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Original Article

An updated look at physical exercise and its effect on overweight and obesity in children and adolescents with down syndrome: a comprehensive systematic review

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Abstract:
Introduction: Down syndrome is a prevalent chromosomal disorder associated with high health risks. Children and teens with Down syndrome are prone to overweight and obesity. Physical exercise is a crucial factor in preventing and treating obesity in this population. This review aimed to study the impact of exercise intensity, physical fitness, and exercise-based programs on the treatment of obesity in children and adolescents with Down syndrome. **Material and methods:** A systematic review was done by using MEDLINE/PubMed, WOS (Web of Science), Scopus, and SportDiscus databases, following the PRISMA declaration. The selection criteria for this analysis were: publications between January 2020 and December 2021; children and adolescents (6 to 18 years old) with Down Syndrome with overweight and obesity; Clinical trials of intervention through physical exercise paying attention to changes in selected clinical trials focused on an exclusive intervention based on physical exercise. A total of 331 studies were found that meet the selection criteria of publication between January 2020 and December 2021, focused on children and youth with Down syndrome with overweight and obesity, evaluating the intervention through physical exercise and its changes in body composition and published in Spanish, Portuguese, or English. The methodological quality of the studies was evaluated using the PEDro scale. **Results:** Despite the limited number of clinical trials, we conclude that the impact of 12- to 16-week training in children with Down syndrome decreases the percentage of fat mass, so this type of training could have an important impact on the comorbidities associated with obesity and the quality of life of this population. **Conclusions:** Some considerations are proposed to contribute to the improvement of the health of individuals with Down syndrome and knowledge in this field.
Key Words*: *intellectual disability; body composition; Body Mass Index; Waist circumference; physical fitness.

Introduction

Down syndrome (DS) is the most common chromosomal disorder: It is due to a complete trisomy Hsa21 or a partial trisomy including the critical region 21q22.3. DS is the leading cause of intellectual disability worldwide. The estimated prevalence of Down syndrome is 1 in 1,000 (de Graaf et al., 2011; 2021). Over the last century, the life expectancy of people with DS has increased significantly (de Graaf et al., 2011). However, it has been found that the average length of life of these people is 55 years, approximately, 11 years less than other people with other intellectual disabilities and 15 years less than the general population (Heller et al. 2008).

DS is also associated with higher rates of congenital heart disease, hearing and vision impairment, thyroid disease, gastrointestinal disorders, cognitive impairment, obstructive sleep apnea and muscular hypotonia, in addition to the high morbidity associated with DS (Alexander et al., 2016; Bull, 2011; Roizen et al., 2014). Additionally, people with DS have a physically inactive lifestyle and poor nutritional choices that lead them to develop physiological conditions such as: cardiovascular diseases, pulmonary hypoplasia, muscle hypotonia, osteoporosis, arthritis, osteoarthritis, diabetes mellitus, and obesity (Heller et al. 2008). In general, it is established that obesity is intrinsically related to adverse health risk factors (e.g., sleep apnea and subclinical hypothyroidism) (Reinehr, 2010), which have a high prevalence in adolescents with Down syndrome. In concrete, pediatric associations and governments have highlighted obesity as a risk factor associated with people with DS (Bull, 2011; Rasmussen et al., 2008).

In 2012, compared to their peers without DS, Dutch children with DS were more overweight (12.12% in boys, and 17.1% in girls) and obese (2..8% in boys and 2.9% in girls) (Van Gameren-Oosterom et al., 2012). Obesity is one of the most serious and prevalent non-communicable diseases today (Suárez-Carmona et al., 2017). It is a chronic disease of multifactorial origin, with a high global prevalence that is associated with

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potentially serious complications and requires a multidisciplinary approach due to its high clinical impact and health cost (World Health Organization, 2017). In it, a series of cellular processes occur that generate metabolic changes, producing a vicious cycle of visceral fat gain induced by genetic and environmental factors (Schwartz et al., 2017).

