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IMPACT OF RESISTANCE TRAINING IN CHILD AND YOUTH POPULATION: A SYSTEMATIC REVIEW

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Abstract. The aim of this study was to find out the resistance training influence on the child and adolescent population, as well as determine the possible risks or benefits that the training of this physical capacity may cause. A systematic review has been carried out on the impact of resistance training in subjects aged between 6 and 18 years. The studies used in this review were identified through Pubmed database, selecting those written in English or Spanish, from 2010 to the present. The revision was carried out between November 2020 and May 2021. A total of 328 articles were identified in the initial search, of which 20 articles were chosen for this systematic review. The results show that the benefits from resistance training clearly outweigh their risks, as long as the training program is supervised and guided by qualified personnel, individualizing the training loads to each subject need. Likewise, resistance training in young population contributes to the improvement of different motor skills and sports activities, resulting in an effective strategy for diseases such as obesity.

Keywords: Childhood, obesity, motor skill, children, exercise.

INCIDENCIA DEL ENTRENAMIENTO DE FUERZA EN LA POBLACIÓN INFANTOJUVENIL: REVISIÓN SISTEMÁTICA

Resumen. El objetivo de esta revisión fue conocer la influencia que tiene el entrenamiento de fuerza en la población infantojuvenil, además de buscar los posibles riesgos o beneficios que pueda ocasionar el entrenamiento de esta aptitud física. Se ha llevado a cabo una revisión sistemática de estudios de intervención sobre el impacto que produce el entrenamiento de la fuerza en sujetos con una edad comprendida entre 6 y 18 años. Los estudios utilizados en esta revisión se identificaron a través de la base de datos PubMed, seleccionando aquellos escritos en inglés o castellano, desde el 2010 hasta la actualidad. La revisión se efectuó entre los meses de Noviembre de 2020 hasta Mayo de 2021. Se identificaron un total de 328 artículos en la búsqueda inicial, de los cuales 20 artículos fueron elegidos para esta revisión sistemática. Dentro de las principales evidencias encontradas, los beneficios derivados del entrenamiento de fuerza se imponen notablemente a los riesgos, siempre y cuando el programa de entrenamiento sea supervisado y pautado por personal cualificado, individualizando la carga a las necesidades de cada sujeto. Asimismo, el entrenamiento de fuerza en esta población contribuye a mejorar el rendimiento de distintas habilidades motoras y actividades deportivas, resultando además una estrategia eficaz ante patologías como la obesidad.

Palabras clave: Infancia, obesidad, habilidad motora, niños, ejercicio.

Introduction

The term strength training refers to a specialized method of conditioning, which involves the progressive use of resistant loads and a variety of training modalities designed to improve health, fitness, and athletic performance (Faigenbaum et al., 2009). Although strength training and weight training are often used as equal terms, the term strength training encompasses a broader range of training modalities and training goals (Faigenbaum et al., 2009).

Strength training in children and young people has been a subject that for many years has generated great controversy regarding the type of training, volume or duration, as well as numerous doubts as to its contribution to this population (Vrijens, 1978). With the passage of time, more research has been done on this subject and from the NSCA study (1985) possible benefits of this training have been found, reflecting improvements on the mastery of motor skills and generating a positive contribution on other abilities.

The physical health-related benefits of strength training for young people is another relevant issue. It has been shown that the implementation of an adequate strength program induces improvements in bone health and body composition, as well as being highly effective in preventing possible injuries, especially in sports (Faigenbaum et al., 2009).

With the right training methods, this type of training for children and adolescents can be relatively safe, leading to an improvement in overall health (Behm, 2008). In addition, another aspect that scientific evidence highlights is the need for supervision and prescription of this type of training by a professional, being key to the effectiveness of training programs, since prioritizing the physical safety of young people will be necessary for the improvement of health and performance (Loyd et al., 2014).

To this day there are still misconceptions about strength training in children that they are more prone to injury than adults. Not only do these notions appear to be incorrect, but children's response to strength training is actually quite similar to that of adults, although they do not gain as much muscle mass (Falk & Dotan, 2019). Under proper guidance and supervision, the incidence of strength training-related injuries is no higher in children than in adults. Strength training has other benefits for children beyond actual strength improvement. It can help reduce the risk of activity-related injuries in general, and especially in other sports. In overweight youth, it can also improve metabolic profile and help in the management of conditions such as diabetes (Falk & Dotan, 2019).

Regarding the prescription of the type of strength training and the development of the sessions in the infant and juvenile population, there are a variety of aspects to take into account, such as the volume of work or the intensity among other things. Given the disparity of methodologies with different types of exercises, there seems to be no ideal training model, although all agree that the training dose should be taken into consideration, this being an important aspect to produce the desired effect (Lesinski et al., 2016).

