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Physical and psychosocial benefits of sports participation among children and adolescents with chronic diseases. A systematic review.

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Abstract

Objective: This study aimed to identify sports interventions for children and adolescents (CaA) with chronic diseases and evaluate their impact on physical, psychological, and social well-being. The findings of this study will contribute to our understanding of the potential benefits of sports interventions for CaA with chronic diseases and inform future interventions to promote their overall health and well-being.

Methods: A systematic review was conducted in eight databases. This systematic review followed PRISMA guidelines and utilized a comprehensive search strategy to identify studies on sport-based interventions for children and adolescents with chronic diseases. The review included randomized controlled trials and observational studies focusing on physical and psychosocial outcomes.

Results: We screened 10123 titles and abstracts, reviewed the full text of 622 records, and included 53 primary studies. A total of 2384 participants were assessed with an average of 45 ± 37 participants per study. Among the included studies involving CaA with chronic diseases with an age range from 3 to 18 years, 19% (n=10 studies) were attention deficit hyperactivity disorder, 21% (n=11) cerebral palsy, 30% (n=16) autism spectrum disorders and 17% (n=9) obesity. Other diseases included were cancer (n=5), asthma (n=1) and cystic fibrosis (n=1). Interventions involved various sports and physical activities tailored to each chronic disease. The duration and frequency of interventions varied across studies. Most studies assessed physical outcomes, including motor performance and physical fitness measures. Psychosocial outcomes were also evaluated, focusing on behavioural problems, social competencies, and health-related quality of life.

Conclusion: Overall, sport-based interventions effectively improved physical and psychosocial outcomes in CaA with chronic diseases. Interventions are generally safe, and participants adhere to the prescribed protocols favorably. Despite that, there is insufficient evidence of interventions' implementation. Future studies should include interventions tailored to meet the common issues experienced by CaA with chronic conditions, providing a comprehensive understanding of the impact of sports interventions on on those affected.

Keywords: children; chronic diseases; psychosocial; physical fitness; quality of life; sports

1. Introduction

Chronic diseases in children and adolescents (CaA) refer to long-term medical conditions requiring ongoing medical care and management. These conditions can affect a child's physical, emotional, and social well-being, lasting for months, years, or even a lifetime (1). Some common examples of chronic illnesses in children include asthma, diabetes, obesity, cystic fibrosis, autoimmune disorders, cancer, and neurological disorders (1). The prevalence of these disorders varies depending on the specific condition and population studied. According to the Centers for Disease Control and Prevention (CDC, 2021), approximately 27% of CaA in the United States have a chronic health condition, and nearly 20% have two or more chronic conditions (2). Considering the significant impact on a child's well-being, as well as on their family and caregivers, effective management and support for these conditions are essential to optimize outcomes and quality of life for affected children and their families (3).

Regular physical activity is a significant non-pharmacological approach that can contribute to overall well-being and improve the quality of life. Current guidelines suggest that CaA aged 5-17, including those with chronic diseases, should engage in at least 60 minutes of moderate to vigorous physical activity (MVPA) daily to support healthy development. Alternatively, they can engage in 20 minutes of vigorous physical activity at least three times a week to achieve the same health benefits (4). These recommendations are based on research and evidence that shows the positive impact of physical activity on overall health and well-being in young people (4). There is evidence showing that effective strategies aimed at reducing attrition rates and optimizing the benefits of physical activity participation can promote health in CaA with a variety of chronic diseases, including obesity (5), asthma (6), cystic fibrosis (7), cancer (8), autism spectrum disorders (9) or attention deficit hyperactivity disorders (10). However, recent literature show that youth with chronic diseases often do not meet these guidelines (11), and while physical activity is considered a cornerstone in the management and treatment of chronic diseases in CaA, several studies have identified significant barriers that hinder young individuals with chronic diseases from engaging in these activities (12).

Some of these barriers include physical limitations, fear of exacerbating symptoms, and lack of knowledge, motivation, or access. CaA with chronic diseases may need access to safe and appropriate facilities, equipment, or programs to support their physical activity goals. Moreover, CaA with chronic diseases may feel socially isolated or excluded from physical activity and exercise opportunities due to their condition (11). This can lead to a lack of social support and a decreased sense of self-efficacy around physical activity. Consequently, since participation in physical activity can present barriers, searching for alternatives that can at least partially limit them is necessary. Sport has been shown to improve young people's physical and psychological function (13). In CaA with chronic diseases, participating in sports could alleviate the barriers reported for physical activity participation because sports provide opportunities for social interaction, structured and supervised activities, and a sense

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of belonging to a team or community (14). Additionally, sports often have clear rules and objectives, which can help individuals overcome the barriers of not knowing what activities to do or how to do them. Regular sports participation can also improve physical fitness, self-esteem, and mental health, which can further motivate individuals with chronic diseases to continue engaging in physical activity (11). Although there is a well-established understanding that physical activity and sports participation offer significant health benefits for healthy CaA (11), the impact of sports engagement on physical fitness and health-related outcomes among young people with chronic illnesses needs to be more adequately explored due to the lack of empirical evidence in this area (11). Therefore, is required in order to determine the positive associations between sports participation and physical and psychosocial well-being in CaA with chronic diseases. Thus, this systematic review aimed to analyze the physical, psychological, and social benefits of participation in sports among CaA with chronic diseases. We aimed to determine what interventions involving sports have been tested in CaA with chronic diseases. With this understanding, our goal is to facilitate the creation of practical applications for engaging in sports participation among various prevalent pediatric chronic diseases.

2. Methods

The methodology for this review was pre-determined and registered in the PROSPERO database (registration number: CRD42023397172). This study adhered to the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions and the PRISMA Statement (15).

2.1 Data sources and searches

A comprehensive search strategy was developed to identify peer-reviewed journal articles until February 15, 2023. Potentially eligible studies were identified through a systematic search in the following databases: PubMed, MEDLINE, CINAHL, SPORTDiscus, Web of Science, Scopus, PsycINFO and ERIC. This review followed the PICOS framework. The search strategy included the study population, condition and context using terms and keywords derived from preliminary searches and with the assistance of experts in the subject area. The study population consisted of children and adolescents (<18 years of age) with chronic diseases (lasting for years or even lifelong), including obesity, asthma, diabetes, haemophilia, cardiovascular diseases (CVD), cancer, cystic fibrosis, epilepsy, developmental disabilities, cerebral palsy, autism spectrum disorders (ASD), attention-deficit/hyperactivity disorder (ADHD) and Post-traumatic diseases. All sport-based interventions were included (intervention). Studies should have either an intervention group with sports and movement-related activities and a control group without targeted sports interventions (e.g., treatment as usual) or only one intervention group (e.g., observational designs); therefore, the primary subset of studies included randomized controlled trials (RCT), but also randomized trials (RT) and observational studies were included. Both physical (e.g., physical fitness, gross motor skills) and psychosocial (e.g., social behaviours, social support, peer relationships, cognitive functions, or health-related quality of life) outcomes were considered. Mental indicators (e.g., self-efficacy, self-esteem, emotional well-being, etc.) were also considered within this group. Limitations on language or publication date were not applied in this study.

2.2 Study selection

Inclusion criteria were controlled studies including a non-intervention group as a comparison and studies using quantitative comparative observational designs performed in CaA <18 years old diagnosed with a chronic condition. Studies were excluded if: a) not participating in any sports interventions, physical activity or leisure-time activities related to sport, b) included without one of the aforementioned chronic conditions, c) participants above 18 years old, d) case reports, non-longitudinal observational studies, qualitative studies, letters, and systematic or narrative reviews, e) did not include physical or psychosocial outcomes.

A two-phase article selection process was conducted. Firstly, the titles and abstracts of the articles were screened, followed by the inclusion phase, where the full text of all articles meeting the inclusion criteria was reviewed. The screening and inclusion phases were carried out independently by two reviewers (BSC and AJSO) who were blinded to each other's assessments. Any articles that did not meet the eligibility criteria were documented with reasons using an eligibility checklist. Any disagreements between the two reviewers were resolved by a third reviewer (JFG).