In the center of the paradigm, several systematic reviews have studied obesity in children and adolescents with physical disabilities, coordination disorders, and intellectual disabilities (Hassan et al., 2019; Hendrix et al., 2017; Maïano et al., 2014). Similar research has recently emerged on children and adolescents with DS. These studies emphasize the need for health promotion initiatives to address the problems of overweight and obesity, thyroid problems, and body composition in this population (e.g., Bertapelli et al., 2016; Ortiz-Ortiz et al., 2019; Suarez-Villadat et al., 2019). One explanation for the development of obesity and overweight in this population seems to lie in different pathophysiological conditions, such as systemic inflammation, metabolic diseases and hypotonia. In this sense, the different interventions carried out with this population are mostly based on interventions grounded mainly on diet and physical exercise (Martínez-Espinosa et al., 2020), especially when trying to modify body composition in people with DS.

Physical activity and physical exercise (PE) are a key factor in the prevention and/or treatment of obesity in children and adolescents. In comparison, daily physical activity can be any type of movement that increases heart rate and helps maintain an active lifestyle, but it does not necessarily have the same medical and physical benefits as planned and regulated exercise, such as PE. It is important to note that regularly planned and regulated PE has a more specific focus on medical and physical goals, while daily physical activity can be more general and not necessarily aimed toward those goals. The literature has discovered that the practice of PE significantly improves many markers related to comorbidities, such as improved glucose metabolism, dyslipidemia, and hypertension. It also reduces risk factors for cardiovascular disease, such as systemic inflammation, oxidative stress, and diabetes. Additionally, PE reduces total and visceral fat, even without significant weight loss (Colquit et al., 2016; García-Hermoso et al., 2015a; 2017; Mead et al., 2017). Despite the growth of scientific evidence on PE and childhood obesity in recent years, few existing studies have focused on obese children or adolescents with DS. According to Mendonca et al. (2010), not many prospective studies have examined the effects of structured physical training in this population. Nor have we found reviews that specifically address PE interventions and their consequences on body composition in children and adolescents with DS. In fact, there are a few studies which, and without underestimating the importance of a healthy diet, observed a superior effect of PE interventions over dietary interventions. One of the most current and relevant is t that by Martínez-Espinosa et al. (2020), who found greater changes in body composition in children and adolescents with DS who followed a planned PE plan (considering intensity, duration, number of repetitions, days per week and with programming). These results contrast with those found in the healthy population. They indicate that exercise intervention in overweight and obese adolescents improves body composition, particularly in reducing body fat (Stoner et al., 2016).

On the other hand, there is no direct link between DS and the ability to participate in physical activity or PE. However, people with DS may have specific challenges that affect their ability to participate in physical activity, such as underlying health problems (Sobey et al., 2015), motor difficulties (Jung et al.2017), and behavioral problems (Dykens et al., 2015). In particular, and directly relating exercise capacity and the syndrome, Mendonca et al., 2010 showed that people with DS have a reduced exercise capacity, specifically due to the interaction between low maximal oxygen uptake (VO2 max) and poor exercise economy. The authors propose that chromosomal characteristics of the disease are the main cause of low peak VO2. Consequently, proper clinical management of reduced exercise capacity in individuals with DS is crucial to ensure their long-term health and productivity. Secondarily, but with an indirect effect on cardiovascular health, recent studies (Alesi et al., 2022) show that there are improvements on global motor coordination (e.g., global motor and global development, global motor coordination and adaptive behavior development area…) when PE programs are programmed for it. This fact can contribute toward a higher quantity and quality of PE practice with children and adolescents with DS and can be sustained for longer.

The aim of this study was to investigate the effect of physical activity programs in children and adolescents with DS on the improvement of body composition in relation to overweight and obesity. It is important to review the existing knowledge base and present the state of the science regarding overweight and obesity in children and adolescents with DS, to guide future research, and to try to create initiatives to reduce overweight and obesity in this very vulnerable population. Based on the results obtained, some guidelines are proposed to contribute to the improvement of knowledge of PE interventions for people with DS.

Material & methods

Search Strategy

The PRISMA guidelines for systematic reviews and meta-analyses were followed for this study (Moher et al., 2009), which includes a 27-item checklist and a four-phase flowchart (Page et al., 2021), as recommended by the Cochrane Collaboration (Higgins et al., 2005). Specifically, for this systematic review, we searched for studies in the following databases: MEDLINE, Web of Science (WOS), Scopus, and SPORTDiscus, which were conducted for the last twenty years, from 2001 to November 31, 2021. The data was extracted on December 6, 2021.