Method

For the development of this review, a search was carried out in PubMed databases between November 2020 and May 2021. A review was made of publications from 2010 to the present. The search was performed following the *Preferred Reporting Items for Systematic reviews and Meta-Analyses* (PRISMA) review protocol, which consists of a 27-point checklist of the most representative sections of an original article (Liberati et al., 2009). The following keywords were used for the PubMed search: Physical activity AND Resistance training, Children AND Strength training, and Strength training AND Children AND Adolescents.

For the selection of the articles a series of inclusion criteria were taken into account: a) Intervention studies that evaluated the effect of a physical training program; b) Studies carried out in children over 6 years old up to 18 years old; c) Randomized and Non-Randomized samples; d) Studies that evaluate the positive effects of strength training; e) The languages selected for the search were English and Spanish.

On the other hand, the criteria chosen for exclusion were the following: a) Studies that did not evaluate the effects of regular physical exercise; b) Studies with adults; c) Clinical trials carrying out strength training programs in children with special needs.

In order to assess the scientific quality of the studies, the *PEDro* scale was used. This scale consists of 11 items, although the evaluation is given out of 10, since the first item is not taken into account in the rating. Scores between 9 and 10 are considered to be of excellent quality; between 6 and 8, of good quality; between 4 and 5, of fair quality and, finally, values lower than 4 mean poor quality.

Results

A total of 328 articles were identified in the initial search. After the first screening, 190 articles were eliminated, leaving 138 articles selected for full-text analysis. Finally, after exclusion of articles that did not meet the inclusion/exclusion criteria, 20 articles were eligible for this systematic review (Figure 1).

