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Review

Effects of exercise, physical activity and sports on physical fitness and body composition in children and adolescents with Down syndrome: a systematic review

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Abstract
The objective of this systematic review (PROSPERO: CRD42024503648) is to analyze and describe the effects of physical activity, exercise and sport interventions on fitness in children and adolescents with DS, to promote the improvement of physical fitness or in body composition. Following the PRISMA guidelines, a search strategy was carried out in four databases (Pubmed, WoS, Scopus and SciELO). Inclusion criteria: studies that used exercise, physical activity or sports as an intervention, which sought to improve physical fitness in children or adolescents with DS. PEDro scale and RoB-2 were used to evaluate the quality of the articles. Of the total number of participants, there were 342 participants in the experimental group and 279 in the control group. To synthesize the information from the studies, it was ordered based on authors and year of publication; country; study design; population; age of participants; intervention; instruments for data collection; results.16 investigations met the selection criteria. 8 studies mention an improvement in muscle fitness, 3 on cardiorespiratory fitness, 2 on body composition, 5 on balance, one on agility and one on functional capacity. The limitations of the study include the heterogeneity of the interventions, which makes their comparison and recommendation

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difficult, and the small number of articles of high methodological quality according to the scales used. It is concluded that physical activity, exercise or sports interventions with a duration of 30 min to 75 min with a frequency of two or three times a week, for a period of 6 weeks up to 36 weeks and even for at least 5 consecutive days, produce improvements in the components of fitness in children and adolescents with Down syndrome. Therefore, it is a viable strategy to seek improvements in the physical condition of children and adolescents with Down syndrome, which could lead to a general improvement in the life of this population. This review received no external funding.

Keywords Down syndrome · Children · Adolescent · Exercise · Physical activity · Sports · Fitness

1 Introduction

Down syndrome (DS) is a disorder caused by the partial or total appearance of chromosome 21 [1–3]. It is the most common chromosomal irregularity, affecting 1 in 787 babies born in United States [4]. DS is a condition that generates multiple health problems, intellectual disability, delayed speech, memory, and learning [5, 6]. People with DS have a high tendency to suffer from congenital heart disease, which is one of the causes most associated with mortality and morbidity [7, 8], in addition, they have a greater tendency to be overweight and obese [9–11], which can generate even more health risks [12].

Some of the causes of overweight and obesity in people with DS are susceptibility to systemic inflammation [13, 14], hypotonia [15, 16], slow metabolism or metabolic diseases [17, 18]. They also have a higher percentage of body fat [19], a lower total lean mass index [20], and a higher percentage of abdominal fat than the typical population [21]. Furthermore, children with DS perform less physical activity than their typically developing peers [22], have high levels of sedentary behavior [23] and a reduced capacity to perform physical activity [24], which generates a predisposition to cardiometabolic risk [25] and poor physical fitness [26].

Physical aptitude or "fitness" is a series of qualities that demonstrate a person's ability to perform physical activity, generally considering cardiorespiratory aspects, strength and muscular power [27]. Currently, fitness is considered a marker of current [28–30] and future health [31], it is also a predictor of mortality from all causes [32, 33]. A good cardiorespiratory condition is associated with better health [34], at the muscular level, we can say that muscular fitness is inversely proportional to metabolic risk and mortality [35]. Furthermore, the number of push-ups [36] and grip strength [37, 38] are also inversely proportional to cardiovascular events and mortality [39], even low grip strength is an indicator of risk associated with hypertension, type 2 diabetes, and dyslipidemia [40, 41]. Adults with DS have lower arm and leg muscle strength [42] and lower cardiorespiratory capacity [43] compared to their typically developing peers. In children, lower trunk strength and balance have been observed compared to their typically developing peers [44], making it important to improve fitness in this population.

It is already known that physical activity, exercise and sport generate multiple health benefits [45, 46] and there are already reviews that mention health benefits in people with DS. For example, neuromuscular exercise in children generates improvements in strength and balance [47] and in adults physical activity improves strength, oxygen consumption, functional mobility and body weight [48]. However, despite these results, the first review focuses on therapeutic activities, such as mechanotherapy, vibration and the use of different unstable surfaces and the second review focuses on the general benefits of physical activity, but in adults with DS. Improvements have even been seen in some components of physical fitness, but such information remains in adults [49], therefore, it is necessary to continue exploring the improvements produced by physical activity interventions in children and adolescents with DS, specifically in physical fitness.

In view of the above and considering the importance of fitness as a present and future marker of health in any population, in addition to the relationship of functionality with physical fitness in this population [50] and the multiple benefits generated by physical activity, exercise and sport, the objective of this review is to examine the effects of activity physical, exercise and sport on fitness in children and adolescents with DS.

2 Materials and methods

2.1 Protocol and registration

This systematic review was conducted by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [51]. The protocol was registered and approved by PROSPERO (code: CRD42024503648).

2.2 Eligibility criteria

For this systematic review, the inclusion criteria were the following: (i) randomized controlled trials (RCTs) or quasi-experimental clinical trials that used exercise, physical activity or sports as an intervention; (ii) that aim to improve some component of the physical fitness in children or adolescent with DS. That is, the PICO framework is (population: children or adolescents with Down syndrome; intervention: exercise, physical activity or sport; comparator: control group; outcomes: some aspect of fitness).

The exclusion criteria were: (i) cross-sectional, retrospective, and prospective studies; (ii) studies with a co-intervention, such as medications, nutritional supplements, or an educational program; (iii) non-original articles (for example, translations, book reviews, letters to the editor); (iv) duplicate articles; (v) review articles (e.g., narrative reviews, systematic reviews, meta-analyses); and (vi) case studies.

2.3 Information and database search process

The search process was carried out in November 2023, using four databases: Scopus (in "Article title, Abstract, Keywords"), Web of Science (in "Topic"), SciELO (in "All indexes") and PubMed (in "Title/Abstract"). The articles used in this review were obtained without restrictions on language or publication year up until the extraction date in November 2023. The search string used was the following: [("Child") OR ("Children") OR ("Adolescent") OR ("Adolescents") AND ("Down syndrome") AND ("Physical activity") OR ("Exercise") OR ("Sports") AND ("Physical fitness") OR ("Fitness")]. In all of the above databases, the "advanced search" function was used in combination with the drop-down and available options for searching the information indicated above in parentheses after each database.

2.4 Studies selection and data collection process

Based on the eligibility criteria, four researchers (F.M.-V., C.F.-V., R.N.M and O.A-R.) were in charge of reviewing and selecting the articles independently. Each author reviewed the titles, abstracts, and keywords for inclusion of the articles in the review. In case of differences between the researchers, a fifth researcher (A.C-P.) acted as mediator for the inclusion or exclusion of an article according to each case.