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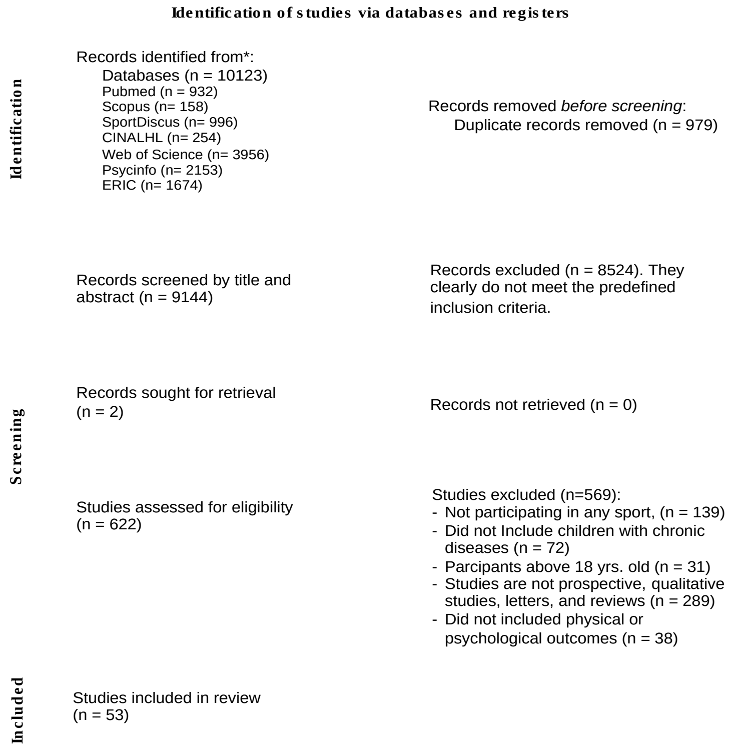

2.3 Search and selection process

The flow chart of the selection process is shown in Fig. 1. We identified 10123 records from the eight databases. From these, 979 duplicates were removed. After the screening of the titles and abstracts, 8524 were excluded. In the inclusion phase, we reviewed the full text of 622 records and all reports were assessed for eligibility. Reasons for exclusion included: a) studies not describing the participation in any sport-related activities (n = 139); b) studies that do not include CaA with chronic diseases (n = 72); c) studies with participants above 18 years old (n = 31); d) studies that were not prospective, qualitative studies, letters, or reviews (n = 289); e) studies not including physical or psychosocial outcomes (n = 38). Finally, we identified 53 studies that met the inclusion criteria (16,17,26–35,18,36–45,19,46–55,20,56–65,21,66,22–25).

2.4 Data extraction

For each study included in the review, data were extracted on: a) general characteristics of the study (author, year of publication, setting -intervention location-, sample size (in controlled studies, the number of participants receiving control and intervention); sociodemographic characteristics (sex, age, chronic disease); description of the intervention (sport, duration, frequency, main results, adverse effects, adherence). Physical and psychosocial outcomes and methods of assessment were also retrieved.

3. Results

3.1 Description of studies

A summary of the included studies is reported in Table 1. The included studies were published from 1994 (62) through 2022 (28,34,55,57). Most studies were published in the 2010s and 2020s, with a significant number published in 2020 and 2021. The studies encompassed a range of designs, sample sizes, and participant characteristics to provide diverse insights into the intervention under investigation. All included studies used a longitudinal design; however, 24% did not include a non-intervention comparison group, 18 (34%) were quasi-experiments, and 22 (42%) utilized an RCT design. A total of 2384 participants were assessed, with an average of 45 participants per study (ranging from 6 (54) to 128 (23) per study). The age of the participants ranged on average from 4.9 ± 0.6 (49) to 15.0 ± 1.0 (63). The age range was 3 to 18 years.

The included studies were categorized based on the type of chronic diseases, considering the following categories: ADHD (n=10), cerebral palsy (n=11), ASD (n=16), obesity (n=9), cancer (n=5), asthma (n = 1) and cystic Fibrosis (n=1).

3.2 Sport interventions

The systematic review included a diverse range of interventions. For individuals with ADHD, interventions involved various sports and physical activities such as basketball, soccer, taekwondo, tag and ball games, table tennis, horse-riding, and target-shooting sports (16–24,65). CaA with cerebral palsy benefited from interventions including golf training, home-based active video games, and participation in soccer, netball, T-ball, cricket, swimming, tennis, dance, martial arts, basketball, soccer, baseball, and adaptive cycling (25–34). The interventions for individuals with ASD encompassed activities such as horse-riding, soccer, judo, ball games, dances, active video games, swimming, and table tennis (17,35,44–49,36–43). CaA with cancer engaged in various activities like ball games, racket sports, fighting activities, dance, basketball, badminton, yoga, skiing, swimming, paddling, climbing and active video games (50–53,66). Interventions for individuals with asthma included active play and games (54). For those with cystic fibrosis, interventions comprised cycling, swimming, walking, dancing, playing ball, skipping ropes, jumping, stretching, and gymnastics (55). The interventions for individuals with obesity included volleyball, football, and physical education activities such as swimming and balloon volleying (56–64). These interventions took place in various settings and facilities. These included schools (n= 6), high schools (n=1) or universities' gymnasiums (n=8), summer camps (n=3), sports centres, community facilities (e.g., shooting associations), homes (e.g., active video games), golf clubs, community therapy centres, clinical settings (e.g., outpatient clinics), horse centres, campsites, judo facilities, local indoor hydrotherapy and swimming pools, YMCA facilities, basketball pitches, gymnastic halls and local soccer clubs.

The duration and frequency of the interventions varied across the studies. Some studies implemented interventions lasted for one week (43,55,66), while others extended over eight months (36), one year (33) or even one and a half years (65). The prescribed exercise frequency in the selected studies also differed, with some studies offering sessions multiple times per week (e.g., five sessions per week), while others provided interventions on a less frequent basis (e.g., one session per week), with most of the studies offering 2-3 sessions per week (16,17,35,36,39,40,42–47,19,48–57,24,58–63,67,25–27,30,31,34). Further details can be found in Table 1.

3.3 Physical and psychosocial outcomes

Physical and psychosocial outcomes are reported in Table 2. Physical outcomes were included in 42 studies, while psychological outcomes were reported in 42 out of 53 studies. Motor performance (e.g., gross motor skills) was assessed in 36 studies (16,17,27–36,18,37–46,19,47–52,20,21,23–26). Most of these studies used the Test of Gross Motor Development-2, Test of Motor Proficiency second Edition (BOT-2), German Motor Test, Gross Motor Function Measure-88 and the Test of Gross Motor Development (TGMD).

Physical fitness was evaluated in 21 (50%) studies. Various fitness assessments were carried out across these studies, including the Brockport Physical Fitness Test (BPFT) or EUROFIT (20,57). The outcomes were measured using a diverse range of instruments. Cardiorespiratory fitness (e.g., aerobic capacity) was assessed using the Bruce treadmill protocol or different progressive ergometer exercise tests, the 20-meter progressive aerobic cardiovascular endurance run (PACER), the six-minute walk test, or the Yo-Yo Intermittent Endurance test. Flexibility was evaluated using the sit and reach or Modified Thomas tests. Upper muscle strength was measured by the number of push-ups or curl-ups, hand-held dynamometers, or medicine-ball launches, while lower-limb muscle strength was assessed through the number of sit-ups in 60 seconds or maximum voluntary isometric contractions. Running speed and agility were gauged using the Shuttle run (10x5m) and the 25-ft walk/run test, and the speed of limb movement was measured using the Plate tapping test. Coordination was evaluated with the Agility t-test and the Timed Up and Go test. Explosive power was assessed through the Muscle Power Sprint Test (MPST), but also in jumping (Standing Broad Jump, Vertical Jump,

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counter movement jump) and throwing (Seated Throw) activities. The static and dynamic balance were evaluated in nine studies (20,21,25,29,32,47,49,51,57), including measures such as the time standing on the left and right foot and the flamingo balance test. Finally, athletic competence was assessed through various skill tasks, such as dribbling and shooting tests, locomotor and ball skills, or the YMCA Water Skills Checklist.

The psychosocial outcomes were categorized into three distinct groups. The first group, labeled "Behavioral Problems and Social Competencies", focused on examining the interplay between behavioural problems and social competencies. These variables aimed to investigate the relationship between different aspects of behaviour and social functioning, encompassing social skills, social behaviour, and psychological factors. The variables within this group encompassed measures of social behaviours, social skills, and peer relationships, as well as psychological factors such as anxiety, depression, and self-perception. Additionally, specific variables related to ASD and ADHD were included to explore the severity of their behaviours and their impact on social functioning.

Social behaviours and skills (behavioural problems and social competencies, or communication skills) were assessed in 13 (25%) studies (16,17,44,48,49,18,35,36,38,39,41–43). The instruments used were diverse, including the Child Behavior Checklist (CBCL), a widely used assessment tool measures behavioural and emotional problems in CaA. The CBCL assesses a wide range of behavioural and emotional domains, including internalizing problems (such as anxiety and depression), and social problems, and it also gathers information about adaptive functioning, such as social skills and activities. The School Social Behavior Scales (SSBS–2) or the Social Skills Improvement System (SSIS) were also used to evaluate these social skills. The Strengths-and-Difficulties-Questionnaire (SDQ) to assess a child's emotional and behavioural well-being or the Goldstein Model to identify emotional regulation and interpersonal relationships were also used. The Social Responsiveness Scale (SRS-2) was one of the most common instruments used to measure social responsiveness and social-communication skills in individuals, and the Repetitive Behavior Scale-Revised (RBS-R) to measure the presence and severity of repetitive behaviours in individuals. Similarly, the Vineland Adaptive Behaviour Scales (VABS-2) measures adaptive behaviours in four main domains: Communication, Daily Living Skills, Socialization, and Motor Skills.

Other psychological factors such as self-image concept and personality (24,27,43,51,56,59,61,63,64), perceived competence (40,59) were assessed using the Self-efficacy Scale, goal attainment scaling (GAS), Perceived Movement Skill Competence (PMSC), Children and Youth Physical Self-Perception Profile (CY-PSPP), The Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA), self-esteem scale of Rosenberg or the Self-Perception Profile for Children (SPPC) that was used in different studies (56,59,64). The Physical Self-Inventory (PSI) was also used to assess various aspects of an individual's physical self-concept. It is designed to evaluate one's perceptions and attitudes towards physical appearance, abilities, and overall physical well-being. The Draw Self-

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Person List or the Body Shape Questionnaire (BSQ) were also used to assess the individual's self-perception.