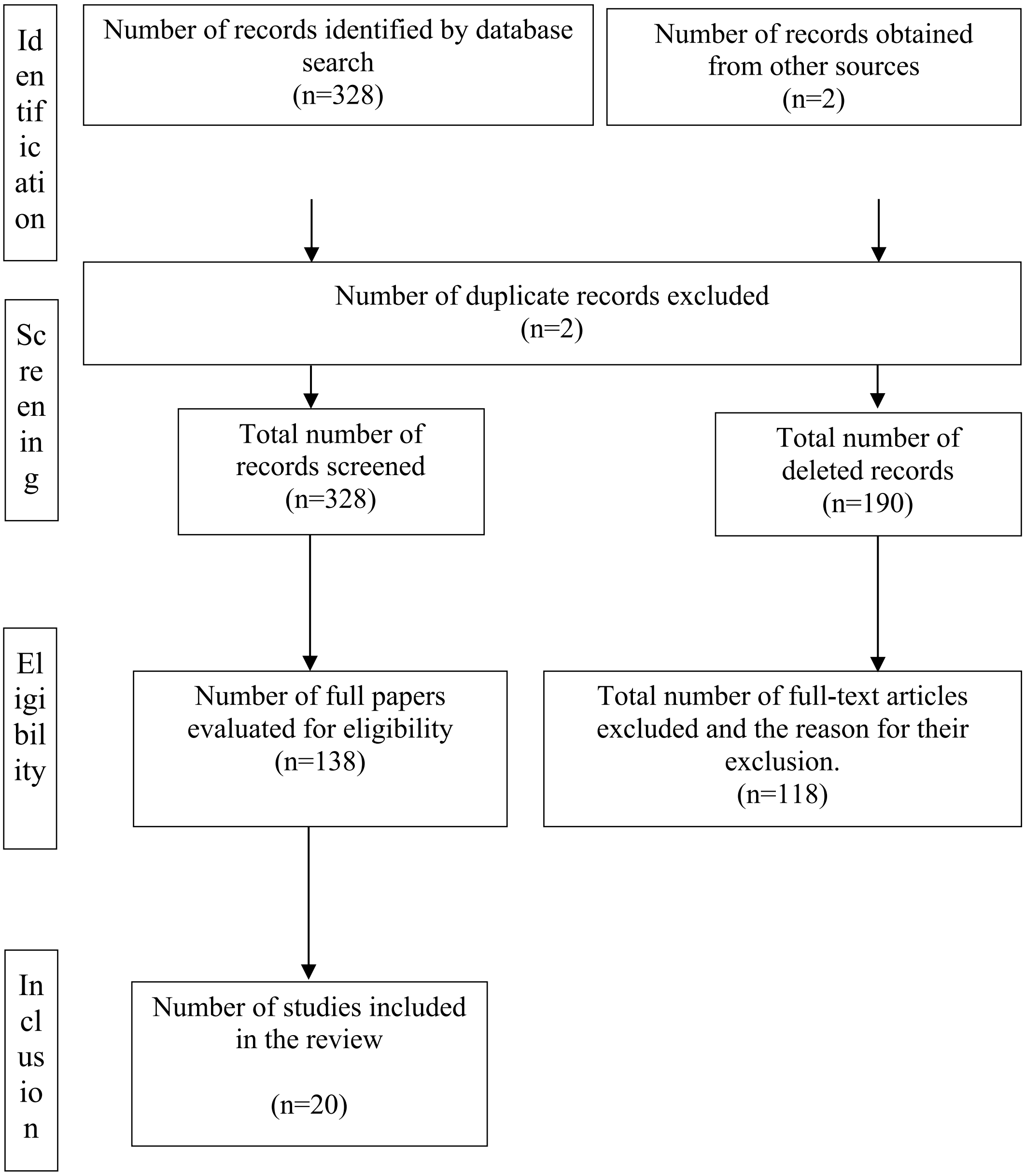

Figure 1. Flowchart

In total, 1461 participants (517 girls and 944 boys) were analyzed in the studies presented in this review. Table 1 describes the studies carried out, describing the type of training performed, the duration of the training programs, the weekly training sessions, and the main findings after the completion of the interventions. Of these, eight studies investigated the effect of strength training in the child-adolescent, athletic population (Rodriguez-Rosell et al., 2017; Panagoulis et al., 2020, Moran et al., 2018; Hopper et al., 2017; Piazza et al., 2014; Amaro et al., 2017; Negra et al., 2016; Parsons et al., 2017), five studies investigated the effect of strength training in obese subjects (Alberga et al., 2016; Goldfield et al., 2015; Monteiro et al., 2015; Schranz et al., 2014; Davis et al., 2011), and seven studies investigated the effect of strength training in the general infant and juvenile population (Pichardo et al., 2019, Meinhard et al., 2013; Granacher et al., 2011; Lee et al., 2012; Lloyd et al., 2016; Bernardoni et al., 2014; Deldin et al., 2019). In all studies, the strength training sessions were supervised by a professional strength expert, controlling in situ the appropriate training load for each subject in order to carry out progressive overload and avoid any type of poor execution or excessive load. The training methods varied among the studies, being able to observe great heterogeneity in the exercises carried out.

Table 1

Description of the intervention studies included in the systematic review.

STUDIO	SAMPLE	INTERVENTION	CONCLUSIONS
Pichardo et al. (2019)	59 children aged 12-14 matched by maturity. 2 groups. Group 1. Performance of combined strength training. N= 29. Group 2. Strength training combined with weight lifting. N= 31.	28 weeks. Sessions 2-3 times per week. Group 1 performed leg exercises, pushing exercises, and pulling exercises with a combination of exercises dedicated to plyometrics. While group 2 also performed strength and plyometric exercises, they substituted some weight lifting exercises for aerobic exercise.	There were no significant differences between the groups, but all variables improved significantly within the group. Both groups achieved small-to-moderate improvements after the first 14 weeks of training, increasing lower body power, upper body power, and speed. Both groups achieved small-moderate improvements in all performance variables after 28 weeks of training. Tests: Resistance Training Skills Battery Quotient (RTSQ), Isometric Mid-Thigh Absolute Maximum Strength Pull (IMTPABS), Isometric Mid-Thigh Pull in Maximum Strength Ratio Scale (IMTPREL), countermovement jump, horizontal jump, and 10 m, 20 m, and 30 m sprint.
Alberga et al. (2016)	304 children aged 14-18 years with body mass index ≥ 85th percentile. 4 groups. Group 1. Aerobic training program. N= 75. Group 2. Strength training program N= 78.	22 weeks. Sessions of a minimum of 40 minutes 2-5 times a week. Group 1 exercised on treadmills, cycloergometers, and treadmills. Group 2 performed a full-body workout consisting of 7 exercises.	Aerobic exercise training alone increased Endurance, while strength training only increased upper and lower body muscle strength. The greatest improvements in overall strength and fitness were demonstrated by combined aerobic and strength training. Aerobic training had the strongest effect on cardiorespiratory fitness.