2.5 Methodological quality assessment and risk of bias

The Physiotherapy Evidence Database (PEDro) scale was used to determine the methodological quality of the articles selected in this review [52, 53]. The PEDro scale presents 11 criteria on internal validity and the presentation of statistical analyses, granting a methodological quality point to the study if it meets the criteria explained and zero points if it is not met [54]. The first criterion does not add points. Articles that receive a score between eight and ten are considered to be of high methodological quality, between four and seven points are considered to be of moderate methodological quality, and those that receive a score between one and three are considered to be of low methodological quality (Table 1).

RoB-2 (Cochrane risk-of-bias 2nd version) was used for risk-of-bias assessment in the selected studies. Each domain was classified as "low"; "some concerns"; "high risk of bias" [55] as appropriate for each randomized clinical trial. Figure 1a details the risks of bias for the investigations that met the selection criteria, and Fig. 1b presents the percentages for each item assessed.

2.6 Data synthesis

For the analysis of the information from the selected studies, the following information was considered (a) authors and year of publication; (b) country; (c) design; (d) research sample for the experimental and control groups; (e) mean age of the participants; (f) interventions developed by the experimental and control groups, considering total and session duration and frequency per week; (g) instruments for the collection of information related to physical fitness; and (h) main outcomes reported from the studies. Finally, to complement the presentation of the results, we have used TIDieR

Table 1 Methodological analysis of the articles (PEDro scale)

Authors	Criteria											
	1	2	3	4	5	6	7	8	9	10	11	Total
Abd El Kafy and Helal [57]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Aly and Abonour [58]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Eid et al. [59]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
González-Agüero et al. [60]	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
González-Agüero et al. [61]	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Gupta et al. [62]	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Jankowicz-Szymanska et al. [63]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Lin and Wuang [64]	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7
Millar et al. [65]	Yes	No	No	Yes	No	No	No	No	No	Yes	Yes	3
Seron et al. [66]	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5
Shields and Taylor [67]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8
Suarez-Villadat et al. [68]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Ulrich et al. [69]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Suarez-Villadat et al. [70]	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Suarez-Villadat et al. [71]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8
Naczk et al. [72]	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6

PEDro scale criteria: 1: Selection criteria were known. 2: The assignment of the participants to the groups was random. 3: The task was hidden. 4: The groups were similar for the most relevant predictive indicators. 5: All participants were hidden. 6: All intervention therapists were concealed. 7: Assessors who measured at least one relevant outcome were blinded. 8: Relevant results were obtained on 85% of at least one of the most important results. 9: All outcomes for participants who completed the intervention were reported, for at least one key outcome. 10: There was a statistically significant comparison between groups for at least one key outcome. 11: The intervention revealed point and variability measures of at least one key outcome

checklist [56] (Supplementary 1) and a summary of the findings by item (muscle fitness, cardiorespiratory fitness and body composition) (Supplementary 2).

3 Results

A total of 368 articles were identified through four databases Scopus (n = 52), WoS (n = 132), PubMed (n = 47) and SciELO (n = 137), of which 53 were eliminated due to duplicates. Of the remaining 315 articles, 283 articles due to titles and abstracts were excluded. 32 articles were evaluated for their eligibility, only 2 of them could not be retrieved for reading, being excluded. Finally, 16 investigations met the selection criteria, and 14 investigations were eliminated due to exclusion criteria (Fig. 2).

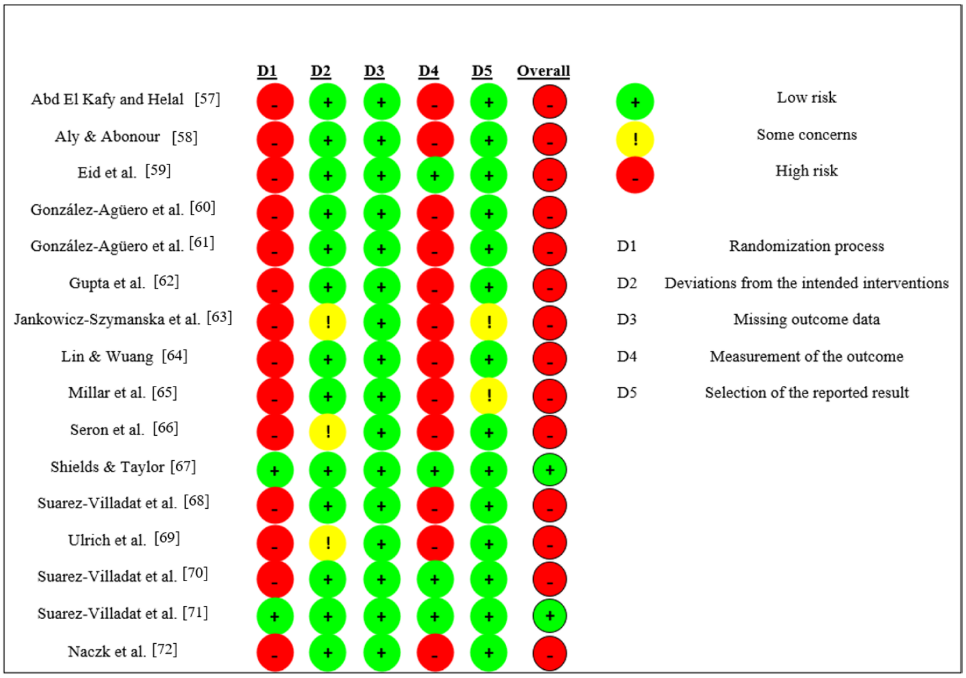
3.1 Studies characteristics

Table 2 summarizes the variables analyzed in each of the selected studies. Of these, two were performed in Egypt [57, 58], one in Saudi Arabia [59], five in Spain [60, 61, 68, 70, 71], one in India [62], two in Poland [63, 72], one in Taiwan [64], two in USA [65, 69], one in Brazil [66], one in Australia [67]. Concerning the design of the studies, 15 were randomized controlled trials and one is a quasi-experimental. In relation to the total number of participants, there were 342 participants in the experimental group and 279 in the control group.

