5MR	PT: own body weight TST: exercises for all muscle groups using weight machines, barbells and own body weight	* BF (p<0.03) n.s. BMF (p>0.05) n.s. LBM (p>0.05)
(Mullane, Bocchicchi et Crespo, 2017)	RCT (intragroup)	N=20 (2 girls y 18 boys) T: I	6-11 years old	8	2 days a week (45') TST at low speed to achieve high intensity 1-2: 60s repeats (with: 2-3s and excen: 2-3s) 3-4: 70s repeats (with:3-4s and excen: 3-4s) 5-6: 80s (with: 4-5s and excen: 4-5s) 7-8: 90s (with:5-6s and excen: 5-6s)	TST: exercises for all muscle groups with weight machine and own body weight.	Intragroup: *BF (p<0.049) ***LBM (p<0.001) **WC (p<0.006) n.s TC (p> 0.05) n.s TG (p> 0.05) n.s LDL (p> 0.05) ** Physical self-efficacy (p<0.008)

RCT: Randomized Controlled Trial; QT: Quasi-experimental trial; CG: control group; EG: experimental group; RT: resistance training; MR: maximum repetition: BMI; Body Mass Index; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; TC: Total Cholesterol; LDL: Low Density Lipoproteins; TG: Triglycerides; HDL: High Density Lipoproteins; BC: Body Composition; BMF: Body Mass Fat; LBM: Lean Body Mass; BMD: Bone Mineral Density; BF: Body Fat; WC: waist circumference: CRT: Circuit Resistance Training; TST: traditional strength training; PT: plyometric training; T: Tanner. *** p>0.001 **p>0.01 *p>0.05 n.s.: not significant

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Study characteristics

The characteristics of the 13 studies are listed in Table 1. The analysis included a total of 584 children in the total number of samples obtained. There were 403 participants in the experimental groups (sample size 6-60 participants) and 151 children in the control groups (sample size 7-19 participants). The age of the subjects ranged from 6-13 years. The studies analysed were conducted in 7 different countries: Australia, Brazil, Canada, Chile, China, USA and Iran.

All the studies complied with the principles of progression, supervision and overload applied to the participants, following an individualised protocol in the delivery of the sessions.

The duration of the programme ranged from 6-24 weeks, the frequency of the intervention ranged from 2-4 days per week, the set volume was maintained in most studies at 1-3 and repetitions ranged widely from 5-20 repetitions, and only in 5/13 studies was there variation in repetitions due to training progression. The duration of the sessions remained between 45-90 minutes. The rest period of the sets was divided in most (12/13) studies from 1-5 minutes, except for the study by Yu et al. (2016) which was 10 seconds rest. In terms of programme intensity, the majority (11/13) used the percentage of one repetition maximum (RM) for monitoring and control of programme participants.

The materials used in the PRT programme intervention in most studies (9/13) were dumbbells, free weight machines and body weight exercises. The remaining 4 studies presented a more dynamic intervention using different materials in the execution of the exercises: elastic bands, medicine balls, heavy bags.

Most of the studies (11/13) were based on a traditional RT programme with work on the large muscle groups, except for two studies that used a training circuit and plyometric work intervention with a combination of RT.

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During the intervention only one of the thirteen studies (Vasquez et al., 2013) received emotional and dietary education for three months, but no calorie restriction or dietary follow-up was performed.

Most of the studies used a traditional PRT programme with moderate (<75% 1RM) to moderate-high (>80% 1RM) intensity of one to three sets ranging from 5 to 20 repetitions over a period of 6 to 24 weeks for treatment, with one to five minutes rest between sets. Significant improvements have been found in anthropometric parameters (body composition, waist circumference and bone mineral density), as well as substantial improvements in lipid profile but less conclusive in blood pressure and psychological parameters (self-concept and self-esteem) in paediatric age 6-13 years. Although the results should be approached with caution due to the diversity between samples, age, variables measured and training planning, which makes it difficult to compare them.

Following the quality criteria of the PEDro scale, the present systematic review has the majority of studies (10/13) with a low level of risk of bias and only 3 studies with a low quality of risk of bias.

Six studies clearly showed randomisation, but only two of them described allocation concealment. Most of the studies did not present assessor blinding, only one of the studies did (Yu et al., 2016).