	Group 3. Combined aerobic and strength training program. N= 75. Group 4. Control group that did not exercise. N= 76.	Group 3 trained a combination of the two previous groups aiming for the same volume and intensity. A graded treadmill stress test and a maximal strength test of different exercises were performed pre- and post-intervention. The training program was combined with a maximum daily energy deficit of 250 kcal to promote healthy eating.	
Rodríguez-Rosell et al. (2017).	86 male footballers between 13 and 17 years of age. 3 groups. Group 1. Football players under 13 years of age. N=30. Group 2. Football players under 15 years old. N=28. Group 3. Football players under 17 years of age. N=28. Once divided they were divided into two subgroups: a strength training group and a control group.	6 weeks. 2 workouts per week where we did squat on multipower, 5 max jumps with hands on hips, and 20 m straight line sprint drills. Maximal strength, vertical jump, and sprint were measured before and after.	Improvements in maximal strength, jump height, and sprint time were observed in the subjects, who performed the strength program, while no significant gains were found for any variable in the control group.

Goldfield et al. (2015)	304 adolescents aged 14-18 years with body mass (BMI) at or above the 95th percentile for age and sex or above the 85th percentile plus a cardiovascular risk factor. 91 boys and 213 girls divided into 4 groups. Group 1. Aerobic training. N= 75 (boys and girls). Group 2. Strength training. N= 78 (boys and girls). Group 3. Combined strength and aerobic endurance training. N= 75 (boys and girls). Group 4. Control group. N= 76 (boys and girls).	4 weeks. Gym training 4 times a week. The aerobic training group performed workouts that progressed gradually in exercise duration and intensity. The strength training group performed strength exercises using machines or free weights. The combined training group performed the full aerobic plus resistance training program. Pre- and post-intervention MRI and several tests on mood, body image, and self-esteem were performed. Mood was measured using the Brunel mood scale. Body image was assessed using the Multiple Body Self-Relationship Questionnaire, and physical self-perceptions and global self-esteem were measured using the Harter Physical Self-Perception Questionnaire.	Aerobic, strength, and combined training reduced total body fat and waist circumference in obese adolescents. In the most adherent participants, combined training may cause greater decreases than aerobic or strength training alone.
Monteiro et al. (2015)	48 obese subjects between 11 and 17 years old. 3 groups. Group 1. Aerobic training. 8 girls 10 boys. N=18.	20 weeks. 50-60 minute workouts 3 times per week in both groups. Group 1 sessions consisted of walking and running.	The benefits of exercise in reducing body fat and metabolic risk profiles can be achieved by performing any type of training in obese adolescents.

	Group 2. Carrying out concurrent training. 5 girls 9 boys. N=16. Group 3. Control group. 8 girls 8 boys. N=14.	Group 2 first performed strength sessions consisting of leg press, low rowing, bench press, squats, push-ups, push-ups, leg push-ups, push-ups, seated chest machine, triceps, leg extension, seated and supine trunk extension and then performed the same aerobic session as group 1 but for 30 minutes. Body fat percentage, fat-free mass, android fat percentage by DEXA, and other metabolic profiles were measured at baseline and after the interventions.	
Meinhard et al. (2013)	102 boys and girls between 10 and 14 years of age. 4 groups divided by the classes of the school year. Group 1. Intervention in children. N=32 Group 2. Intervention in girls. N=22 Group 3. Control in children. N=28 Group 4. Control in girls. N=20	19 weeks. Strength training twice a week. Seven multi-joint exercises in circuits of barbell back squat, barbell stride, fitball back extension, abdominal crunch, bench press with barbell, barbell, and press rowing Energy expenditure, leg and arm strength, and body composition were measured before the intervention after the intervention and 3 months after the end of the study.	Targeted strength training significantly increases spontaneous daily physical activity behavior in children. The least active children showed the greatest increase in energy expenditure. Girls showed a similar increase in strength but not in energy expenditure. This may be explained by their earlier pubertal development. Strength training may be a promising strategy in schools to counteract declining levels of PA. Leg and arm strength increased due to the training intervention in both boys and girls (a leg press for the lower body and a Smith machine for the upper body were used to reach these conclusions). In addition, body composition and kcals expended per minute were also measured.

Panagoulis et al. (2020)	28 prepubertal adolescent boys. 2 groups. Group 1. Control group. Participated only in conventional football training. N = 14 1(14 ± 0.57 years, Tanner stage 2. 8 ± 0.6) Group 2. Participated in neuromuscular integrative training in addition to conventional football training. N = 14 1(12 ± 0.5 years, Tanner stage 2.6 ± 0.5).	8 weeks. 3 neuromuscular training sessions per week. The protocol included the following exercises throughout the training: squat, Romanian deadlift, Bulgarian squat, Romanian deadlift with one leg, box jumps, and core exercises and then adding stability exercises and exercises with body weight. Speed, (10, 20 m), change of direction (COD), jumping performance and strength were measured before and after training.	An 8-week neuromuscular program can induce positive adaptations in the performance of early adolescent soccer players during the season, suggesting that neuromuscular training may be an effective training intervention for this age group.
Schranz et al. (2014)	56 obese children between 13 and 17 years old. 2 groups. Group 1. Strength training. N= 30. Group 2. Control group. N= 26.	6 months. 3 strength training sessions per week of 75 minutes. A total of 10 multi-joint exercises with guided machines and free weights. The exercises performed were bench press, leg press, pull-up, leg curl (lying or seated), shoulder press (seated), seated rowing, biceps curl, triceps extension, calf raise (seated), and abdominal contraction. Outcomes were assessed at 3 months, 6 months (just after the end of the trial), and 12 months.	A 6-month strength training intervention can positively affect the self-concept and strength of overweight and obese adolescents. The performed physical tests were maximum repetition in bench press on Smith machine and leg press. Both tests showed improvements in the intervention group compared to the control group.