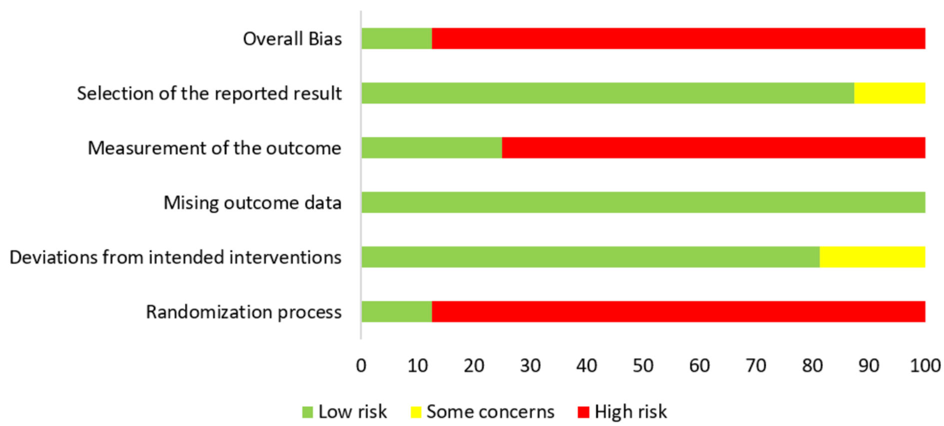
3.2 Results of the PEDro scale on the research included in the review

Articles with a score of 8 to 10 are considered to be of high methodological quality, those of 4 to 7 of moderate quality, and those with a score of less than 4 of low quality. In this review, 1 article scored 3 points, 3 articles scored

Fig. 1 **a** Assessment of risk of bias based on the Cochrane risk of bias tool. **b** Risk of bias graph



a. Assessment of risk of bias based on the Cochrane risk of bias tool.



b. Risk of bias graph

4 points, 3 articles scored 5 points, 4 articles scored 6 points, 2 articles scored 7 points, 2 articles scored 8 points and 1 article score 9 points, i.e., 1 low quality article, 12 articles of moderate quality and 3 of high quality (Table 1).

3.3 Results of risk of bias

Figure 1a shows the information related to the risk of bias associated with the studies incorporated in this systematic review. The results of the analysis show that 14 of 16 studies included presented a high risk of selection bias and the remaining two were categorized as low risk. Figure 1b shows the percentage obtained per sentence in each assessed element, where they are classified under the same three concepts (low risk, some concerns, high risk).

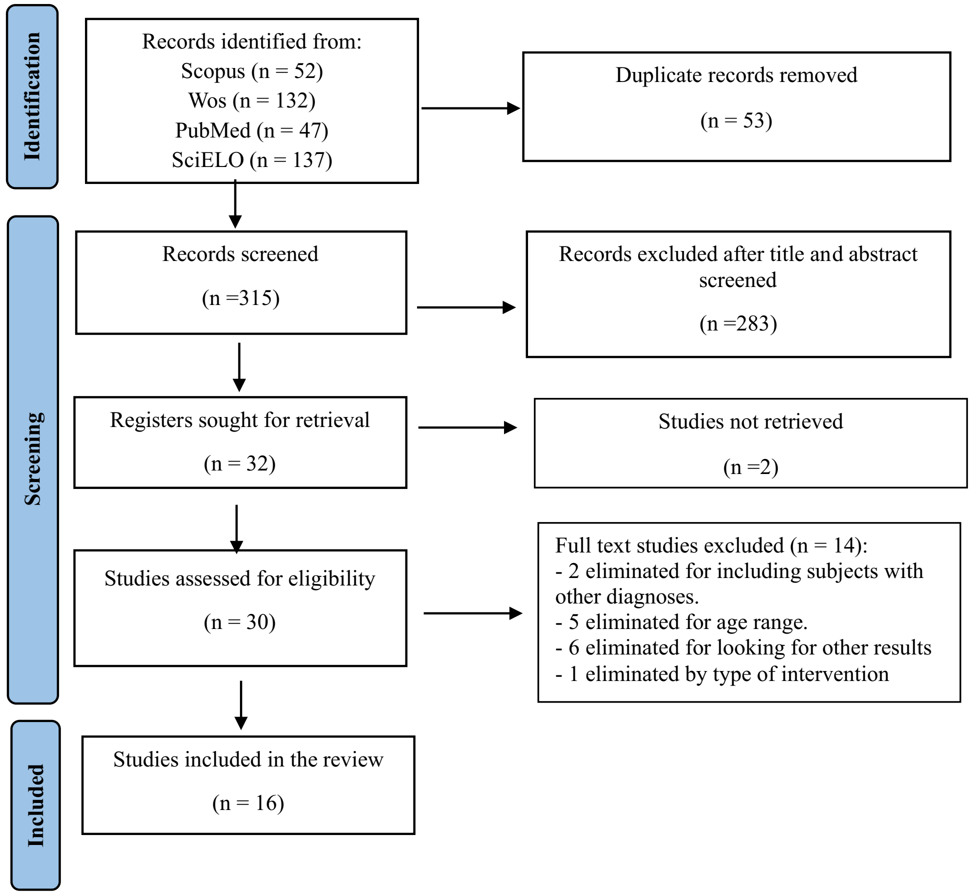


Fig. 2 PRISMA flowchart of the search strategy and study selection

3.4 Muscle fitness

In the study by Lin and Wuang [64] significant between-group improvements were observed in the following muscle groups: hip flexors ($p = 0.01$); hip extensors ($p = 0.02$); hip abductors ($p = 0.004$); knee flexors ($p = 0.03$); knee extensors ($p = 0.03$) and ankle plantar flexors ($p = 0.01$). Moderate to large effect sizes (ES) were obtained for all muscle groups as well (0.51–0.89). In this study, muscle fitness was measured in pounds with a hand-held dynamometer.

In Shields and Taylor [67] work, the experimental group increased lower extremity muscle strength compared to the control group. The increase in lower extremity strength represented a 42% increase in baseline strength in the experimental group compared to the control group. There were no significant ($p > 0.05$) differences between groups for upper extremity muscle strength. In this work, the muscle fitness was measured in kilograms (kg) using 1 repetition maximum (1RM).

The intervention by Ulrich et al. [69], found group main effects for knee flexion. The EXP-L (experimental group) had significantly greater knee flexion in the right leg ($p = 0.041$) and significantly greater knee flexion in the left leg ($p = 0.026$). Muscle fitness was measured in kg with a hand-held muscle tester.

Gupta et al. [62], following the intervention, observed that the difference between the experimental and control groups was statistically significant in terms of strength in all muscle groups. A significant difference was reported for hip flexors ($p = 0.001$), hip extensors ($p = 0.002$), hip abductors ($p = 0.001$), knee flexors ($p = 0.03$), knee extensors ($p = 0.01$), ankle plantar flexor ($p = 0.02$). In this article, muscle fitness was measured in pounds with a hand-held dynamometer.

The intervention by Eid et al. [59], in post-treatment measurements, the study group showed a significant increase in peak torque of the right and left knee flexors and extensors compared to the control group ($p < 0.05$). In this research, muscle fitness is measured through torque on an isokinetic dynamometer.

In the work of Suarez-Villadat et al. [70], significant differences between both groups were observed, specifically, in handgrip strength ($p = 0.048$), standing long jump test ($p = 0.041$), timed stand-up test of 10 (s) ($p = 0.048$), 30 s sit-ups ($p = 0.025$). In this study, muscle fitness was measured in kg, cm, s, and repetitions.