Another group of instruments used to measure various aspects of personality, behaviour, and psychological well-being included the IPAT 16 Personality Factors or the Eysenck Personality Inventory (EPI), which measures individual personality traits. The Test of Everyday Attention for Children (Tea-Ch) to identify attentional difficulties or the Behavior Assessment System for Children" (BASC) measures various domains, including emotional symptoms, adaptive skills, social skills, problem behaviours, and self-perceptions. The Mooney Problem Checklist is used to identify behavioral and emotional problems in CaA, and the Minnesota Multiphasic Personality Inventory (MMPI) is also used to assess various aspects of personality, including depression, anxiety, social introversion, and personality disorders.

Specific instruments such as the ADHD rating scale (ADHD-RSIV) and the German version of the Conners-3 were used to assess various domains of ADHD symptoms, such as inattention, hyperactivity, impulsivity, and peer relations. The Autism Rating Scale-Third Edition (GARS-3) scale to evaluate and measure the severity of ASD symptoms in individuals (e.g., social interaction, communication, and repetitive behaviors or restricted interests), together with the Chinese version of the Social Communication Questionnaire (SCQ) designed to gather information about a child's social communication skills and behaviors that are associated with ASD. In participants with obesity, the Salience of Weight-Related Issues Scale (SWRIS) was used to measure weight-related issues' influence on an individual's self-perception and overall well-being.

Another group of variables focused on Executive Functioning and Attention Abilities. Multiple domains of attention, including selective attention, sustained attention, attentional control, and divided attention, were assessed with the Test of Everyday Attention for Children (Tea-Ch). To delve deeper into executive functions, various tests were carried out, among which the following stood out: Wisconsin Card Sorting Test (WCST), that assesses cognitive flexibility, set-shifting, and problem-solving abilities; The Stroop test, that measures cognitive flexibility and inhibition. The Childhood Executive Functioning Inventory (CHEXI) and the Delis-Kaplan Executive Function System (D-KEFS) focused on working memory, inhibition, cognitive flexibility, planning, and organization. Another specific test used to evaluate executive functions included the modified Simon Task or the Go/No-Go (GNG) task (inhibition), the modified Flanker task (switching), or the modified version of the color span backward task (updating). Finally, various studies used the digit span (forwards/backwards) and the letter–number-sequencing task of the HAWIK – IV to assess working memory. The Corsi block tapping task (CBTT) was also used to measure spatial working memory.

The last group focused on Health-Related Quality of Life (HRQoL). Both generic and disease-specific assessment tools were used in the included studies. The generic instrument more widely used was the Pediatric Quality of Life Inventory (PedsQL) (53,55,63,64,66). Other general instruments included

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the General health questionnaire (GHQ) (30), the Child Health Questionnaire (CHQ) (49), Pediatric Outcome Data Collection Instrument (PODCI) (33), KIDSCREEN-27-total score (23) or the Vécu et Santé Perçue de l'Adolescent et de l'enfant (VSP-A) (51). The disease-specific instruments (n = 4) included examples in asthma: Paediatric Asthma Quality of Life Questionnaire (PAQLQ) (54) or Cerebral Palsy (CP QOL-Child) (28). The Neuro-QoL pediatric assessments (34) were designed to assess HRQoL in CaA with neurological conditions.

3.4 Adverse events and adherence to the interventions

None of the interventions investigated exhibited any discernible adverse effects. One particular study conducted by Clutterbuck et al. (28) on CaA with cerebral palsy observed some activity modifications to adapt them to the individual participant's capabilities. However, aside from this specific instance, no detrimental outcomes were reported across the reviewed interventions.

In addition to the absence of discernible adverse effects, the studies included in the systematic review reported favourable adherence rates to the investigated interventions. While most of the selected studies did not report data on adherence in their sport-based interventions, the collective findings revealed that participants consistently adhered to the prescribed protocols and guidelines, demonstrating a high level of engagement and commitment. The study by Benzing and Schmidt on ADHD (24), specifically focusing on the exergaming condition, revealed a relatively high dropout rate among participants Along line, the study conducted by Lai et al. (34) on individuals with cerebral palsy, which explored video and music as intervention components, reported varying adherence rates throughout the intervention. Specifically, participants exhibited a mean adherence of 90% (44 out of 49 minutes) in week 1, followed by 83% (56 out of 68 minutes) in week 2. However, adherence rates slightly declined to 69% (45 out of 65 minutes) in week three and decreased to 43% (40 out of 95 minutes) in week 4. The interventions targeting individuals with ASD consistently reported high adherence rates. In addition to the high adherence rates reported in interventions targeting ASD, it is noteworthy to mention the study by Westergren et al. (54), which focused on patients with asthma. This study reported a remarkable adherence rate exceeding 90% among the participants. Furthermore, when considering interventions targeting obesity, the reported adherence rates consistently surpassed 75% in the reviewed cases.

4. Discussion

This systematic review aimed to examine the effects of sports interventions on physical and psychosocial outcomes in various populations, including individuals with ADHD, cerebral palsy, ASD, cancer, asthma, cystic fibrosis, and obesity. The review found that sports interventions encompassing a wide range of activities, such as basketball, soccer, swimming, and active video games, yielded positive outcomes in terms of motor performance, physical fitness, social behaviours and skills, psychological factors, executive functioning and attention abilities, and health-related quality of life. The variations in duration and frequency underscore the importance of personalized approaches when designing therapeutic interventions. Factors such as the specific condition, the age and abilities of the participants, and the desired outcomes all contribute to determining the most suitable duration and frequency for these interventions. Still, overall, sports interventions showed promising benefits in improving the target populations' physical and psychosocial outcomes. Despite the promising results, youth with chronic diseases often fail to meet the guidelines for healthy physical activity. Only 26% of youth with chronic diseases participate in sports once a week (68). This means they engage in competitive and recreational sports even less frequently than their healthy peers. Different barriers can explain these differences, including both personal (e.g., attitudes from the parents or teachers) and environmental factors (e.g., transportation to an adapted sports facility) (69).

CaA with cerebral palsy, with moderate to severe learning disabilities encounter limited access to physical activity and sports (70); consequently, the most frequently performed physical or sports activities were based on smart devices, specifically video games (25,26,30,31), as well as video dancing (Lai et al., 2022). This highlights the growing utilization of technology in promoting physical activity in this population to increase motivation (71). Motivation was identified as a significant factor influencing adolescents' participation in physical activity (72). However, these interventions' physical and psychosocial benefits must be considered with caution. For example, six weeks of home-based WiiTM training plus usual therapy did not improve coordination, strength, or hand function in children with 9.5 $\pm$ 1.9 years of age (26). Further, eight weeks of a video-game based therapy did not enhance manual dexterity for carrying out everyday tasks in children aged 7.0 $\pm$ 1.9 years (31). There could be several reasons why video game-based therapy in CaA with cerebral palsy may not improve physical or psychosocial outcomes. Some potential reasons include a lack of specificity, as these interventions may not specifically target the underlying motor impairments and functional limitations associated with cerebral palsy. The games used might not adequately address the specific movement patterns or motor skills that need to be improved (73). Another important reason can be insufficient dosage. The frequency and duration, and intensity of video game-based sessions may not be sufficient to induce meaningful changes in motor abilities. Among the included studies, the intervention period varied from 4 (30,34) to 12 (25,26) weeks, with sessions lengths of only 25 min (30) to 30 min (31). Individual differences can also partly explain the lack of significant differences in some outcomes.

We provided evidence that sports interventions can significantly contribute to better motor function and physical fitness, which is particularly important in youth with a neuromuscular disorder (74). Due

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to decreased coordination, these children typically required additional time to perform motor tasks compared to their peers without such impairments. Children with cerebral palsy can have diverse presentations and varying levels of motor impairments (i.e., spasticity, dyskinetic or/and ataxic), with abnormalities of coordination and balance (75). Video game-based interventions may only cater to some of the individual needs and abilities, leading to limited effectiveness across the population. Lastly, limited transfer to real-life activities might also be an influencing factor as the movements and coordination required in video games may not directly translate into improved abilities for real-world tasks.

The findings of one study (70) identified four categories of factors that influence participation in physical activity: (1) Musculoskeletal pain and other; (2) Knowledge, exercise skills, and life skills such as problem-solving, decision-making, planning, and organizing; (3) Availability challenges, including lack of transportation, professional guidance, adapted and community-based programs, and enjoyable activities; (4) Social support from professionals and peer support with opportunities for social interaction. Therefore, in contrast with the more severely affected children, those with mild to no learning disabilities utilized physical activity to manage pain and maintain functional abilities. In the current study, multiple types of sports activities were used as individual (e.g., golf, gymnastics, or swimming) and collective (e.g., Soccer, netball). These interventions promoted motor skill gains and sports-specific physical competence, improved fitness, mobility, and global function, and favoured enjoyment and HRQoL. Sports can, therefore, play a crucial role in overcoming barriers to physical activity in CaA with cerebral palsy by addressing musculoskeletal pain and other impairments (70). Sports have contributed to the development of knowledge and exercise skills, and by offering enjoyable activities, these activities can enhance the attractiveness and accessibility of physical activity for these CaA. However, some considerations must be highlighted. In this population group professional guidance is determinant to cater the adapted sport-based programs to the specific needs of children with cerebral palsy (28); coaches should tailor the sport interventions to accommodate individual capabilities and ensure a safe and inclusive environment. Further, coaches should align the sport interventions with the child's functional goals. These goals may include improving motor skills, coordination, balance, flexibility, and physical fitness. Finally, coaches should foster positive social interactions among participants and encourage peer support. Providing CaA with cerebral palsy opportunities to collaborate and participate alongside their typically developing peers can enhance their overall experience (76). In the current review, coaches prioritized the safety of the participants. They were aware of the specific risks associated with cerebral palsy and took appropriate precautions to minimize the risk of injury during training and competitions.