Granacher et al. (2011)	28 boys and girls between 14 and 16.7 ± 0.6 years. 2 groups. Group 1. Participated in strength training program. 8 girls and 6 boys. N= 14. Group 2. Control group. 7 boys and 7 girls. N= 14.	8 weeks. 2 lower limb strength training sessions twice a week. Pre, post, and follow-up testing included measurements of static and quasi-dynamic postural control on balance platforms, analysis of VJH height on a strength platform, and assessment of maximal isometric leg extension strength (peak isometric strength and rate of force development on a leg press). Pre- and post-intervention measurements of maximal isometric strength and rate of strength development of leg extensors, vertical jump height (VJH), and assessment of static and dynamic postural control.	The results showed that the training could have an impact on improving the level of performance in various motor skills and sport activities in physical education.
Lee et al. (2012)	45 obese children between 13 and 16 years old. 3 groups. Group 1. Performed strength training program. N= 16. 14.6 ± 1.5 years Group 2. Performed aerobic training program. N= 16. 15.2 ± 1.9 years Group 3. Control group. N= 15.	3 months. 60 minutes of training 3 times per week in the aerobic training group with treadmills, elliptical, or bikes. 60 minutes of training 3 times per week in the strength training group. Each training session included leg press, leg extension, leg curl, leg press, chest press, lat pull down, seated rowing, biceps curl, triceps extension, push-ups, and sit-ups.	Both aerobic and strength training alone were effective in reducing abdominal fat and intrahepatic lipids in obese adolescent boys. Strength training, but not aerobic training, is also associated with significant improvements in insulin sensitivity. Changes in visceral fat were associated with changes in intrahepatic lipids and insulin sensitivity.

	14.8 ± 1.4 years	Fat loss, insulin sensitivity, and insulin secretion were measured before and after the trial without caloric deficit.	
Moran et al. (2018)	22 young male swimmers pre PHV (11.9 ± 1.2 years) and post PHV (15.0 ± 1.1 years). 4 groups Group 1. Pre PHV. N=14 Group 2. Post PHV. N=8 Group 3. Control pre PHV. N=15 Group 4. Post PHV control. N=7	8 weeks. 2 workouts per week, 30 minute sessions. The workouts were based on strength circuits that included goblet squats, push-ups, planks, glute bridges, and strides. Subjects performed physical fitness tests the week before and the week after the trial. Anthropometric measurements, jump test, and body mass. Specifically, a handgrip dynamometer to assess grip strength, a jumping mat to assess vertical jumping, and a portable pull cord to measure pulling capacity were used to measure the tests performed on the subjects.	The results of this study show that strength training can improve performance in both pre and post PHV swimmers, showing greater benefits in post PHV swimmers.
Hopper et al. (2017)	23 female netball players aged 12.17 ± 0.94 years. 2 groups. Group 1. Performed neuromuscular training. N= 13.	6 weeks. 3 non-consecutive workouts per week of approximately 1 hour. The sessions were divided into two parts, one part of different plyometric exercises and another part of strength exercises, where the	The intervention significantly improved sprinting, change of direction speed, vertical jumping, and movement in 11-14 year old netball players. The control group showed no significant improvement in any of the physical performance measures or movement competence assessments over the course of the 6-week intervention.