Table 2 Studies reporting on the effect of physical activity, exercise and sport on fitness in children and adolescents with DS

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
Abd El Kafy and Helal [57]	Egypt	RCT	35 EG: 18 CG: 17 45.7% Female	9.50 9.22	Rowing aerobic exercise 30 × 3, min/week 12 weeks	Chest physical therapy group	Vital capacity (L) Forced vital capacity (L) Forced expiratory volume (L) Peak expiratory flow rate (L/min)	Vital capacity (L) ↑ Forced vital capacity (L) ↑ Forced expiratory volume (L) ↑ Peak expiratory flow rate (L/min) ↑ Significant differences posttreatment
Aly and Abonour [58]	Egypt	RCT	30 EG: 15 CG: 15 30% Female	8.11 8.34	Physical program with core stability exercises 45–60 × 3 min/week 8 weeks	Physical program without core stability exercises	Overall stability index Anterior–posterior stability index Medial–lateral stability index	Overall stability index ↓ Anterior–posterior stability index ↓ Medial–lateral stability index ↓ Significant differences posttreatment
Eid et al. [59]	Saudi Arabia	RCT	31 EG: 15 CG: 16 45.1% Female	10.26 10.05	Physical program with isokinetic training 45–60 × 3 min/week 12 weeks	Physical program without isokinetic training	Right knee flexors peak torque Right knee extensors peak torque Left knee flexors peak torque Left knee extensors peak torque Overall stability index Anterior–posterior stability index Medial–lateral stability index	Right knee flexors peak torque ↑ Right knee extensors peak torque ↑ Left knee flexors peak torque ↑ Left knee extensors peak torque ↑ Overall stability index ↓ Anterior–posterior stability index ↓ Medial–lateral stability index ↓ EG vs CG: significant differences in favor EG

Table 2 (continued)

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
González-Agüero et al. [60]	Spain	RCT	26 EG: 13 CG: 13 50% Female	13.7 15.4	Physical conditioning combined with a plyometric jumps training program 20—30 × 2 min/week 21 weeks	Activities not mentioned	Fat mass (kg) Whole body Trunk Lower limbs Upper limbs Lean mass (kg) Whole body Lower limbs Upper limbs	Fat mass (kg) Whole body ↔ Trunk ↔ Lower limbs ↔ Upper limbs ↔ Lean mass (kg) Whole body ↑ Lower limbs ↑ Upper limbs ↔ EG vs CG: significant differences in favor EG
González-Agüero et al. [61]	Spain	RCT	27 EG: 14 CG: 13 44.4% Female	13.7 15.6	Circuit training programme with a plyometricjump 20—30 × 2 min/week 21 weeks	Usual activities	Exercise Time VO_2max RERmax VEmax HRmax	VO_2max ↑ RERmax ↑ VEmax ↑ HRmax ↑ EG vs CG: significant differences in favor EG
Gupta et al. [62]	India	RCT	23 EG: 12 CG: 11 39.1% Female	13.50 13.00	Exercise training programme Until all repetitions are finished 3 × week 6 weeks	Usual activities	Muscle strength: Hip flexors (lb) Hip extensors (lb) Hip abductors (lb) Knee flexors (lb) Knee extensors (lb) Ankle plantarflexor (lb) Total score of balance subset of BOTMP	Muscle strength: Hip flexors ↑ Hip extensors ↑ Hip abductors ↑ Knee flexors ↑ Knee extensors ↑ Ankle plantarflexor ↑ Total score of balance subset of BOTMP ↑ EG vs CG: significant differences in favor EG
Jankowicz-Szymanska et al. [63]	Poland	RCT	40 EG: 20 CG: 20 50% Female	16.8 16.8	Exercises with the use of unstable surface 45 × 2 min/week 12 weeks	Activities not mentioned	Length of the path of the COG Time differences in keeping COG in the 13 mm radius circle	length of the path of the COG ↓ Time differences in keeping COG in the 13 mm radius circle ↓ EG vs CG: significant differences in favor EG

Table 2 (continued)

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
Lin and Wuang [64]	Taiwan	RCT	92 EG: 46 CG: 46 53.2% Female	15.6 14.9	Strength and agility training program 25 × 3 min/week 6 weeks	Usual activities	Muscle strength: Hip flexors (lb) Hip extensors (lb) Hip abductors (lb) Knee flexors (lb) Knee extensors (lb) Ankle plantarflexor (lb) Agility Body strength	Muscle strength: Hip flexors ↑ Hip extensors ↑ Hip abductors ↑ Knee flexors ↑ Knee extensors ↑ Ankle plantarflexor ↑ Agility ↑ Body strength ↑ EG vs CG: significant differences in favor EG
Millar et al. [65]	USA	RCT	14 EG: 10 CG: 4 21.4% Female	18.4 17.0	Walk/jog training program 50 × 3 min/week 10 weeks	Usual activities	VEmax VO_2max HRmax RERmax	VEmax ↔ VO_2max ↔ HRmax ↔ RERmax ↔ EG vs CG
Seron et al. [66]	Brazil	Quasi-experimental	41 EG ATG: 16 EG RTG: 15 CG: 10 39% Female	15.7 16 14.4	ATG Aerobic training 50 × 3 min/week 12 weeks RTG Resistance training 50 × 2 min/week 12 weeks	Activities not mentioned	Body weight Fat % BMI WC (cm)	Fat % ↔ for ATG and RTG Fat % ↑ CG BMI and WC ↓ for ATG BMI and WC ↔ RTG and control
Shields and Taylor [67]	Australia	RCT	23 EG: 11 CG: 12 26% Female	15.9 15.3	Progressive resistance training program Until all repetitions are finished 2 × week 10 weeks	Usual activities	Chest press 1RM Leg press 1RM Timed Up and Down Stairs test (sec) Grocery Shelving Task (sec)	Chest press 1RM ↔ Leg press 1RM ↑ Timed Up and Down Stairs test (sec) ↔ Grocery Shelving Task (sec) ↔ EG vs CG: significant differences in favor EG

Table 2 (continued)