Individuals diagnosed with ADHD often experience social isolation and rejection due to limited motor skills development, lack of coordination, and diminished attention and executive functioning abilities (16). Sports activities offer unique physical, psychological, and social advantages, distinguishing them from traditional exercise interventions (77,78). Given the characteristics of individuals with ADHD,

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sports can be viewed as a promising tool with significant potential to address their needs. This perspective is supported by the findings of the nine identified articles on sports programs targeting individuals with ADHD in the current review. These studies reveal improvements in physical fitness, motor skills, and variables related to sports performance (16–24), as well as enhancements in psychosocial variables (16–18,21–24). However, despite these positive findings, further studies with robust designs and methodologies are needed, particularly randomized controlled trials (RCTs) with longer durations, as most of the existing research does not exceed three months.

The articles found exhibit a high degree of heterogeneity regarding the type of sport. This limitation prevents the recommendation of a specific sport for this population. However, many of the identified sports share the common element of teamwork or group participation (16–19,21,22). This is important because children with ADHD often have problems with peer relationships and are at increased risk for long-term deficits in social functioning (18). Additionally, some of these studies simultaneously included multiple sports activities in the intervention (16,18,19,21,24). This may be beneficial, as evidence suggests that interventions incorporating multiple activities may have the most significant potential to improve ADHD symptoms (24). The weekly frequency of the sessions also varied significantly across the different studies. Although there appear to be some benefits with only one session per week (20,21,23), this needs to be examined more accurately and in more detail. Similarly, the duration is also an aspect that needs to be clarified. Nevertheless, it is worth noting that the only RCT among the nine articles reported benefits with just three sessions per week, lasting 30 minutes each, over a period of 2 months (24). These authors propose exergaming as an alternative to traditional physical activity programs, as children with ADHD often find them less interesting and exhausting, limiting their engagement (79).

Along the same line, in patients with ASD, two of the studies also employed active video games (40,46). Active video games offer a multisensory and interactive experience which could improve motivation to participate in physical activities. Compared with sports and active recreation activities (46), exergaming (Kinect) improved motor function in CaA with ASD. However, the authors reported that these interventions might not sufficiently promote correct movement patterns to influence skills in CaA (40). Ball games and sports (43) have led to have significantly enhanced motor motor skills, particularly object-control skills, among the participants (39). Moreover, fitness changes were only assessed after sports interventions (45,47,49). These changes in aerobic capacity, flexibility, balance, upper and lower limb strength or muscle endurance have been reported to have in other psychosocial outcomes (80). Another important aspect to bear in mind when programming sport-related activities in this patient's group is the type of grouping: individual sports vs team sports. Some studies reported significant improvements in repetitive behaviours, social interaction, social communication or emotional response both with individual activities (e.g., horse riding (35), judo (37) or table tennis (17,48)) or team sports (e.g., soccer (36) or mini-basketball (41,49)).

Improvements in executive functioning and attention abilities were reported in five studies (17,41,44,46,48). Possible explanations for these improvements include the involvement in structured rules and routines, which can help develop cognitive skills (i.e., components of executive functioning) (81). Further, the requirement of concentration and focus can also enhance attention skills (35). Additionally, participating in team sports can foster social interaction and cooperation, which in turn can positively impact executive functioning and attention abilities (41,46).

Only five have focused on CaA with cancer (50–53,66). Nevertheless, despite the low number of studies, the methodological quality of all the studies is high. The settings where the studies were conducted reflect the unique situation in this population, as CaA with cancer combine long periods in the hospital with treatments at home. Thus, we found one in-hospital study (50), one home-based study (53), and three mixed settings (51,52,66). Due to the characteristics of this condition, where the immune system can be affected, the possibility of offering sports programs through exergames can be an alternative. The findings in this regard are controversial, as one study did not find differences between the intervention and control groups in physical outcomes (52). Similarly, in the study by Howell et al. (53), the intervention was delivered through an interactive website designed to encourage physical activity through rewards. Such alternatives and interventions are supported by the growing body of knowledge that uses gamification and new technologies to promote healthy lifestyles with promising results (82). Given the long hospitalization periods, it is important to create in-hospital programs. In this regard, Speyer et al. (50) obtained positive results in physical, social, and psychological aspects in less than four weeks with only three sessions of 30 minutes per week, combining different sports.

Only one article was identified in patients with asthma (54). Significant improvements in lung function and cardiorespiratory fitness was reported in this twice weekly (6 weeks) intervention based on the ball and team games. Additionally, improvements in the quality of life were obtained. Participants in the study were involved in different focus groups, and they could express that their daily lives and participation in physical activity were constrained by asthma (e.g., they became rapidly exhausted). Reasons limiting their adherence were also described. On the one hand, the authors highlighted the importance of instructors in creating enjoyable programs, enhancing the children's normality and independence, and on the other, the importance of mutual support between participants, which may let them feel normal and competent.

In cystic fibrosis, only one study was included (55). Different activities were performed (cycling, swimming, walking, dancing, playing ball, skipping ropes, jumping, upper extremity stretching, and trunk and lower extremities) over one week resulting in improvement in physical function; however, despite this study was conducted over 70 participants, the short duration of the program and the control of variables require caution when interpreting the results. Despite this, the authors believe that these sports activities can potentially improve these patients' quality of life.

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Finally, despite the many existing studies on physical activity in CaA with obesity (83), only nine articles have examined the effects of a sports program on this population. Of these, four have utilized team sports (57,58,64,84), two have employed group-based sports activities (56,59), and three have opted for mixed interventions alternating between group sports/team sports or individual sports activities (60,62,63). This heterogeneity makes it difficult to establish recommendations regarding the most suitable type of sports intervention for obesity treatment in this age group. CaA with obesity sometimes experience rejection from their peers due to their lack of physical activity skills (85). Consequently, it is important to offer alternatives based on sports programs or non-competitive games as motivating practices for this population, as these ages are crucial for developing this condition and adherence to physical activity. In the current review, psychosocial outcomes were assessed in 6 studies, overall showing improvements in several indicators of health status (e.g., self-esteem improved) and perceived competence (56,59,64).

The interventions' duration ranges from 4 to 24 weeks, although most of them are ≥ 10 weeks. According to a systematic review that studied the duration of interventions for reducing overweight and obesity in CaA, the duration of the studies may not be adequate, as they recommend at least ten months (40 weeks) to avoid rebound effects and, therefore, achieve positive medium-to-long-term results (86). Undoubtedly, the duration of interventions can influence the outcomes, as well as the adherence to them. Therefore, finding a balance will be necessary.

4.1 Adverse events and adherence to the interventions

The findings of this systematic review align with previous literature concerning the absence of adverse effects in sport-related activities for CaA with chronic diseases (87,88). The collective evidence from this review supports the notion that the investigated interventions are generally safe in sport-related contexts, with no reported detrimental outcomes. It is important to acknowledge the study of Clutterbuck et al. (28) on children with cerebral palsy, which observed activity modifications to accommodate individual capabilities, demonstrating a proactive approach to ensure participant safety. However, apart from this particular study, the absence of adverse effects was consistently observed across the reviewed interventions, reinforcing the relative safety of these interventions in CaA with chronic diseases engaging in sport-related activities.

Regarding adherence rates, the collective results indicate favourable adherence to the prescribed protocols among participants, demonstrating high engagement and commitment. These findings are consistent with previous studies that reported positive adherence outcomes in sport-related interventions for CaA with chronic diseases, reporting average adherence rates, regardless of condition (e.g., cancer, cardiovascular disease, and diabetes), of 77% (89). However, it is important to consider the study conducted by Benzing and Schmidt on ADHD (24), which specifically investigated the exergaming condition and reported a relatively high dropout rate. This finding

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echoes previous literature highlighting the potential challenges in maintaining adherence in certain interventions, particularly in specific populations such as individuals with ADHD. As reported above, active video games (i.e., exergaming) ve been shown to be beneficial for CaA in clinical and rehabilitative settings (90). Data from the literature indicate that these interventions may offer an interesting impact on childhood with chronic diseases; nonetheless, there are also potential challenges in maintaining adherence to these interventions. When compared to sport-related activities, active video games often involve solitary gameplay, which may limit social interaction. This is particularly important in the current review, where social support was crucial in maintaining adherence to exercise programs (17,44,59). Without opportunities for social engagement or competition, individuals may feel less motivated to continue with exergaming (24).