4. Discussion

The aim of this study was to conduct a review of the existing scientific literature that addressed PRT programmes on certain anthropometric (body composition, BMI, waist circumference and bone mineral density), physiological (blood pressure and lipid profile) and psychological (self-concept and self-efficacy) health parameters in boys and girls aged 6 to 13 years. The main findings are that PRT programmes in isolation and with moderate (<75% 1RM) to moderate-high (>80% 1RM) intensities of 1-3 series with repetitions ranging from 5-20 repetitions, seem to cause a positive and significant effect on variables collected in anthropometric parameters, especially on body composition, waist circumference and bone

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mineral density in healthy or overweight or obese boys and girls aged 6 to 13 years old, as well as substantial improvements in the lipid profile of the participants.

Effects of PRT on anthropometric health parameters

11 of the 13 studies reviewed showed significant improvements in body composition, more specifically in body fat reduction (Yu et al., 2005; Yu et al., 2008; Naylor et al., 2008; Sgro et al., 2009; McGuigan et al., 2009; Vasquez et al., 2013; Alberga et al., 2013; Cunha et al., 2015; Yu et al., 2016; Thompson et al., 2017; Mullane et al., 2017). In addition, 4 of the 13 studies showed significant reductions in waist circumference in young people (Naylor et al., 2008; Lau et al., 2010; Vasquez et al., 2013; Mullane et al., 2017).

Of the above studies, the longest lasting was the study by Sgro et al., 2009, which established a 24-week PRT programme in children aged 7-12 years. The results showed a significant reduction of 8.1% in body fat mass at the end of the programme and it was concluded that the longer the duration of the training programme, the greater the benefits obtained in the participants in relation to anthropometric parameters.

On the other hand, two studies showed an increase in lean body mass in school children. Yu et al. (2005) conducted a 6-week (3 days/week) traditional PRT programme in obese children aged 8-11 years, resulting in a significant increase in lean body mass (2.4%) and a reduction in body fat compared to the control group (1%). Another similar study (McGuigan et al., 2009) showed significant reductions in body fat percentage and increases in lean body mass, but no influence on body mass index (BMI). Along the same lines, a review of the effects of PRT on childhood obesity (Oh et al., 2014) reported positive changes in body composition with significant increases in lean body mass and reductions in body fat percentage without improvements in BMI, considering it a safe and effective training programme to combat the effects of obesity at this school age.

Five of the 13 studies observed showed significant increases in bone mineral density (BMD) (Yu et al., 2005; Yu et al., 2008; Sgro et al., 2009; Lau et al., 2010; Cunha et al., 2015). In this sense, several studies affirm bone mineral concentration in children and

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adolescents after the implementation of a PRT programme (Faigenbaum and Myer, 2010; Stricker et al., 2020). Lau et al. (2010) investigated that six weeks of PRT produced significant increases in BMD in obese children assessed by dual-energy X-ray absorptiometry (DEXA). After PRT intervention in obese children, another similar study, (Sgro et al., 2009) reported a significant BMD increase after 16 weeks of 4.9% and after 24 weeks of 6.2% as measured by DEXA. Therefore, strength or weight training stimulates and improves BMD, and Barbieri and Zaccagni (2013) conclude that a PRT programme seems to have a positive effect on BMD at an early age and qualify it as an interesting means to prevent and reduce osteoporosis in adulthood.

Effects of PRT on physiological health parameters

Three of the 13 studies observed showed significant improvements in high-density lipoprotein (LDL), total cholesterol (TC) and triglycerides (TG) in participants (Vasquez et al., 2013; Yu et al., 2016; Ramezani et al., 2017). Likewise, studies on lipid profile showed significant reductions in LDL and TG in obese children and adolescents, in addition to improving their health-related fitness and decreasing metabolic risk (Branco et al., 2020). In the present review, Ramezani et al. (2017) showed reductions in lipid profile values after a PRT programme in obese children aged 8-12 years. Similarly, Yu et al. (2016) investigated that 10 weeks of PRT in healthy 11-13 years olds significantly reduced LDL and TC and found no significant differences in participants' blood pressure (BP). Another prominent study in children and adolescents showed reductions in lipid profile, attenuating TG and LDL concentrations (Santos et al., 2020), suggesting that a supervised and regulated PRT programme is able to promote adjustments in different biochemical variables in children and adolescents.