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
Suarez-Villadat et al. [68]	Spain	RCT	45 EG: 15 CG: 30 44.4% Female	13.93 13.71	Swimming program 50 × 2 min/week 36 weeks	Recreational swimming	BMI WC (cm) WtHR % Triceps (mm) Subscapular (mm) Suprailiac (mm) Thigh (mm) Body Fat %	BMI ↓ WC (cm) ↓ WtHR % ↓ Triceps (mm) ↓ Subscapular (mm) ↓ Suprailiac (mm) ↔ Thigh (mm) ↔ Body Fat % ↓ EG vs CG: significant differences in favor EG
Ulrich et al. [69]	USA	RCT	72 EG: 36 CG: 36 56.5% Female	12.4 12	5 consecutive days of bicycle training for 75 min/day	Usual activities	Knee extension right leg Knee extension left leg Knee flexion right leg Knee flexion left leg Balance right leg Balance left leg Body fat % Time spent in sedentary activity Time spent in moderate to vigorous activity	Knee extension right leg ↔ Knee extension left leg ↔ Knee flexion right leg ↑ Knee flexion left leg ↑ Balance right leg ↔ Balance left leg ↔ Body fat % ↓ Time spent in sedentary activity ↓ Time spent in moderate to vigorous activity ↑ EG vs CG: significant differences in favor EG

Table 2 (continued)

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
Suarez-Villadat et al. [70]	Spain	RCT	50 EG: 25 CG: 25 40% Female	14.06 14.32	Exergames program 60 × 3 min/week 20 weeks	Usual activities	BMI WC (cm) Hip circumference (cm) Triceps (mm) Subscapular (mm) Suprailiac (mm) Thighs (mm) Body Fat % BAI % Handgrip strength (kg) Standing long jump (cm) Deep trunk flexibility test (cm) 10 timed-stand test (s) 30-s sit-up (number) Timed Up and Go test (s) 6 min walk test (s)	BMI ↔ WC (cm) ↓ Hip circumference (cm) ↓ Triceps (mm) ↔ Subscapular (mm) ↓ Suprailiac (mm) ↓ Thighs (mm) ↔ Body Fat % ↓ BAI % ↓ Handgrip strength (kg) ↑ Standing long jump (cm) ↑ Deep trunk flexibility test (cm) ↔ 10 timed-stand test (s) ↑ 30-s sit-up (number) ↑ Timed Up and Go test (s) ↑ 6 min walk test (s) ↑ EG vs CG: significant differences in favor EG

Table 2 (continued)

Study	Country	Study design	Groups (n) and Sample size Female (%)	Mean age (year)	Intervention		Data collection instruments of physical fitness	Main outcomes
					Experiment group (EG)	Control group (CG)		
Suarez-Villadat et al. [71]	Spain	RCT	50 EG aerobic: 25 EG strength: 25 38% Female	18.37 18.30	Aerobic program Strength program 60 × 3 min/week 16 weeks	Without CG	BMI WC (cm) Hip circumference (cm) WtHR % Handgrip strength (kg) Standing long jump (cm) Motor fitness (s) Cardiorespiratory fitness (laps) 6 min walk test (s)	BMI strength ↔; aerobic ↑ WC (cm) strength ↔; aerobic ↔ Hip circumference (cm) strength ↔; aerobic ↑ WtHR % strength ↔; aerobic ↔ Handgrip strength (kg) strength ↑; aerobic ↑ Standing long jump (cm) strength ↑; aerobic ↓ Motor fitness (s) strength ↑; aerobic ↓ Cardiorespiratory fitness (laps) strength ↑; aerobic ↑ 6 min walk test (s) strength ↑; aerobic ↑ Significant differences posttreatment
Naczk et al. [72]	Poland	RCT	22 EG: 11 CG: 11 36.3% Female	14.9 14.4	Swimming program 90 × 3 min/week 33 weeks	Usual activities	Body mass (kg) BMI Fat % Fat (kg) VO_2 max HRmax	Body mass (kg) ↓ BMI ↓ Fat % ↓ Fat (kg) ↓ VO_2 max ↑ HRmax ↑

In the intervention by Suarez-Villadat et al. [71], the strength group obtained significant differences in all fitness variables: handgrip strength ($p = 0.029$), standing long jump test ($p = 0.032$), measured in kg and cm.

In the study by Naczk et al. [72], the exercise group showed a statistically significant increase in hand grip strength, abdominals, arm strength-endurance ($p \leq 0.05$), measured in kg, repetitions and s, respectively.

3.5 Cardiorespiratory fitness

Abd El Kafy and Helal [57], in their intervention, the study found improvements in the experimental group, specifically, in vital capacity (l), forced vital capacity, forced expiratory volume (l), maximum expiratory flow rate (l/m), all results with $p < 0.05$. All variables were measured with ergospirometry.

In the intervention by González-Agüero et al. [61], the exercise group increased all of their cardiorespiratory parameters compared to baseline, maximal heart rate, maximal respiratory quotient, maximal ventilation, maximal oxygen uptake ($p < 0.05$). Furthermore, and despite having similar values before training, the exercise group showed higher values than the control group in all cardiorespiratory parameters after training ($p < 0.05$). These values were obtained using an open circuit ergospirometer.

In the intervention by Millar et al. [66], after training, both the control and experimental groups showed no changes in VO_2 max ml·kg^{-1} min^{-1} (absolute and relative), V_E l·min^{-1} (expired volume × minute), Heart Rate and Respiratory Exchange Ratio. This intervention used an ergospirometer.

In the study by Naczk et al. [72], the exercise group also showed a statistically significant increase in aerobic capacity, this was observed using VO_2 max (L/m) and VO_2 max (ml/kg/m) both values with a value of $p \leq 0.05$. This study used an ergospirometer.

3.6 Body composition

Seron et al. [66] observed in their work that the percentage of body fat did not change significantly for both groups that participated in the training intervention, however, the control group (CG) showed a significant increase in this variable ($p = 0.049$). On the other hand, for the Aerobic Training Group (ATG), body mass index (BMI) and waist circumference (WC) were significantly reduced, ($p = 0.010$, $p = 0.017$), while resistance training group (RTG) and GC showed no differences in these variables. To obtain the measurements, a plethysmography device, a 2-m measuring tape, a digital scale and a stadiometer were used.

The intervention of Ulrich et al. [69], showed that, in general, the EXP-L group had significantly decreased the percentages of body fat in post-1 ($p = 0.004$) (7 weeks after the intervention) and post-2 ($p = 0.006$) (1 year after the preintervention). The values were obtained through electronic scale, stadiometer and skinfold thickness.

In the intervention by Suarez-Villadat et al. [68], the exercise group exhibited significant decreases in all body composition variables, however, the control group showed significant increases in all body composition variables. Specifically, the exercise group shows lower levels of BMI ($p = 0.001$), WC ($p = 0.049$), waist to height ratio (WtHR) ($p = 0.038$), triceps ($p = 0.043$) and body fat ($p = 0.049$) compared to the CG. The values were obtained through electronic scale, non-elastic tape and skinfold thickness.

In the study by González-Agüero et al. [60], the exercise group significantly increased total and lower extremity lean mass after training ($p < 0.05$), however, no significant changes in fat mass were seen. The values were obtained through whole-body scan by dual energy X-ray absorptiometry.