	Group 2. Control group. N= 10.	following exercises were combined throughout the 6 weeks: back squat, front squat, inverted pull-ups, supine pull-ups, barbell rowing, incline bench press, bench press, Romanian deadlift, strides, and military press. They completed a battery of tests before and after the VJH and PAR-Q intervention.	After completion of the 6-week neuromuscular program, the data revealed that the intervention group performed significantly better than the control group in all physical performance tests.
Piazza et al. (2014)	57 rhythmic gymnasts 12.0 +/- 1.8 years. 3 groups. Group 1. Non-specific strength training with dumbbells. N= 19. Group 2. Performed specific strength training with weighted belts. N= 18. Group 3. Performed non-specific strength training. N= 20.	6 weeks. 3 sessions per week. Group 1 carried out a training program based on the execution of squats and variations of these with dumbbells. Group 2 performed a training program based on back strides, power skips, strides, skipping, and jumps. The following pre- and post-intervention tests were performed: squat jump test, countermovement jump test, jump test, hip flexibility, and anthropometric measurements.	Both non-specific and specific strength training positively affected jumping performance with an increase in lower extremity explosive strength of 6-7%, with no side effects. The flight time of the countermovement jump increased significantly, while the ground contact time of the jump test decreased significantly. No significant differences between groups were detected for flexibility, body mass, calf, and thigh circumference. Therefore, six weeks of strength training integrating different elements of rhythmic gymnastics training improves jumping ability in young female athletes.
Lloyd et al. (2016)	80 school-aged children were categorized into 2 maturity groups (pre- or post-PHV) and then randomly assigned.	6 weeks. Training twice a week. Group 1 included barbell back squats, barbell lunges, dumbbell step ups and leg presses in their workouts, group 2 performed a battery	Plyometric training made the greatest gains in all performance variables in pre-PHV children, while combined training was the most effective in eliciting changes in all performance variables for the post-PHV cohort. The study indicates that plyometric training may be more effective for short-term gains in jumping and sprinting in children who are pre-PHV.

	4 groups which in turn are divided into 2 (pre or post PHV). Group 1. Performed traditional strength training. N= 20. Group 2. Performed plyometric training. N= 20. Group 3. Performed combined strength and plyometric training. N= 20. Group 4. Control group. N=20.	of jumping and landing mechanics exercises, and group 3 performed 2 plyometrics exercises from group 2 and barbell squats and lunges. Acceleration, maximal running speed, squat jump height, and reactive strength index data were collected before and after the intervention.	
Amaro et al. (2017)	21 prepubertal male swimmers aged 12.7 ± 0.8 years with at least 2 years of competitive swimming experience and no previous strength training experience. 3 groups. Group 1. Performance of the series by number of repetitions. N= 7. Group 2. Performance of the series by time in seconds. N= 7. Group 3. Control group. N= 7.	10 weeks. 2 sessions per week. Mean strength, mean mechanical impulse, vertical jump, mean ball throwing values, and crawl swimming performance were assessed pre-intervention after 6 weeks of the program and after 10 weeks.	Significant improvement in the performance in swimming crawl style and especially in the 50 m race with group 2 showing greater improvements. As for the vertical jump, an improvement was observed in groups 1 and 2. Regarding ball throwing, a significant improvement was observed in group 2. On the other hand, it was observed that strength and mechanical impulse did not show an improvement effect.

Negra et al. (2016)	24 male soccer players aged 12.7 ± 0.3 years. 2 groups. Group 1. Performed 3 weekly sessions of football specific training and 2 sessions of high speed strength training. N= 13. Group 2. Control group. They carried out 5 weekly sessions of specific football training. N= 11.	12 weeks. 2 sessions per week of 80-90 minutes on average. Pre- and post-training tests were carried out to evaluate muscle strength, jumping ability, linear speed, and change of direction by means of different tests. Specifically, pre- and post-tests included a maximal strength test in half squat, squat jump and countermovement jump, evaluation of 5 consecutive jumps, long jump test, linear sprint test, The Illinois change of direction test, and The T test to evaluate change of direction.	Improvements were observed in the group that carried out the high speed strength training program: Significant increases in half squat performance. Increased jumping performance, increasing the values in the vertical jump. Increased 10 m sprint performance. However, no significant improvements were seen in the direction change tests.
Bernardoni et al. (2014)	45 girls aged 11 to 12. 2 groups. Group 1. 2-3 strength training sessions in the physical education sessions. N= 22. Group 2. Control group. 2-3 sessions of conventional physical education per week. N= 23.	7 months. 2-3 strength training sessions per week on non-consecutive days. The strength training was based on circuits that included exercises with body weight, resistance bands, and dumbbells where the whole body was worked. Pre-intervention and post-intervention whole body and regional DXA scans were performed using a GE Healthcare Lunar iDXA densitometer to measure bone mineral content, bone mineral density, non-bone fat free mass, and fat mass.	The school-based strength training intervention produced maturity- and region-specific bone gains in adolescent girls. Strength training may be a good osteoporosis prevention strategy for adolescent girls.