Similarly, the study by Lai et al. (34) on individuals with cerebral palsy, utilizing video and music as intervention components, reported varying adherence rates throughout the intervention period. While the adherence rates were initially high, they gradually declined over time. Similarly to exergaming, the lack of personalized feedback and progression tracking faces potential challenges in maintaining adherence. Individuals may struggle to stay motivated and engaged with the intervention without individualised goals, progress tracking, or tailored feedback. This finding is consistent with previous research that has acknowledged the potential fluctuations in adherence levels in long-term interventions. It emphasizes the importance of continuous monitoring and adaptation of intervention strategies to sustain engagement and adherence over extended periods. Moreover, it seems that while supervised exercise interventions are effective and safe in CaA with chronic conditions; however, the adherence of these CaA (i.e., cancer survivors) to supervised exercise interventions is high compared to non-supervised interventions (91). Conversely, the interventions targeting individuals with ASD reported high adherence rates, aligning with previous literature highlighting the strong willingness of individuals with ASD to participate and adhere to interventions. Similarly, the study by Westergren et al. focusing on patients with asthma reported an exceptional adherence rate exceeding 90%. These findings correspond to previous research indicating that tailored interventions can effectively promote adherence in specific populations, such as individuals with ASD and asthma. Furthermore, interventions targeting obesity consistently reported adherence rates surpassing 75%, which aligns with previous literature emphasizing the importance of lifestyle modifications and behavioural changes in managing obesity. These adherence rates indicate a high level of dedication and commitment among individuals undergoing interventions for obesity, supporting the notion that tailored approaches can effectively promote adherence and positive outcomes in weight management programs (92). Further, proper design and implementation of physical activity interventions are crucial for maximizing fitness, and these improvements in fitness in this population resulted in increasing overall health benefits.

Overall, the findings of this review corroborate and expand upon previous literature regarding the absence of adverse effects and favourable adherence rates in sport-related activities for CaA with

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chronic diseases. They highlight the need for continued research and the development of tailored interventions to ensure participant safety and optimize adherence in this population.

4.2 Study limitations

The systematic review has several limitations. Firstly, a wide range of chronic diseases are included in the review, which may introduce heterogeneity in terms of the underlying pathophysiology, treatment approaches, and individual needs. Additionally, the age range of the participants is broad, spanning from early childhood to adolescence, which further adds to the variability in terms of developmental stages and potential differences in intervention outcomes. Moreover, the review encompasses a diverse array of sports and physical activities, making it challenging to draw definitive conclusions regarding the specific benefits of each discipline. Another limitation pertains to using various assessment instruments across studies, which introduces variability in outcome measures and may impact the comparability of results. Despite these limitations, the systematic review provides valuable insights into the potential effects of sports interventions in CaA with chronic diseases, serving as a foundation for future research and intervention development.

5. Conclusion

Sports interventions in CaA with chronic diseases promote motor skill gains, sports-specific physical competence, fitness, mobility, global function, enjoyment, and health-related quality of life. The reviewed interventions demonstrated a relative safety profile with no reported adverse effects. Adherence rates were generally favourable, with high levels of engagement and commitment observed. Challenges in maintaining adherence were noted in certain interventions, particularly in populations such as individuals with ADHD. Tailoring interventions to individual capabilities, providing professional guidance, and fostering positive social interactions were highlighted as important considerations in maximizing the benefits of sports interventions on physical and psychosocial outcomes in CaA with chronic diseases. Nevertheless, further research is needed to better understand the specific determinants of these interventions, including frequency, duration, or type, and to establish the positive associations between sports participation and the overall well-being of CaA with chronic diseases. These results provide valuable insights for practitioners, coaches, and athletes alike, promoting confidence in implementing these interventions as part of comprehensive training and performance enhancement programs without significant concerns regarding adverse effects.

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ANNEXES

Table 1. Characteristics of the included studies

Authors	Year	Sample (n or %males); study desgin	Age (±SD), range	Study Popilation	Setting	Sport/PA	Intervention	
							Duration	Duration/Frequency
Verret et al.	2010	21 (EG, n=10; CG, n=11) quasi-experimental	9.1 (1.1), range: 7-12	ADHD	School gymnasium	Basketball, soccer, exercise stations, and tag and ball games	10 wks	45 min, 3 x wk
Pan et al.	2016	32 (EG, n=16, CG, n=16) quasi-experimental	8.9 (1.5), range 6-12	ADHD	University (table tennis center)	Racket sport (table tennis)	12 wks	70 min, 2 x wk
López-Willians et al.	2005	63 (92% males)	9.1 (1.7), range 6-12	ADHD	The summer treatment program	Sports skills training (basketball, soccer, baseball, and swimming).	8 wks	8h/day, 5 x wk
O´Connor et al.	2014	98 (EG, n=52, CG, n=46) quasi-experimental	6,6 (0,6), range 5-8	ADHD	Sports centre	Soccer and tee ball	8 wks	9 h, ≈3h x day

Pan et al.	2017	24 (EG, n=12, CG, n=12) quasi-experimental	9.6 (2.5), range 7-14	ADHD	Gymnasium at the university	Horse-riding	12 wks	90 min, 1 x wk
Ziereis and Jansen	2015	43 (EG1, n=13, EG2, n=14, CG, n=16) quasi-experimental	9.4 (1.4), range 7-12	ADHD	Gymnasium at the university	Sport games (e.g., Beach volleyball, handball, throwing and catching) climbing, wrestling games, gymnastics, track and field, sprint and hurdling	12 wks	60 min, 1 x wk
Hupp and Reitman	1999	10 (EG, n= 3)	8.7 (1.1), range 6-10	ADHD	Elementary school campus	Basketball	3 wks	210 min, 5 x wk
Gohr Månsson et al.	2019	128 (EG = 64; CG n = 64) (85.16% male) quasi-experimental	11.5 (1.3), range: 10-14 years	ADHD	Local shooting associations	Target-shooting sport	24 wks	24 sessions: 20–45 min, 1 x wk
Benzing & Schmidt	2019	51 (EG = 28; CG = 23) (82.4% male) RCT	10.6 (1.3), range: 8-12 years	ADHD	At home	Exergaming - Xbox Kinect (Microsoft, Redmond, WA)	8 wks	24 sessions: 30 min, 3 x wk
Kadri et al.	2019	38 (EG = 20; CG = 20) (95% male) RCT	14.3 (3.2), range:	ADHD	Private martial arts facility	Taekwondo	1.5 years	50 min, 2 x wk
Gercek et al.	2021	19 (EG, n=9, CG, n=10) quasi-experimental	8.3 (2.1), range 6-12	Cerebral palsy	Golf clubs	Virtual and traditional golf training	12 wks	60 min, 3 x wk
Chiu et al.	2014	62 (EG, n=32, CG, n=28) RCT	9.5 (1.9), range 6-13	Cerebral palsy	Home	Home-based Wii Sports Resort training	12 wks	40 min, 3 x wk

Hilderley et al.	2020	20 (EG, n=11, CG, n=9) RCT	12.0 (2.6), range 8-17	Cerebral palsy	Therapy rooms or gymnasiums	Movement skills (e.g., run, jump, and kick) applied in a sports or athletics	6 wks	45 min, 2-3 x wk
Clutterbuck et al.	2020	54 (EG, n=29, CG, n=25) RCT	8.9 (2.0), range 6-12	Cerebral palsy	Community therapy centre	Soccer, netball, T-ball and cricket	8 wks	8 sessions: 60 min, 1 x wk
Ross et al.	2017	97 (51% males)	11.4 (3.1), range 6-18	Cerebral Palsy	Local community center	Swimming, tennis, dance, martial arts, basketball, soccer, baseball, and adaptive cycling.	6 wks	360 min, 5 x wk
Pourazar et al.	2018	30 (100% males) EG, (n=15; CG, n=15) RCT	11.2(0.8), range: 7-12 years	Cerebral palsy	Virtual Reality	Virtual Reality Games: Bowling and golf	4 wks	25 min, 3 x wk
Clutterbuck et al.	2022	54 (EG, n = 29; CG, n = 25) RCT	8.8 (2.0), range: 6-12 years	Cerebral palsy	Not reported	Physiotherapist-led, sports-specific gross motor activity training, sports education, teamwork development and confidence building for four sport: soccer, netball, T-ball and cricket	8 wks	8 sesions (8 hours: 60 min, 1 x wk)
Zoccolillo et al.	2015	22 (EG, n= 11; CG, n=11) cross--over RCT	6.9 (1.9), range: 4-14 years	Cerebral palsy	Outpatients clinic	Virtual Reality Games	8 wks	16 sessions (30 min): 2 x wk
Polat et al.	2020	44 (11 girls, and 33 boys) (EG = 22; CG = 22) quasi-experimental	7.8 (2.5), range: 4-11 years	Cerebral palsy	At home	Sport activity movements including basic gymnastic positions	8 wks	40 sessions: 50 min, 5 x wk