In the intervention by Suarez-Villadat et al. [70], different improvements were observed in the experimental group, including improvements in WC ($p = 0.046$), hip circumference ($p = 0.034$), subscapular ($p = 0.043$), suprailiac ($p = 0.021$), body fat % ($p = 0.041$) and Body adiposity index (BAI) ($p = 0.044$). The values were obtained through electronic scale, non-elastic tape and skinfold thickness.

The research by Suarez-Villadat et al. [71], mentions that the aerobic group showed an increase in BMI and hip circumference and that in the strength group no significant differences ($p < 0.05$) were found in the body composition variables. The values were obtained through electronic scale and non-elastic tape.

In the study by Naczk et al. [72], the exercise group showed significant decreases in body mass, body fat, and BMI. All results with a $p \leq 0.05$. The values were obtained through bioelectrical impedance.

3.7 Other measured variables

In the study by Lin and Wuang [64]. The mean baseline total agility score was 11 for both groups. After the intervention, these scores increased to 16 for the exercise group and decreased to 10 for the control group, respectively. A significant difference ($p = 0.02$). The agility score was through the BOT-2 test.

In the work of Shields and Taylor [67], the functionality of the upper limb and lower limb was measured through two tests, for the lower limb the Timed Up and Down Stairs test was used, the participants must ascend, turn and go down a flight of stairs as quickly as possible, the result was 0.5 and for the Grocery Shelving Task (upper limb), which involves taking things in and out of a bag and then stacking them on a shelf at the height of shoulders. The result was 0.3 and 0.5 which represented moderate effects respectively.

Gupta et al. [62], performed exercises for balance training. When analyzing the scores of the control and experimental group after the intervention period, they were statistically different except for three components: walking on a line, standing on a balance beam with eyes closed, and stepping over a response lever on the bar of balance. Overall, there was a statistically significant difference ($p = 0.007$) in overall scores between the two groups. The balance score was through the Bruininks Oseretsky Test of Motor Proficiency (BOTMP) test.

In the intervention of Eid et al. [59], there was a significant decrease in anteroposterior stability index (AP), mediolateral stability index (ML) and general stability index (OSI) in the experimental group compared to the control group ($p < 0.05$). Balance assessment was carried out using the Biodex Stability System.

Jankowicz-Szymanska et al. [63] mention that members of the experimental group scored significantly better on the balance test after completing the training program. The length of the COG trajectory (general center of gravity) decreased in them by an average of 22% in the test with eyes open and 25% in the test with eyes closed. In the control group, the mean differences did not exceed 2%. This study used a balance platform to obtain the values.

In the research by Aly and Abonour [58], the experimental group performed Jeffrey's core stability exercises three times a week. There was a significant decrease in the anteroposterior, mediolateral, and overall stability indices of the study group compared to the control group after treatment ($p < 0.001$).

In the Millar et al. [65] intervention, the exercise group showed significant improvement in maximal exercise time and grade ($p < 0.05$). Additionally, gains in walking ability were seen for the experimental group. This intervention used a treadmill test grades to obtain the values.

In the study by Naczk et al. [72], the exercise group also showed a statistically significant increase in mental adaptation and skills balance control movement measured through the "Water Orientation Test Alyn 2" (WOTA2). The effect size of the training noted in the exercise group for mental adaptation and skills balance control movement was classified as very high (5.37 and 3.30, respectively).

Finally, Table 3 synthesizes the selected studies with regard to country, design, sample, intervention, data collection instruments of fitness and outcomes.

4 Discussion

The objective of this systematic review was to examine the effects of physical activity, exercise and sports on fitness in children and adolescents with DS. The main findings show that physical activity, exercise and sports have a positive and significant effect on some variables of fitness, especially on muscle fitness, cardiorespiratory fitness, body composition, balance, agility and functional capacity.

Of the 16 articles included in the review, 11 based their intervention on exercise [57–64, 66, 67, 71], two on physical activity [65, 70] and three on sports programs [68, 69, 72]. Concerning intervention times, one study used 5 days of intervention [69], one study used 16 weeks [71], one study used 20 weeks [70], one study used 33 weeks of intervention [72], four studies carried out 12 weeks [57, 59, 63, 66], one study carried out 8 weeks [58], two studies carried out 10 weeks [65, 67], two studies used 6 weeks of intervention [62, 64], two studies used 21 weeks [60, 61], one used 36 weeks of intervention [68]. Although there is heterogeneity around the types of intervention, there is a certain consensus on the weekly frequency and the minimum time of exercise, 2 or 3 weekly sessions with a minimum of 30 min, for at least 6 weeks and even for at least 5 consecutive days to see significant effects on fitness.

Table 3 Exercise, physical activity or sport protocol used in included studies

	Intervention protocol
Abd El Kafy and Helal [57]	Warm-up (5 min): stretching exercises for upper and lower extremities and thoracic mobility exercises Main session (20 min): rowing exercise on the basis of 2-min work and 1-min rest Cool down (5 min): stretching exercises for upper and lower extremities and thoracic mobility exercises
Aly and Abonour [58]	Warm-up: not mentioned Main session (45–60 min): first and second week: Contracting abdominal muscles while lying in a supine position (3 sets and 20 reps in each set) Contracting abdominal muscles while lying in a prone position (3 sets and 20 reps in each set) Contracting abdominal muscles while in a squat position (3 sets and 20 reps in each set) Third week Contracting abdominal muscles while lying in a supine position with one leg stretched and the other bent at knee and pressed against the abdomen (3 sets and 20 reps in each set) Contracting abdominal muscles while lying in a prone position with one leg stretched and the body weight on the other leg which is bent at knee (3 sets and 20 reps in each set) Side lying bridge for each side of the body (6 reps, 10 s pause) Fourth week Contracting abdominal muscles while lying in a supine position and pulling the limbs upward with arms and legs kept close together (3 sets and 20 reps in each set) In squat position, one leg is raised and pulled outward and backward (3 sets for each leg and 20 reps in each set) Trunk rotation while holding weights in each hand (3 sets each part of the body and 20 reps in each set) Fifth week Sitting on a Swiss ball and holding the abdomen in (3 sets,10 s) Squatting while the Swiss ball is on the shoulder (3 sets and 15 reps for each set) Bringing up the arms and legs simultaneously in the prone position (3 sets and 10 reps for each set) Sixth week Bending 45 degrees to the left or right Bridging while shoulders and hands are on the floor and one leg is raised (3 sets and15 second pause for each set) Contracting abdominal muscles while lying in a supine position on the Swiss ball (3 sets and 20 reps for each set) Seventh week Lying supine on the Swiss ball and rotating the trunk to the sides (3 sets and 15 reps for each set) Doing the above exercise with holding weights in the hands (3 sets and 15 reps for each set) Side lying bridge with bringing up the leg (6 repetitions for each side of the body and 10-s pause) Eighth week Lying supine on the Swiss ball and holding the abdomen in and bringing one leg up (3 sets and 20 reps for each set) Raising the opposite arm and leg while squatting (3 sets and 20 reps for each set) Bridge so that the feet are placed on the Swiss ball and raise one leg (3 sets and 15 s pause for each set) Cool down: not mentioned
Eid et al. [59]	Warm-up: 5 sets of quadriceps and hamstrings stretching with 30 s of stretching, followed by 30 s of relaxation, walking, slow running, and free gymnastic activities (at angular velocities of 90°/s and 120°/s) Main session: 3 sets of 10 repetitions of maximal concentric isokinetic contractions for knee flexors and extensors, with a 3-min rest between two angular velocities Cool down: not mentioned
González-Agüero et al. [60]	Warm-up (5 min): activities not mentioned Main session (10–15 min): 1 or 2 rotations in a circuit of 4 stages Stage 1 (jumps): standing vertical jump, jump with run-in, drop jump, drop jump + horizontal jump. From the third week, participants carried adapted-medicine balls while performing the jumps Stage 2 (press-ups on the wall): participants placed their hands on a wall and performed press-ups standing with their feet separate from the wall Stage 3 (elastic-fitness bands): lateral rows, bicep curls and frontal rows Stage 4 (adapted-medicine balls) standing throw and catch Cool down (5 min): activities not mentioned