Davis et al. (2011)	38 adolescent girls (15.8 ± 1.1 years) with overweight/obesity. 3 groups. Group 1. Aerobic training + strength. N= 14. Group 2. Aerobic training + strength + motivational interviewing behavioral therapy. *N*= 12. Group 3. Control group. N = 12.	16 weeks. 2 sessions of 60-90 minutes per week, (30-45 minutes of cardiovascular activity along with a total of 30-45 minutes of strength training per workout). Group 2 also received four individual motivational interviewing sessions and four group sessions throughout the program. The exercises included in the strength circuits were leg press, quadriceps extension on machine, triceps extension, abdominal plank, abdominal crunch, squat, shoulder press on machine, heel raises, biceps curl, bench press, hamstring curl, high pull-up rowing, rowing machine.	Participants in group 1 and 2 compared to the control group significantly increased their physical fitness. Results were also seen in decreases in waist circumference, subcutaneous adipose tissue, visceral adipose tissue, fasting insulin, and insulin resistance.
Parsons et al. (2017)	40 female athletes aged 10-14 years of which 36 completed the study. 2 groups. Group 1. Strength training focused on the lower body. N= 19. Group 2. Strength training focused on the upper body. N= 17.	12 weeks. 2 training sessions of 1 hour per week. Strength training based on exercises with your own body weight and free weights. The exercises performed by group 1 were squat, lunges, glute abduction, and hamstring curl with glides. The exercises performed by group 2 were chest press, biceps curl, shoulder press, and dumbbell rowing.	There was no difference between groups on the improvement of landing jumping skills.

Deldin et al. (2019)	28 boys and 27 girls between 12 and 18 years old. 2 groups. Group 1. Strength training. N = 14 boys and 14 girls. Group 2. Aerobic training. N= 14 boys and 13 girls.	3 months. Group 1. 80 minutes per week of strength training. Group 2. 80 minutes per week of aerobic training. The strength training performed by group 1 included exercises with guided machines and worked all muscle groups. Tests to determine participants' physical capacity included a treadmill test to assess cardiorespiratory fitness and a leg press and chest press test with one repetition maximum, in addition to receiving hematological and biochemical tests before and after the trial.	With the exception of abdominal SAT, there were no treatment differences by sex or exercise in total and regional fat reductions. In response to strength training, increases in total and regional skeletal muscle were significantly greater in boys than in girls.

Note: PHV = PHV = Peak height velocity; PA = Physical Activity; SAT= Subcutaneous adipose tissue

Table 2 shows the methodological quality of the articles reviewed with a rating range from 6/10 to 9/10 on the PEDro scale.

Table 2
PEDro scale results

AUTHORS (YEAR)	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Pichardo et al. (2019)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Alberga et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Rodríguez-Rosell et al. (2017).	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Goldfield et al. (2015)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Monteiro et al. (2015)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Meinhard et al. (2013)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Panagoulis et al. (2020)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Schranz et al. (2014)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Granacher et al. (2011)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Lee et al. (2012)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Moran et al. (2018).	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Hopper et al. (2017)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Piazza et al. (2014)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Lloyd et al. (2016)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Amaro et al. (2017)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Negra et al. (2016)	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	7
Bernardoni et al. (2014)	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Davis et al. (2011)	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	6
Parsons et al. (2017)	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes	6
Deldin et al. (2019)	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7

Discussion and conclusions

Over the last few years there has been controversy about strength training and children, about the possible effects on both performance and development. Strength training could have an impact on improving the level of performance in various motor skills and sporting activities in physical education, as well as being a promising strategy in schools to counteract decreasing levels of physical activity (Meinhard et al., 2013).

Comparisons have been made between strength training and aerobic training (Pichardo et al., 2019; Alberga et al., 2016; Lee et al., 2012; Goldfield et al., 2015), where the benefits of the different trainings are tested. Both types of training seem to have significant improvements in terms of power (Pichardo et al., 2019), being the aerobic training where greater benefits were found at cardiorespiratory level (Alberga et al., 2016). Other authors (Goldfield et al., 2015) mention that where they find greater benefits in fat loss is in a type of training that combines both types of skills. However, other authors find benefits related to insulin sensitivity in strength training (Lee et al., 2012).

Strength training can also be performed as an anti-obesity strategy (Alberga et al., 2016; Goldfield et al., 2015; Monteiro et al., 2015; Schranz et al., 2014; Lee et al., 2012; Davis et al., 2011). In comparing different types of training, Goldfield et al. (2015) observed how both aerobic, strength, and combined training reduced total body fat and waist circumference in obese adolescents. Following this same line, it has been seen that metabolic risk profiles can be achieved by performing any type of training in obese adolescents (Monteiro et al., 2015). Another research by Schranz et al. (2014) showed that training can positively affect self-concept in addition to strength in overweight and obese adolescents. Finally, it is highlighted that programmed training can become an excellent tool for the improvement of cardiorespiratory health (Alberga et al., 2016).