In the search of the databases indicated above, the population was children and adolescents with DS, the intervention was on obesity and the variables were those related to PE. The Medical Subject Headings (MeSH) descriptors used to determine the population was DS, Down's syndrome, Downs syndrome, trisomy 21, or chromosome 21. In addition, age was used to delimit age: child, children/s, childhood, boys, girl, adolescent/s and youth/s. The terms of the intervention were physical activity (PA), training, sport, exercise, or physical fitness; and lastly, the terms related.

Inclusion Criteria

The inclusion criteria were publication between January 2020 and December 2021, focused on children and adolescent (6 to 18 years) with DS with overweight and obesity, evaluating the intervention through physical exercise and its changes in body composition and published in Spanish, Portuguese or English.

Data Extraction

The article selection process followed the PRISMA methodology used for systematic reviews and meta-analyses (Tricco et al., 2018). The analysis of data extraction was performed with "Paperpile", a reference management software, where duplicate articles were eliminated once the search was performed in the five databases. Two review authors (D.M-R. and V.A-R.) screened articles in a blinded, standardized manner, with disagreements in judgement resolved by consensus or a third reviewer (E.J.F-O). When the full texts were not available, the lead author was contacted and asked to provide the full text to assess eligibility. If no response was received, these studies were excluded, as their eligibility could not be fully assessed. If a study was mentioned several times, only the most recent publication was included in the analysis. Then, a first screening was performed based on the title and abstracts to eliminate irrelevant studies. After identifying potential articles for inclusion in the review, the full texts were read to select those that met all the inclusion criteria and therefore became part of the systematic review (Figure 1). The study authors participated in all the described steps of article selection.

Methodological Quality Assessment

To assess the quality of the methodology used by the studies that were finally included in the systematic review, we used the PEDro scale, developed by the Centre for Evidence-Based Physiotherapy, which helps users to quickly identify whether the methodological quality is excellent (9-10), good (6-8), fair (4-5) or poor (<4). This score is based on expert consensus and is intended to eliminate the risk of bias.

Results

Study Flow

331 studies were found after searching the different databases: MEDLINE (n = 104), WOS (n = 201), Scopus (n = 13) and SportDiscus (n = 13). After eliminating 62 duplicate studies, 269 were reviewed, including their title and abstract, and 197 studies that did not meet all the inclusion criteria were eliminated. After this first screening, 20 full studies were evaluated as potential studies to be included in the qualitative analysis. Finally, three studies were included in this analysis, since 2 studies did not meet the age criterion, 8 did not relate exercise to obesity, and the rest were either not training-based interventions or did not compare DS obesity with other groups of the same age (Figure 1).

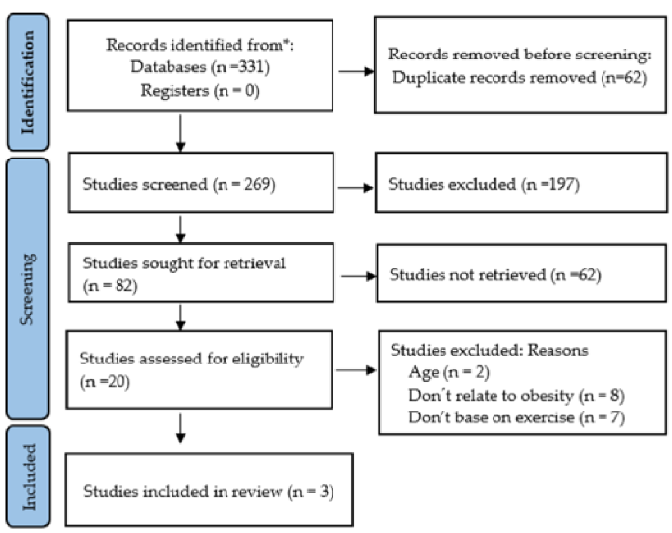

Figure. 1 Flowchart of the systematic review selection process Aren't based on exercise:-

Methodological Quality

According to the PEDro scale, the methodology of those studies with a score of 9-10 is considered "excellent," those with a score of 6-8 are considered "good" and those studies with a score of 4-5 are considered "fair". In the present review, all the studies (Ordonez et al., 2006; Seron et al., 2014; Ortiz-Ortiz et al., 2019) had a good methodology (Table 1).