Table 3 (continued)

	Intervention protocol
González-Agüero et al. [61]	Warm-up (5 min): activities not mentioned Main session (10–15 min): based on 4 stages jumps: standing vertical jump, run and jump, drop jump (jump height between 40 and 50 cm), drop jump + horizontal jump (jump height between 40 and 50 cm. From the third week, the participants use medicine balls Wall push-ups: participants placed their hands on a wall and performed press-ups standing with their feet separate from the wall Fitness elastic bands: side row, biceps stretch and frontal row Adapted medicine balls: throwing and receiving, with a distance of 3 o 4 m Cool down (5 min): activities not mentioned
Gupta et al. [62]	Warm-up: not mentioned Main session (35–45 min): resistance exercises using sandbags were given for hip flexors, abductors, extensors, knee flexors and extensors and ankle plantar flexors. For each muscle group two sets of 10 repetitions were given, the resistance was increased by half a kilogramme (1.1 lbs) when the child was able to complete the sets with ease and without undue stress Second part (balance training): horizontal jumps, vertical jumps, one leg stance with eye open, tandem stance, walking on line, walking on balance beam and jumping on a trampoline. Each activity was given initially for 10 repetitions; it was increased by five repetitions when the child was able to do it with ease Cool down: not mentioned
Jankowicz-Szymanska et al. [63]	Warm-up: not mentioned Main session (45 min): balance training: prone- and back-lying rocking on a rehabilitation ball, prone-lying in hand support on a rehabilitation ball (lower extremities straight in knee joints, placed in trunk extension), in kneeling position with hands and knees resting on rehabilitation pillows, attempts at keeping balance and alternate upper right and left limb raising to horizontal position, keeping the correct sitting posture on a rehabilitation ball, balancing the pelvis in the sagittal plane while sitting on the ball, balancing the pelvis in the frontal plane with alternate right and left foot raising above the floor, standing on two-feet on a rehabilitation pillow, attempt at performing a knee bend while standing on a rehabilitation pillow, walking barefoot on a spiked gum mat, walking barefoot on a 10 cm Cool down: not mentioned
Lin and Wuang [64]	Warm-up (3 – 5 min): active stretching exercise Main session (20 min): Based on the virtual reality Nintendo game, where participants chose their 15 favorite sports, most virtual game simulations require gross movement of the extremities and continuous postural shifting to accomplish the task. For example, golfing required quick position shifting while boxing required weight transfer between the lower extremities Cool down: not mentioned
Millar et al. [65]	Warm-up (10 min): activities not mentioned Main session (30 min): Continuous walking and jogging Cool down (5—10 min): activities not mentioned
Seron et al. [66]	Aerobic Training Group Warm-up (5–10 min): Main session (30 min): treadmill or bike with heart rate intensity corresponding to 50–70% of the heart rate reserve during 30 min Cool down (5–10 min): stretching exercises Resisted Training Group Warm-up (5–10 min): Main session (50 min): 9 exercises and consisted of 3 sets of 12 maximum repetitions (12 MR) for each exercise, with 1-min interval between sets and 3 min between exercises. Exercises: bench press machine, leg extension, front pull-down, cable biceps curl, standing hip flexion with ankle weights, cable triceps, calf raise with ankle weights, front raises with dumbbell weights, and abs Cool down (5–10 min): stretching exercises
Shields and Taylor [67]	Warm-up: not mentioned Main session (Until all repetitions are finished): 6 exercises using weight machines; 3 for the upper limbs (lat pull-down, seated chest press, seated row) and 3 for the lower limbs (seated leg press, knee extension, calf raise) Cool down: not mentioned

Table 3 (continued)

	Intervention protocol
Suarez-Villadat et al. [68]	Warm-up (10 min): Swimming in front crawl style and breaststroke style Main session (35 min): Exercises using technical support elements (e.g. pull-buoy, tables, shovels, fins) increasing the heart rate to between 140–160 beats/min. Swimming in front crawl and breaststroke. Maximum heart rate frequencies 160–180 beats/min in front crawl Cool down (5 min): Soft swim, muscle relaxation and lowering heart rate and respiratory rate. The back or breaststroke technique is used
Ulrich et al. [69]	Warm-up: not mentioned Main session (70 min): exercises on an adapted bicycle, to learn to ride a bicycle, increasing the difficulty and incorporating fewer support wheels Cool down: not mentioned
Suarez-Villadat et al. [70]	Warm-up: activities not mentioned Main session (60 min): sports-related games (Wii-sports or Wii-sports Resort). A collection of twelve sports simulations (i.e. tennis, baseball, bowling, golf, canoe, cycling, boxing) Cool down: activities not mentioned
Suarez-Villadat et al. [71]	Aerobic Group Warm-up (10 min): activities not mentioned Main session (45 min): Participants walked on a treadmill and participated in adapted or modified games and collective sports: soccer and basketball games with a ball to develop launching, games to develop careers, games to develop the ability to walk, games to develop the ability to hit, games to develop lifting, carrying and transporting. The actions included qualities of coordination, balance, movements, jumps, throws, receptions Cool down (5 min): activities not mentioned Strength Group Warm-up (10 min): activities not mentioned Main session (45 min): The loads and intensities of the exercises were personalized, session exercises: horizontal rowing with dumbbell, chest press with dumbbells, split squat with dumbbells (one forward leg), step ups, TRX, dumbbell squat (Legs apart), propellant with elastic band, squat band (elastic band), drag exercises 5–8 kg, multiple exercises with resistance bands, scrolling exercises with ball Cool down (5 min): activities not mentioned
Naczk et al. [72]	Warm-up (20 min): outside the pool (10 min) and warm-up in water (10 min) Main session (30–50 min): first stage, which lasted 4 weeks, the adolescents were getting used to the aquatic environment, and mainly water games were used to that effect. At this stage swimming session lasted 70 min Second stage, which also lasted 4 weeks, water games were still carried out and the participants were taught to exhale into the water, slide on the chest and back, and make simple jumps into the water. At this stage swimming session lasted 80 min Third stage, lasting 15 weeks, the adolescents learned to swim in the four swimming styles: backstroke, crawl, breaststroke and butterfly. At this stage swimming session lasted 90 min The last 10-week stage was aimed at improving swimming skills, focused on improving the swimming technique. At this stage swimming session lasted 90 min Cool down (20 min): Games in the water