Two of the 13 studies analysed showed significant improvements in BP (Naylor et al., 2008 and Vasquez et al., 2013). Along the same lines, Naylor et al. (2008) showed no significant differences in the BP of participants in an eight-week PRT programme in children. This is in line with a review and meta-analysis by Guillem et al. (2020) of the effects of RT on BP in children and adolescents, where eight studies were analysed showing no significant decreases in BP in young people, and no enlightening results on participants' BMI. Further high quality studies are needed to clarify the association between PRT and BP in children.

Effects of PRT on psychological health parameters

Studies on the psychological benefits through a PRT programme in young people are very limited. A recent systematic review on the effects of RT on physical fitness (PF) in children, concluded that RT is an effective method to improve cardiorespiratory fitness in children aged 6-12 years (Le-Cerf et al., 2022). In this sense, a randomised controlled trial conducted by Ortega et al. (2017) on PF and its relationship with subcortical structures in children showed that both cardiorespiratory fitness and muscular strength were significantly associated with greater development of certain subcortical brain nuclei, developing greater cognitive capacity which, in turn, may favour children's mental health (Ortega et al., 2017).

In this review, only 2 out of 13 studies analysed showed significant improvements in self-concept and self-efficacy in children at the end of a PRT programme (Yu et al., 2008 and Mullane et al., 2017). In this sense, Yu et al. (2008) reported that a PRT programme in children aged 8-11 years for six weeks improved confidence in strength and endurance, but there were no significant results in global self-concept. Another similar study (Mullane et al., 2017) showed significant results on physical self-efficacy in children aged 6-11 years over eight weeks. In a systematic review and meta-analysis (Collins et al., 2019) on the effects of PRT on self-concept interventions in youth, the authors concluded that PRT in isolation has a positive impact on some psychological aspects of children, as appears to be endurance self-efficacy, strength and global self-esteem, which are key variables for children's confidence in performing any PA. However, in this aspect, more and higher quality studies should be carried out in order to analyse in depth the effects of PRT on this parameter at school age.

5. Conclusion

This systematic review concludes that PRT is an effective method for improving anthropometric parameters (body composition, waist circumference and BMD) in healthy, overweight or obese boys and girls, as well as substantial improvements in the lipid profile of young people. In blood pressure and psychological parameters (self-concept and self-esteem)

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more studies should be addressed due to the limited scientific evidence collected in this review in paediatric age 6-13 years.

Most studies used a traditional PRT programme with moderate (<75% 1RM) to moderate-high (>80% 1RM) intensity of one to three sets with repetitions ranging from 5 to 20 repetitions over a period of 6 to 24 weeks for treatment, with one to five minutes rest between sets.

Despite the diversity of samples and training programmes found in our review, we recommend the use of PRT programmes as strategies to favour the quality of life and well-being of children, respecting their previous experience, age, interests and pathologies related to overweight or obese children.

The main benefit of the practical application of this review is that it can be useful for coaches and teachers to work on health-oriented strength capacity and achieve healthy benefits in this population of children.

6. Limitations and new proposals

There is a need to propose more randomised studies without including the adolescent period for a better interpretation of the results. More studies covering a homogeneous training programme in terms of intensity, volume, duration or frequency of training are needed, as some studies varied on a large scale in some of these variables, for a better comparison of the results. In this sense, future research is needed to specify the effects of PRT on physiological and psychological parameters in boys and girls.

On the other hand, there are limitations in our research that should be taken into account when interpreting the results. In terms of age, the present systematic review included studies with boys and girls <13 years old, presumably prepubertal, and prior to sexual maturation. However, there is significant inter-individual variation in the level, moment and timing of biological maturation, so the relative mismatch and wide variation in biological maturation between boys and girls of the same chronological age highlights limitations in the use of chronological age as a determinant. In addition, most interventions were carried out on

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boys. Along the same lines, there is a need for studies evaluating PRT programmes in healthy children at this paediatric age, because most studies included overweight or obese children.

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