Feitosa et al.	2017	17 (70.6% male)	10.6 (1.7), range: 7–14 year	Cerebral palsy	Not reported	Adapted Sport: Swimming and seven a side soccer (soccer, n=11, swimming n= 4, soccer and swimming n=2)	1 year	Soccer (52 sessions); swimming (104 sessions) both (156 sessions)
Lai et al.	2022	58 (43% males) EG, n=29; CG, n=29) RCT	14.0 (3.0) range: 8-17 years	Cerebral palsy	At home (asynchronous training)	Music video movement	4 wks	12 sessions, 3 x wk
García-Gómez et al.	2013	16 (EG, n=8, CG, n=8). quasi-experimental	range 7-14	ASD	Horse center	Horse-riding	12 wks	60 min, 2 x wk
López-Diaz et al.	2021	15 (100% males)	8.6 (1.1), range 6-12	ASD	Community Sport setting	Soccer	8 months	60 min, 2 x wk
Morales et al.	2021	11 (64% males)	10.2 (2.4), range 9-13	ASD	Judo facility	Judo	8 wks	75 min, 1 x wk
Bo et al.	2019	9 (100% males)	9.2 (1.8), range 8-13	ASD	Community setting	Free play, ball games, Group instruction ball skills	2 wks	210 min, 5 x wk
Lee et al.	2020	19 (% males not reported)	9.3 (3.0), range not reported	ASD	Recreation center	Ball games and dances	8 wks	45 min, 2 x wk
Ewards et al.	2017	30 (EG, n=11, CG, n=19) RCT	range 6-10	ASD	Not reported	Kinect Sports Season 2 (Specific mini-games (e.g., baseball, golf, tennis, table tennis, soccer, bowling, volleyball, and football)	2 wks	45-60 min, 3 x wk

Wang et al.	2020	59 (EG, n=30, CG, n=29) quasi-experimental	5.1 (0.6), range 3-6	ASD	School	Mini-basketball	12 wks	40 min, 5 x wk
Pan et al.	2010	16 (EG, n=8, CG, n=8) quasi-experimental	7.2 (1.2), range 6-9	ASD	Local indoor hydrotherapy and swimming pool	Swimming	10 wks	90 min, 2 x wk
Guest et al.	2017	13 (0% males)	9.7 (1.0), range 8-11	ASD	Summer camp	Track and field, basketball, soccer, and baseball.	1 wk	Not reported
Yeung Any Tse et al.	2019	40 (EG, n=19, CG, n=21) RCT	9.9 (1.1), range	ASD	School gimnasium	Basketball	12 wks	45 min, 2 x wk
Fragala-Pinkham et al.	2011	12 (EG, n=7, CG, n=5) quasi-experimental	9.6 (2.6), range 6-12	ASD	YMCA	Swimming	14 wks	40 min, 2 x wk
Rafiei Milajerdi et al.	2021	60 (SPARK: 20; Kinect: 20; CG: 20). (95% males) RCT	8.2 (1.5), range: 6-10	ASD	Not reported	Sports, Play and Active Recreation for Kids (SPARK); exergaming Tennis (Kinect)	8 wks	24 sesions (14-hour intervention: 35 min), 3 x wk
Hassani et al.	2020	30 (66.7% male) (ICPL: 11; SPARK: 10; CG: 9) RCT	8.8 (0.8), range: 8-11 years	ASD	Indoor sessions	I Can have a physical literacy (ICPL); Sport, Play, and Active Recreation for Kids (SPARK)	8 wks	16 sessions (60 min): 2 x wk

Pan et al.	2017	32 (EG = 16; CG n = 16) RCT	8.9 (1.5), range: 6-12 years	ASD	multipurpose room at the university	Table tennis	12 wks	24 sessions: 70 min, 2 x wk
Pan et al.	2017	22 (EG, n= 11; CG, n=11) RCT	9.1 (1.7), range: 6-12 years	ASD	multipurpose room at the university	Table tennis	12 wks	24 sessions: 70 min, 2 x wk
Cai et al.	2020	29 (EG = 15, CG = 14) (86,2% males) quasi-experimental	4.9 (0.6) range: 3-6 years	ASD	Basketball Pitch	Mini-Basketball	12 wks	40 min, 5 x wk
Speyer et al.	2010	30 (60% males) Cross-over RT	13.6 (2.9), range 9-18	Cancer	Hospital facility	Ball games (Soccer, handball, volleyball), racket sports (Tennis, badminton, squash), fighting activities (English boxing, French boxing, fencing, karate), etc.	<4 wks	30 min, 3 x wk
Saultier et al.	2021	80 (EG, n=41, CG, n=39) RCT	10.4 (0.5), range 5-18	Cancer	In-hospital and outdoor activities.	Multi-activity sessions (dance, basketball, badminton, yoga, skiing, swimming, paddling, etc.)	3 wks + two weekend + long stay 5 days	90-240 min, 5 x wk
Hamari et al.	2019	36 (EG = 17; CG = 19) (72.2% male) RCT	7.8, range: 3–16 year	Cancer	Both during hospitalization and at home	Active video games - Nintendo WiiFit™ games	8 wks	56 sessions: 30 min, 5 x wk
Howell et al.	2018	78 (EG = 53, CG = 25) (44.9% males) RCT	12.7 (1.1), range: 11-15 years	Cancer	At home	Interactive website designed to encourage physical activity via rewards	24 wks	Voluntary

William et al.	2018	222 (EG = 117; CG = 105) RCT	12.6 (2.0); range: 9-16	Cancer	Campsite	Climbing, trampoline, Mini Olympics	4 days	4 sessions
Westergren et al.	2016	6 (67% males)	10.5 (0.5), range 10-12	Asthma	School gymnasium	Active play (e.g., ball and team games and games of 'tag'.	6 wks	60 min, 2 x wk
Hakim et al.	2022	70 (EG, n=35, CG, n=35) RCT	10.1 (1.4), range 8-12	Cystic Fibrosis	Not reported	cycling, swimming, walking, dancing, playing ball, skipping ropes, jumping, upper extremity stretching, and trunk and lower extremities (gymnastics)	1 wk	30-45 min, 4 sessions
Walker et al.	2003	95 (EG; n=57, CG, n=38) quasi-experimental	13.1 (3.4), range 9-18	Obesity	Summer Camp	skill-enhancing physical activity sessions	4 wks	60 min, 6 sessions
Cristian-Cosmin et al.	2022	28 (EG, n=14, CG, n=14) quasi-experimental	9.4 (1.0), range 8-11	Obesity	School gimnasium	Volleyball	24 wks	90 min, 3 x wk
Cvetković et al.	2018	42 (EG, n=14, EG2, n=14, CG, n=14) RCT	Range 11-13	Obesity	Outdoors on artificial grass	Football	12 wks	60 min, 3 x wk
Cliff et al.	2007	13 (36% males)	10.4 (1.2), range 8-12	Obesity	School	Six locomotor skills (run, gallop, hop, leap, horizontal jump, slide) and six object-control skills (two-handed t-ball strike, stationary dribble, catch, kick, overhand throw, underhand roll) in a fun and enjoyable context.	10 wks	120 min, 1 x wk

Griffin et al.	2013	43 (39% males)	10.4 (0.6), range 8-12	Obesity	University gimnasium	Swimming + physical education (e.g., balloon volleying with short-handled rackets, passing, dribbling, and trapping with a partner,	3 wks	45 min + 60 min, 5 x wk
Jette et al.	1977	21 (100% males) (EG, n=11; CG, n=10). quasi-experimental	15.3 Years	Obesity	High school facility	Lacrosse	20 wks	45 min aprox., 2 x wk
Korsten-Reck et al.	1994	62 (56.5 males)	10.3 (1.6) range 9-12 years	Obesity	Swimming Pool, Gymnastic hall	Swimming, gametype activities, rhythmic activities and endurance walking are included	24 wks	60 min, 3 x wk
Lofrano-Prado et al.	2022	72 (34 boys), (EG, n=37; CG, n=37) RCT	15.0 (1.0), range 13-18 Years	Obesity	Clinical setting	Team sports, circuit training, active games, and physical challenges	12 wks	60 min, 2 x wk
Seabra et al.	2016	88 (100%), EG, n=29; CG1, n=29; CG2, n=30 Quasy-experimental	10.3 (1.3) range 8-12 Years	Obesity	Local soccer club	Football	24 wks	60-90 min, 3 x wk

ADHD: Attention-Deficit/Hyperactivity Disorder; ASD: Autism Spectrum Disorder; EG: experimental group; CG: control group; RCT: randomized controlled trial. YMCA: Young Men´s Christian Association

Table 2. Physical and psychosocial outcomes, adverse events and adherence to the interventions included in the systematic review

Authors (year)	Study Popilation	Physical Outcomes	Psychosocial Outcomes	Instruments	Results	Adverse effects	Adherence
Verret et al. (2010)	ADHD	Aerobic capacity, flexibility, muscular endurance, Gross motor skills	Behavioral problems and social competences; Attention functions and response inhibition; Auditory sustained attention, divided attention	Test of Gross Motor Development-2, Bruce treadmill protocol, sit and reach test, push-up (maximum number) and sit-up (maximum in 60 s) tests. Child Behavior Checklist; Test of Everyday Attention for Children (Tea-Ch)	Increased muscular capacity as assessed by the number of push-ups. Motor skills (locomotion score and raw-motor-skills score), behaviour, and neuropsychological variables (information processing, and a better auditory, sustained attention)	Not reported	Not reported
Pan et al. (2016)	ADHD	Motor skills	Social behaviors and executive functions	Long form of the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), Child Behavior Checklist (CBCL), children's version of the Stroop Color and Word Test	Manual coordination, strength and agility, behavioral problems (social problems, attention problems, aggressive behaviors)	Not reported	89%
López-Willians et al. (2005)	ADHD	Strength/endurance, running speed,	Social behavior and peer relationships	Sit-ups, fifty-Yard Dash, Average Skill Scores, Peer Nominations.	Both athletic performance and social behavior were significant predictors in the social acceptance of children with ADHD	Not reported	Not reported
O´Connor et al. (2014)	ADHD	Athletic competence and Motor Proficiency		Different skill tasks, Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)	Improvements in sport knowledge and performance and in gross and fine motor skills	Not reported	Not reported