Some clinical trials wanted to observe the effects of training in different sports such as football (Rodriguez-Rosell et al., 2017; Panagoulis et al. 2020; Negra et al., 2016), swimming (Moran et al., 2018; Amaro et al., 2017), rhythmic gymnastics (Piazza et al., 2014), or netball (Hopper et al., 2017). The contribution of Rodriguez-Rosell et al. (2017) related to strength and football showed benefits in maximal strength, vertical jump, and sprint time compared to the control group. On the other hand, Negra et al. (2016) showed benefits in the half squat and, as in the previous study, in jumping and sprinting. Meanwhile, Panagoulis et al. (2020) established that neuromuscular training can induce positive adaptations in the performance of early adolescent soccer players during regular season. Regarding swimming, Moran et al. (2018) seem to find improvements in body composition, vertical jump, and anthropometric measurements, while the study by Amaro et al. (2017) mentions that they found improvements in swimming crawl style especially in 50 meters as a result of strength training. Likewise, the relationship of strength training and rhythmic gymnastics was shown with increased jumping performance and an increase in lower extremity explosive strength of 6-7%, with no side effects (Piazza et al., 2014). In a less common sport such as netball, we also wanted to evaluate the influence of strength training, observing an improvement in sprinting, change of direction, and high jump as a result of strength training (Hopper et al., 2017).

Regarding strength training as a function of gender, Meinhard et al. (2013) wanted to make a comparison of strength training in boys (10-14 years) and observed that girls showed a similar increase in strength, but not in energy expenditure, which they do not attribute all the credit to this type of training but may also be explained by their earlier pubertal development. Another research that compared strength training as a function of gender was that of Deldin et al. (2019), who allude that strength training produced significantly greater increases in total and regional skeletal muscle in boys than in girls.

Within physical education in the school setting, strength training could also have a place, showing that it could have a positive impact on improving the level of performance in various motor skills and sporting activities (Granacher et al., 2011). Lloyd et al. (2016) did a study where they evaluated strength training, plyometrics training, and a combined training in school-aged boys and girls pre and post their peak performance velocity (PHV). The authors mention that it was the plyometrics training where the pre-PHV children made the greatest gains in all performance variables, while the combined training was the most effective in eliciting changes in all performance variables for the post-PHV cohort, in both cases speaking over a short period of time (Lloyd et al., 2016).

Other authors such as Davis et al., (2011) also relied on school girls for their intervention, where they showed a decrease in waist circumference, subcutaneous adipose tissue, visceral adipose tissue, fasting insulin, and insulin resistance, thus significantly improving their fitness. In addition, strength training may be a promising strategy in schools to counteract decreasing levels of physical activity (Meinhard et al., 2013).

In terms of improvement in landing jumping skills, there was no difference between groups on improvement following an intervention comparing lower body focused strength training and upper body focused strength training in female athletes (Parsons et al., 2017).

In this review we have found some limitations that are set out below: studies with a short duration of time. The time period of the interventions is different and generally short, with interventions lasting 7 months and interventions lasting only 4 weeks. In addition, the authors use different training methods, which makes it difficult to make a proper comparison and to know which methodology offers the best results. On the other hand, most of the investigations (n=8) analyzed strength training in comparison to other types of training and as many (n=8) to see the performance of this type of training within a specific sport, and very few (n=4) chose to analyze strength directly. The age of the children is very different from one study to another, there being significant differences in their maturation, many of the improvements obtained could be due to the maturational development. Similarly, the sample of more than half of the studies included (n=12) is less than 50, which may be too small to extract results.

After reviewing the studies analyzed, it can be concluded that strength training in the infant and juvenile population is an effective and safe strategy to contribute to improving strength parameters and general physical health, thus clarifying the possible doubts of the population as to whether or not strength training is beneficial. Regarding the method and strength exercises proposed, heterogeneity has been found among the different works analyzed, with no clear consensus among them and showing that some types of exercises are not better than others, being the key to progress the individualized progressive overload. In addition, another important part of strength training in children and adolescents is that it does not generate negative impacts on health, both physical and psychological; being a great ally to combat pathologies such as obesity, generating a good physical preparation for young athletes, and can contribute positively to school physical education. Future interventions in this type of population are recommended, carrying out more programs of only regular strength training in order to clearly demonstrate the benefits of strength training, since many studies combine it with aerobic training, which can make it difficult to clarify that the improvements obtained are mainly caused by strength training.

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