Table 1. Quality of intervention studies assessed on the Physical Therapy Evidence Database (PEDro) scale.

PEDRro scale	[32]	[33]	[21]
1. Selection criteria	No	No	NO
2. Random assignment	Yes	No	Yes
3. Hidden assignment	No	Yes	No
4. Comparative groups at the beginning	No	Yes	Yes
5. Subjects blinded	No	No	No
6. Blinded administrators	No	No	No
7. Blinded evaluators	No	No	No
8. Adequate follow-up	Yes	Yes	Yes
9. Analysis of all subjects (intention to treat)	Yes	Yes	Yes
10. Comparison between groups	No	Yes	Yes
11. Measures of variability	Yes	Yes	Yes
Total	4	6	6

Excellent (9-11); good (6-8); average (4-5); poor quality (<4)

Characteristics of the Studies

The characteristics of the three studies included in the present systematic review are summarized in Table 2. These studies had samples of between 17 and 41 people, wherein the participants were subjected to a PE intervention of 12 to 16 weeks of duration. In all the studies, the body mass of children and adolescents with DS was analyzed. The results found in these 3 studies are presented below in chronological order of publication.

In the study by Ordonez et al. (2006), 22 adolescents with DS were subjected to PE for 12 weeks, consisting of three one-hour sessions per week both on land and in water. In Durnin and Womersley (1974) anthropometric measurements were used to calculate the percentage of fat mass, and a paired t-test was performed to evaluate differences in anthropometric characteristics between before and after the PE intervention. It was observed that 31.8% of the individuals studied were overweight and 27.3% were obese before starting. Mean fat mass percentage was significantly reduced at the end of the study ($p = 0.021$). Hence, we can conclude that adolescents with DS can reduce their fat mass percentage significantly with 12 weeks of PE.

In 2014, Seron et al. conducted a study on 41 adolescents with DS to assess the impact of aerobic and resistance exercises on their body composition. The participants were divided into three groups: Control (10 individuals, 6 female), Aerobic Training (16 individuals, 5 female), and Resistance Training (15 individuals, 5 female). The exercises consisted of 3 weekly sessions of aerobic training at 50-70% of heart rate reserve and 2 weekly sessions of resistance training with 12 maximum repetitions. The evaluation of fat percentage was performed by plethysmography. Waist circumference (WC), body weight, and height were also measured in the study. The paired t-test was used to compare these variables before and after the exercise program. The results showed no significant change in fat mass percentage for both groups, but a significant increase in the Control Group (31.3±7.2 to 34.0±7.9). However, both body mass index (BMI) and WC significantly decreased for the Aerobic Training Group (BMI from 27.0±4.4 to 26.5±4.2, WC from 87.3±11.1 to 86.2±9.7), while the Resistance Training Group and Control Group saw no changes in these variables. The conclusion was that BMI and WC were significantly reduced only in the Aerobic Training Group, while an increase in fat percentage was seen in those who did not participate in the intervention.

In the last study by Ortiz-Ortiz et al. (2019), 13 children with DS participated in an Experimental Group and underwent a physical conditioning program for 16 weeks, 5 times per week, in 55-minute sessions. There was a Control Group of 9 children, who continued with their usual activities offered by the institution, including Spanish language, natural sciences, personal independence and health protection skills, mathematics, and art (e.g., painting, coloring storybooks). The results obtained indicated that there were significant reductions in BMI from before to after the intervention in both the Experimental Group (22.2 ± 2.5 vs. 20.7 ± 2.5 kg/m 2; $P \leq 0.0001$), and the Control Group (23.3 ± 4.9 vs. 21.9 ± 4.6 kg/m2; $P \leq 0.001$). There were significant pre-and post-intervention reductions in medial calf skinfold (14.9 ± 5.5 vs. 14.6 ± 3.2 mm; $P = 0.008$). Thus, they concluded that physical training improves the body composition of children with DS, leading to an improvement in their quality of life.

Table 2. Summary table of the studies comprising the systematic review.