4.1 Muscle fitness

Improvements were observed in strength [59, 62, 64, 67, 69–71], in lower limb lean mass [60]. These results are important since strength is associated with a lower prevalence of chronic diseases [73] and lean mass is a predictor of mortality [74]. On the other hand, adults with DS show similar or lower muscle mass and strength indices than older adults with sarcopenia [75], therefore, it is necessary to incorporate strength exercise from an early age. Likewise, it corroborates that training strength in a traditional way is safe [76]. This review corroborates what was mentioned by Melo et al. [77] that exercise promotes multiple health benefits.

4.2 Cardiorespiratory fitness

In the cardiorespiratory aspect, three studies declared significant improvements [57, 61, 72] and one study did not declare improvements [65]. A possible justification for the difference in significant results could be the lack of increase in intensity by Millar et al. [65], who maintained the same intensity throughout the entire intervention, on the other hand, González-Agüero et al. [61] increased the series and repetitions throughout the intervention, likewise, Naczk et al. [72] increased the core part of the intervention by 10 min every 4 weeks and Abd El Kafy and Helal [57] increased the intensity by 10% for each advanced phase during the intervention. The non-use of progressive overload could justify the non-improvement of VO_2 max [78]. Another possible justification could be the reduced and altered responses of people with DS in blood pressure [79], heart rate [80] and autonomic dysregulation [81], which could cause problems in the adaptations generated by exercise. This review corroborates what was mentioned by Bahiraei et al. [82], that although there are improvements with exercise in the responses of the cardiorespiratory system, they are not consistent in people with Down syndrome.

4.3 Body composition

In relation to body composition, the body fat percentage variable was intermittent in terms of results, two investigations confirmed improvements [68, 69] and two investigations did not show significant changes [60, 66], a systematic review mentions the contradiction in this variable [83]. A possible explanation could be the weekly time dedicated to physical activity, González-Agüero et al. [60], dedicated 30 min, two times a week to their intervention and Seron et al. [66], they performed the exercise intervention only two times a week for 30 min. Suarez-Villadat et al. [68] and Ulrich et al. [69], dedicated 50 min, three times a week and 75 min for 5 consecutive days, respectively.

In addition, González-Agüero et al. [60] and Seron et al. [66] performed the measurements with plethysmography and dual energy X-ray absorptiometer respectively, while Suarez-Villadat et al. [68] and Ulrich et al. [69] worked with an adipometer (caliper) and skin folds. Which could justify the difference in results, since compared to dual X-ray absorptiometry, bioelectrical impedance analyzers and skinfold thickness equations do not provide 100% accurate measurements of body fat percentage [84].

4.4 Other measured variables

Five studies reported an improvement in balance [58, 59, 62, 63, 72]. A very important aspect, since the balance of children with Down syndrome is lower than that of their peers with typical development and can negatively influence gait [85]. One study reported an improvement in agility and coordination [64], one in functionality of the MMSS and MMII, mainly, it translates into muscle mobility [67] and Millar et al. [65] mention benefits in the ability to walk. Variables that can contribute to a better physical performance and perhaps optimize the aforementioned results. In addition, these results are also important, since balance, coordination, agility, and walking can influence children's social relationships [86].

All the aforementioned results are important, since children and adolescents with intellectual disabilities do not meet the minimum recommendations for physical activity [87] and have low levels of physical fitness [88], like their peers with DS [22]. It also corroborates what was mentioned by Benavides et al. [89], a specific program of physical activity, exercise or sport improves the physical condition of children and adolescents with DS. Also, it confirms what was said by Lip and Rodríguez [90], physical activity, exercise, sports, games and physical education classes should be used as means of preventing diseases associated with overweight and obesity, as alternative means of rehabilitation and as effective elements of sociocultural insertion and reintegration, which adds to the multiple benefits indicated in this review, muscular fitness, cardiorespiratory fitness, body composition, balance, agility and functional capacity.

4.5 Limitations and strengths

Among the strengths of this study is that all the included studies have a control group, also that the present systematic review is based on the 2020 PRISMA guide. On the other hand, by including children and adolescents within the review, there is a certain similarity with the ages of the participants. Among the limitations of the study is the wide heterogeneity of exercise interventions, which generates difficulty in recommending in a much more specific way and determining which is most effective as an additional and/or complementary treatment. Likewise, the intelligence quotient (IQ) of the participants or their sex was not considered when presenting the results. Another limitation was the failure to conduct a meta-analysis, which could have allowed us to quantify which exercise is most appropriate for this population and facilitate comparison between studies.

4.6 Future implications

For future studies it would be interesting to do other sports such as tennis, paddle tennis or some HIIT protocol. Also, it would be interesting to consider the participants' level of physical activity, caloric intake, and nutritional habits to review the ambiguous result of fat percentage in more detail. Finally, check if there are improvements in the levels of anxiety, stress, depression, sleep quality and social aspects.

5 Conclusions

The evidence collected in this review indicates that physical activity, exercise and sport have a significant improvement on fitness in children and adolescents with DS, specifically muscle fitness, cardiorespiratory fitness, body composition, balance, agility and functional capacity. Therefore, it is a concrete proposal that should be considered as an additional treatment or complementary therapy to improve functionality, quality of life or as a prevention method against diseases related to overweight and obesity in children and adolescents with SD. It is a safe tool that can even be used within physical education class due to its strong sociocultural-emotional impact. Specifically, physical activity, exercise or sports interventions with a duration of 30 min to 75 min with a frequency of two or three times a week, for a period of 6 weeks up to 36 weeks and even for at least 5 consecutive days, produce improvements in the components of fitness in children and adolescents with DS.

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