Pan et al. (2017)	ADHD	Aerobic capacity, flexibility, muscular endurance, Gross and fine motor skills		Bruininks–Oseretsky Test of Motor Proficiency, Second Edition (BOT-2), The 20-m progressive aerobic cardiovascular endurance run (PACER), isometric push-up, curl-up, and back-saver sit-and-reach tests from the Brockport Physical Fitness Test (BPFT)	Significant improvement in all BOT-2 and fitness measures: total motor composite score, all four motor composite scores (fine manual control, manual coordination, body coordination, strength and agility) and cardiovascular fitness. Balance and flexibility yielded medium effect sizes, and small effect sizes were observed regarding abdominal and upper body muscle strength and endurance	Not reported	Not reported
Ziereis and Jansen (2015)	ADHD	Motor performance. Static and dynamic balance.	Executive functioning. Working memory	The digit span (forwards/backwards) and the letter–number-sequencing task of the HAWIK – IV. The M-ABC 2	Significant main effects for digit-span, letter–number-sequencing, catching and aiming	Not reported	Not reported
Hupp and Reitman (1999)	ADHD	Dribbling and chooting test	Good sportsmanship, sport interest	Direct Observation of Game Performance. Basketball Interest Inventory (BII)	Participants would develop basketballskills, exhibit more sportsmanlike behavior, and become more interested in basketball by the end of the three-week camp	Not reported	Not reported
Gohr Månsson et al. (2019)	ADHD		Inattention, hyperactivity, and impulsivity; emotional and behavioral functioning (prosocial behavior and positive attributes; HRQoL	ADHD rating scale (ADHD-RSIV); Strengths-and-Difficulties-Questionnaire (SDQ); KIDSCREEN-27-total score	Significant beneficial effects on four of the eight secondary outcomes: parent-rated ADHD-RS-IV-total score, parent-rated SDQ-total score, QbTest™ measurements of the	Not reported	Not reported

					Reaction Time Variation (RTVar), and of Omission Errors		
Benzing & Schmidt (2019)	ADHD	Motor skills.	Executive functions (inhibition, switching, updating); inattention, hyperactivity, and impulsivity	Inhibition was assessed using a modified Simon Task; Switching was assessed using a modified Flanker task; Updating was assessed by a modified version of the color span backward task; ADHD symptoms were assessed using the German version of the Conners-3 scales; Motor ability was assessed using six out of eight test items of the German Motor Test.	Exergame intervention group improved in specific executive functions (reaction times in inhibition and switching), general psychopathology as well as motor abilities compared to control group	Not reported	There was a high dropout rate in the exergaming condition (n=6)
Kadri et al. (2019)	ADHD		Cognitive function (attentional inhibitory control and sustained and selective visual attention)	Stroop Color-Word Test, Ruff 2 and 7	Participants who received the program had a better cognitive performance in terms of selective attention than those in the control condition	Not reported	Not reported
Gercek et al. (2021)	Cerebral palsy	Aerobic capacity, flexibility, muscular endurance, balance, spasticity level, gross motor skills		Gross Motor Function Measure-88 , Modified Ashworth Scale, lateral step up, curl up, six-minute walk, sit and reach, Modified Thomas, and static balance tests	Decreased gastrocnemius and soleus spasticity. increase in sit-and-reach, lateral step-up, six min walk, and curl up test scores	Not reported	Not reported
Chiu et al. (2014)	Cerebral palsy	Coordination, strength, or hand function.		Tracking task, maximum voluntary isometric contraction, Hand function was measured using the Ninehole Peg Test and	Wii™ training did not improve coordination, strength, or hand function	No serious adverse events	Not reported

				the Jebsen–Taylor Test of Hand Function.			
Hilderley et al. (2020)	Cerebral palsy	Gross motor skills, aerobic capacity, lower limb strength,	Self-efficacy, goal achievement, child perceptions of goal performance and satisfaction	20-item Rasch-scaled Challenge, Canadian Occupational Performance Measure (COPM), Self-efficacy Scale, goal attainment scaling [GAS], 30 s lateral step-up and 6-min walk test (6MWT)	Sports skills training is an effective approach to promote advanced motor skill gains. COPM change scores and high programme enjoyment were significantly increased	None	90%
Clutterbuck et al. (2020)	Cerebral palsy	Functional mobility, Physical activity competence, strength	HRQoL	Children's motor function (GMFCS), Functional Mobility Scale (FMS), Test of Gross Motor Development-second edition (TGMD-2), Muscle Power Sprint Test (MPST), Timed Up and Go (TUG), running (10x 5 Meter Sprint Test (10x5mST), Cerebral Palsy Quality of Life- Child (CP QOL-Child)	Clinically significant improvements on self-identified sportsfocussed participation and activity level goals.	Modifications to activities were reported	>75%
Ross et al. (2017)	Cerebral Palsy	Mobility, cardiorespiratory fitness, flexibility, balance, walking speed, gross motor skills		Timed Up and Go, modified 6-min walk distance and 25-ft walk/run over time. Children in Gross Motor Classification System level III	Significant improvements in the Timed Up and Go, modified 6-min walk distance and 25-ft walk/run over time. Children in Gross Motor Classification System level III made the largest gains.	Not reported	Not reported

Pourazar et al. (2018)	Cerebral palsy	Motor skills	HRQoL	Simple Reaction Time (SRT) and Discriminative Reaction Time (DRT). General health questionnaire (GHQ).	Reaction Time measures significantly improved in experimental group following the VR intervention program	Not reported	Not reported
Clutterbuck et al. (2022)	Cerebral palsy	Physical competence; walking; running; jumping; throwing; sports participation	HRQoL	mCOPM activity goals and high-level gross motor batteries (Test of Gross Motor Development (TGMD-2); GMFM-Challenge) and walking (Timed-Up-and-Go), running (Muscle Power Sprint Test; 10x5m Sprint Test), jumping (Standing Broad Jump; Vertical Jump) and throwing (Seated Throw) items. General participation and quality of life were also measured	Sports Stars group improved sports participation and activity goals and sports-specific physical competence vs waitlist-control.	Not reported	Not reported
Zoccolillo et al. (2015)	Cerebral palsy	Motor skills		Quality of Upper Extremities Skills Test (QUEST). upper limb dissociated movements (of shoulder, elbow, wrist and fingers); grasp function, protective upper limb extension and weight bearing. 2. Visual-Motor Integration functioning scale (VIM) for hand abilities, and visual-motor integration	Virtual reallity improved the motor functions of upper limb extremities (increased quantity of limb movements), but failed in improving the manual abilities for performing activities of daily living which benefited more from conventional therapy	Not reported	Not reported
Polat et al. (2020)	Cerebral palsy	Gross Motor skills, Walk, Balance	Impact on Family	Impact on Family Scale (familial and social impact), Gross Motor Function Classification System, the Gross Motor Function Measure, One Minute Walk Test,	A significant difference was found only in the Visual Pain Analog Scale	Not reported	Not reported

				Time standing on the left and right foot			
Feitosa et al. (2017)	Cerebral palsy		HRQoL, biopsychosocial profile	QOL was evaluated by the Pediatric Outcome Data Collection Instrument (PODCI) and the biopsychosocial profile by the Behavior Checklist for Children/Adolescents (CBCL)	Significant improvement in the dimensions of transfers and mobility, upper extremity function and global function. significant improvement considering the attention disorder syndrome, and the attention deficit hyperactivity disorders	Not reported	Not reported
Lai et al. (2022)	Cerebral palsy		Enjoyment , HRQoL	Children's Assessment of Participation and Enjoyment (CAPE); The Neuro-QoL pediatric assessments	The qualitative findings highlighted 5 critical factors that influenced participants' adherence to the program: caregiver support, video elements, suitable exercises, music, and behavioral coaching	No	Mean adherence was 90% (44/49 min) in week 1, 83% (56/68 min) in week 2, and 69% (45/65 min) and 43% (40/95 min) in weeks 3 and week 4, respectively

García-Gómez et al. (2013)	ASD		Adaptive skills, social skills, leadership, withdrawal, anxiety, depression, behavioural problems, atypicality, aggressiveness, hyperactivity, attention problems, and somatization. HRQoL	Behavior Assessment System for Children" (BASC), Quality of life (ad hoc)	Significant improvements in aggressiveness, "Interpersonal relations" and "Social inclusion"	Not reported	Not reported
López-Diaz et al. (2021)	ASD	Motor skills	Social Skills	Ad Hoc instrument (lickert scale 1-5). The Goldstein Model identifies specific social skills and categorizes them into different domains, including verbal and nonverbal communication, problem-solving, emotional regulation, and interpersonal relationships	Improvement in both motor skills and social skills.	Not reported	Not reported
Morales et al. (2021)	ASD		Autism-related behaviors and social communication difficulties	Autism Rating Scale-Third Edition (GARS-3) scale	Significant improvements in repetitive behaviours, social interaction, social communication and emotional response	Not reported	Not reported
Bo et al. (2019)	ASD	Gross motor skills on locomotor and ball skills	Social communication skills and behaviors	The Test of Gross Motor Development-3 (TGMD-3; The Chinese version of Social Communication Questionnaire (SCQ)	Significant improvements on locomotor, ball skills, and overall TGMD scores	Not reported	Not reported