	Sample	Volume	Exercises	Parameters	Results
Ordonez et al., 2006	n=22 (100% male) Age: 16.2 +/- 1.0 years old.	12 weeks: 3 sessions 30 min (first two weeks), 45 min (next two weeks) and 60 min) the remaining eight weeks)	The intensity level was prescribed and monitored based on heart rate, in both water and on land	Durnin-Womersley anthropometric measurements. Weight (Kg) Fat mass (%)	The percentage of fat mass was significantly reduced, from 31.8 +/- 3.7% to 26 +/- 2.3%, at the end of the study (p = 0.021). Weight (kg): From 78+/-4.8 to 75.1+/-4.2.
Seron et al., 2014	15.5 +/-2.7 years old	12 weeks: aerobic, 3 times per week, and resisted, 2 times per week	Aerobic: intensity of 50-70% of the reserve heart rate. Resisted: intensity of 12 repetitions maximum	Plethysmography with Bod Pod equipment. Fat mass (%) BMI WC	The percentage of fat mass did not change significantly for both groups but increased in the CG (31.3±7.2 versus 34.0±7.9). BMI and WC were significantly reduced for the ATG (BMI: 27.0±4.4 and 26.5±4.2; WC: 87.3±11.1 and 86.2±9.7), while the RTG and CG showed no differences in these variables
Ortiz-Ortiz et al., 2019	n=22 (from 8 to 16 years old). EG, n=13, and CG, n=9.	EG: 16 weeks: 5 sessions a week of 55 minutes CG: continued with their usual activities offered by the institution	Progressive resistance exercises aimed at increasing strength, muscle tone, and weight control	Medial calf skinfolds and BMI was calculated from height and weight	There were significant reductions in BMI from pre- to post-intervention in both the EG (22.2 ± 2.5 vs. 20.7 ± 2.5 kg/m 2; P ≤ 0.0001), and the CG (23.3 ± 4.9 vs. 21.9 ± 4.6 kg/m2; P ≤ 0.001). Significant pre-and postoperative reductions in medial calf skinfold in the EG (14.9 ± 5.5 vs. 14.6 ± 3.2 mm; P = 0.008).

Notes. EG: Experimental Group; CG: Control Group; BMI: Body Mass Index; WC: Waist Circumference

Dicussion

The aim of this study was to investigate the effect of physical activity programs in children and adolescents with DS on the improvement of body composition in relation to overweight and obesity. Based on the available evidence, we can conclude that a 12- to 16-week exercise program has a positive impact on the body composition of children with DS, as it reduces their fat mass percentage. This type of intervention has the potential to improve their overall health and enhance their quality of life by mitigating the obesity-related comorbidities that they face.

As has been suggested for young people without disabilities, a lack of physical activity may contribute to overweight and obesity in young people with DS (Mead et al., 2017). Children and adolescents with DS are often more sedentary (Izquierdo-Gomez el al., 2015), do not meet the recommended amount of daily aerobic activity (Pitteti et al., 2013), and have lower levels of PE than young people without DS (Izquierdo-Gomez et al., 2013). In addition, PE levels may decrease with age in young people with DS (Pitteti et al., 2013). More specifically, they indicate that children with DS tend to have lower levels of physical activity than their peers without DS. Furthermore, they do not meet the PE guidelines for different age groups. The overall result may lead to an increased risk of numerous secondary health conditions related to the decline of developed PE (Fox et al., 2019).

All of these aspects may contribute to the high rates of obesity in children and young people with DS, particularly as they grow into adulthood (Betarpelli et al, 2016). However, few studies have examined the direct relationship between PE and overweight/obesity in children and adolescents with DS and almost all the authors agree on the need for research with larger samples, better methodological designs, and greater accuracy in the estimation of the effect of PE on adiposity (e.g., Segura-Jíménez et al., 2016; Shields et al., 2017). In addition to encouraging PE in children and adolescents with DS, adequate levels of PE and the removal of barriers to participation in PE also need to be increased (Fox et al., 2019).

Although the literature on the benefits of PE in children, adolescents, and adults with DS is growing (Dodd et al., 2005; Li et al., 2013; Segura-Jíménez et al., 2016; Shields et al., 2017), interventions directly related to children or adolescents with DS and obesity are limited (Betarpelli et al., 2016). Specifically, the interventions in children and adolescents with DS, in which exercise is used as an independent variable, find the maintenance of PE levels (Hassan et al., 2019) and decreased BMI (Suarez-Villadat et al., 2019). As with the rest of the interventions with PE, this can be done alone or combined with other types of interventions such as nutritional and/or behavioral. If we look at the existing literature on interventions based exclusively on PE, we find studies in which the percentage of fat mass and weight are reduced (Maïano et al., 2014; Ordonez et al., 2006; Seron et al., 2014), there is a significant increase in muscle mass (González-Agüero et al, 2011a; 2011b), and improvement in other parameters directly related to metabolic health (Seron et al., 2015; Segura-Jímenez et al., 2016), as well as other interventions where there are no significant changes in direct or indirect parameters (González-Agüero et al., 2011a; 2011b; 2013), although they did offer encouraging data. It should be borne in mind that there is a great deal of disparity and heterogeneity in the types of interventions used in all the studies found. Hence, much more data is needed, with a better methodology and a larger sample to conclude this matter.

If we focus on PE interventions combined with others, the results are somewhat more encouraging, although as mentioned above, there are many differences in the interventions proposed by the studies. Thus, we find studies that are done in the family environment (Brown et al., 2015; Curtin et al., 2013) or the clinical environment (Mosso et al., 2011). A review (González-Agüero et al., 2010) found that these types of combined interventions result in changes in weight, body fat, and fat mass, although they concluded that changes in a healthy lifestyle and secondary health conditions represent an under-researched area in these populations.

The diversity of the studies found makes it difficult to effectively compare results among them due to various methodological differences or the type of sample, among other matters. Besides, the small sample size in the studies encountered makes the interpretation of the results more complicated. The literature reviewed classified overweight and obesity with BMI threshold values established for children and adolescents in the general population. The suitability of using BMI cut-off points from the general population for young people with Down syndrome is uncertain due to their distinct body proportions and potential measurement errors in using only BMI values (Suárez-Carmona, & Sánchez-Oliver, 2018). As cited in the articles reviewed, different types of instruments are used to measure key anthropometric parameters. Most of the instruments used to measure body fat and fat-free mass show a high level of accuracy in the reviewed studies. However, no clear protocols used to perform the measurements are referenced, which is an important limitation of these reported studies. In addition to these instruments, the use of accelerometers is also suggested as a precision method to assess physical activity. Because of this, there are a great number of studies that have used different approximations regarding design and interventions, which limit the generalization of findings (Betarpelli et al., 2016).

Future research could aim to determine the potential benefits of exercise (e.g., type, frequency, intensity, goals) for children and adolescents with DS, helping them to achieve healthier body composition, cardiorespiratory fitness and physical fitness and, in turn, improve the quality of life of this population. Issues to be considered in the design of new studies involving DS and obesity or overweight include cardiorespiratory fitness. This is a feasible method in DS subjects without congenital heart disease. This method is also useful for measuring the level of fitness for safe physical activity.

Conclusions

Overall, children and young people with DS appear to have higher levels of overweight and obesity compared to the general youth population, which in turn appears to increase their health risk. These body composition characteristics result from the interaction of a variety of factors and therefore require interdisciplinary work. That is, studies and approaches which include multifactorial and interdisciplinary interventions are needed to understand how to optimize the quality of life in this population. However, this work has shown that interventions based on physical activity alone, both strength and cardiovascular endurance, can be successful in improving body composition in children and adolescents with DS. A 12-16 week physical exercise program for children and adolescents with DS reduces fat mass percentage and improves parameters such as weight, BMI, and WC. It is important for caregivers, trainers, and those living with children or adolescents with Down syndrome to prioritize their health by promoting physical exercise. Moreover, it should not be forgotten that children and adolescents with DS possess a set of health, anatomical, physiological, cognitive, and psychosocial attributes that predispose them to physical limitations (Pitetti, 2013), making possible interventions even more difficult to implement. For all these reasons, a personalized and tailored approach may be needed to support these individuals to participate in physical activity and improve their health and well-being.

Conflicts of interest The author(s) declared no have conflict of interest concerning this work, authorship, and/or publication of this paper.

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