Lee et al. (2020)	ASD	Gross motor skills	Social Skills	Social Responsiveness Scale, 2nd edition (SRS-2), the Physical Activity Questionnaire for Older Children (PAQ-C), and the Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition (BOT-2)	Significant improvements in object-control skills for the participants	Not reported	Not reported
Ewards et al. (2017)	ASD	Gross motor skills	Perceived competence	Gross Motor Development-3 (TGMD-3), golf skill assessments, a golf swing and golf putt, The Pictorial Scale of Perceived Movement Skill Competence (PMSC)	no significant improvement in the actual OC skill scores, owever, improve their perceptions of competence	Not reported	Not reported
Wang et al. (2020)	ASD		Executive functions, Social Communication Impairment, Repetitive behaviors	Childhood Executive Functioning Inventory (CHEXI), Social Responsiveness Scale Second Edition (SRS-2), Repetitive Behavior Scale-Revised (RBS-R)	Significant improvement on working memory, on inhibition, on regulation, social communication and repetitive behavior	Not reported	Not reported
Pan et al. (2010)	ASD	Aquatic skill measures	Social behavior	The HAAR checklist, School Social Behavior Scales (SSBS–2)	Significant social improvements were seen together with aquatic skills in the participants	Not reported	Not reported
Guest et al. (2017)	ASD	Gross motor skills	Physical self-perceptions, Social and adaptive behaviour	The Test of Gross Motor Development (TGMD-2), Children and Youth Physical Self-Perception Profile (CY-PSPP), The Children's Self-Perceptions of Adequacy in and Predilection for Physical Activity (CSAPPA), Social Skills Improvement System (SSIS), The Vineland	Motor skills significantly improved, as well as physical self-perceptions and self-efficacy of sport ability, and social skills following the intervention	Not reported	Not reported

				Adaptive Behaviour Scales, 2nd edition (VABS-2)			
Yeung Any Tse et al. (2019)	ASD		Social responsiveness and social communication skills; response inhibition and impulsivity; Executive functions (inhibition control and working memory)	Social Responsiveness Scale (SRS-2), Corsi block tapping task (CBTT), GNG task,	Positive influences of physical activity on sleep quality and inhibition control	Not reported	97.8%
Fragala-Pinkham et al. (2011)	ASD	Swimming skills, Muscle endurance, Mobility skills	Satisfaction	YMCA Water Skills Checklist, modified, Multidimensional Paediatric Evaluation of Disability Inventory Mobility scale (M-PEDI), curl-up and isometric push-up tests, programme satisfaction questionnaires	Improvements for swimming skills	no injuries or adverse events were reported	79-100%
Rafiei Milajerdi et al. (2021)	ASD	Motor skills	Executive functions	Movement Assessment Battery for Children-Second Edition (MABC-2); Wisconsin Card Sorting Test (WCST)	MS: SPARK group improved significantly from pre- to post-test compared with the other groups in aiming and catching. EF: Kinect group showed more correct responses than the SPARK and control groups	Not reported	Not reported
Hassani et al. (2020)	ASD	Motor skills; Running speed and agility, balance,		BOT test of Motor Proficiency (measure of gross and fine motor skills). Running speed and	ICPL and Spark groups had increased MS. Significant differences between groups on	BOT test: response speeds	Not reported

		bilateral coordination, and strength		agility, balance, bilateral coordination, and strength). Fine MS (response speed, visual motor control, upper –limb speed and dexterity), and upper limb coordination	gross MS. There were significant differences between the control and ICPL groups, and between the experimental Spark and experimental ICPL groups	were not recorded	
Pan et al. (2017)	ASD	Motor skills	Executive function; social behavioural masures	Motor skill proficiency BOT-2; executive function: computer version of the Stroop Test. Child Behavior Checklist (CBCL)	EG significantly exhibited improvements in motor skill proficiency (the total motor composite and two motor-area composites) and executive function (three indices of the Wisconsin Card Sorting Test). The effectiveness appeared to have been sustained for at least 12 weeks	Not reported	The excellent program adherence (88%–90%) and no dropout from the interventio n confirmed that it was feasible for children with ADHD to complete.
Pan et al. (2017)	ASD	Motor skills	Executive function	Motor skill proficiency; BOT-2; executive function: computer version of the Wisconsin Card Sorting Test (WCST)	EG significantly exhibited improvements in motor skill proficiency (the total motor composite and two motor-area composites) and executive function (three indices of the Wisconsin Card Sorting Test). The effectiveness appeared to	Not reported	Not reported

					have been sustained for at least 12 weeks		
Cai et al. (2020)	ASD	Physical fitness (Running speed and agility, balance, flexibility, and strength)	Social Responsiveness	The 2×10 meter shuttle run test for speed-agility, standing long jump tests for muscular strength, the sit-and-reach test for flexibility and the balance beam test for balance. Social Responsiveness Scale—Second Edition (SRS-2)	A combined cognitive and physical training program, improved social communication and white matter integrity among ASD children	Not reported	Not reported
Speyer et al. (2010)	Cancer		HRQoL	Child Health Questionnaire (CHQ)	Physical functioning, role/social-physical, self-esteem, and mental health dimensions improved	Not reported	Not reported
Saultier et al. (2021)	Cancer	Aerobic capacity, flexibility, balance, upper and lower limb strength and muscle endurance	Self-esteem; HRQoL	six-minute walk test (6 MWT), sit-and-reach test, flamingo balance test, medicine-ball launch, Chair test, and sit-up score. PSI-VSF: Physical Self-Inventory, VSP-A: Vécu et Santé Perçue de l'Adolescent et de l'enfant.	Improved exercise capacity, self-esteem, and QoL were also improved	No adverse event occurred	Not reported
Hamari et al. (2019)	Cancer	Motor skills		Motor performance was estimated using the Movement Assessment Battery for Children-2 (M-ABC2) test. Experiences and fidelity of the intervention were examined with an interview	No differences between the intervention and control group in PA, motor performance, or fatigue	Adverse effects were not reported	Not reported

Howell et al. (2018)	Cancer	Handgrip strength, lower-limb strength	Neurocognitive General intelligence, Executive Function, HRQoL	Jamar hand held dynamometer, full sit ups and either a knee or full pushup for 30 seconds, Wechsler Abbreviated Scale of Intelligence (WASI), Delis-Kaplan Executive Function System (D-KEFS), Pediatric Quality of Life Inventory (PedsQL)	Hand grip strength, number of sit-ups and pushups, neurocognitive function, and HRQoL outcomes improved in the intervention, but not in the control group	Not reported	Not reported
William et al. (2018)	Cancer		Self-efficacy, HRQoL	Self-efficacy was assessed using the Physical Activity Self-Efficacy scale (PA-SE); Chinese version of the Paediatric Quality of Life Inventory (PedsQL)	The experimental group showed statistically significantly higher levels of self-efficacy ($P < 0.001$), and better quality of life ($P < 0.01$) than the control group at 12 months	Not reported	Not reported
Westergren et al. (2016)	Asthma	Lung function, Cardiorespiratory fitness	HRQoL	FEV1, VO2max during maximal treadmill running, Paediatric Asthma Quality of Life Questionnaire (PAQLQ)	Children perceived that their fitness and asthma had improved, and reported increased HRQoL	Not reported	90%
Hakim et al. (2022)	Cystic Fibrosis		HRQoL	Pediatric Quality of Life Inventory (PedsQL)	Improvement in physical function	Not reported	Not reported
Walker et al. (2003)	Obesity		Self-esteem,Self-Perception, worries,	The Self-Perception Profile for Children (SPPC), The Salience of Weight-Related Issues Scale, The Pictorial Figure Silhouette Scale	Body shape dissatisfaction significantly decreased and self-esteem improved. Global self-worth had increased by the end of the camp, as had athletic competence and physical appearance esteem	Not reported	Not reported

Cristian-Cosmin et al. (2022)	Obesity	Physical fitness (balance, running speed – agility, speed of limb movement, trunk strength, explosive power)		Physical fitness (EUROFIT: balance (Flamingo balance), running speed – agility (Shuttle run: 10 x 5 metres), speed of limb movement (Plate tapping), trunk strength (Sit-ups), explosive power (Standing broad jump)	Significant improvement in fitness and body composition	Not reported	Not reported
Cvetković et al. (2018)	Obesity	Muscular fitness (lower-body power, change-of-direction speed, and flexibility), and cardiovascular fitness		Agility t test, CMJ, Sit and reach, Yo-Yo Intermittent Endurance test	Significant pre-to post improvements in intermittent exercise and change-of-direction speed and a significant lowering of maximal HR	Not reported	Not reported
Cliff et al. (2007)	Obesity	Motor skills, lower-limb muscle strength	Perceived competence	Test of Gross Motor Development (TGMD-2), Self-Perception Profile for Children (SPPC); rising to stand from a chair	Motor development and perceived competence increased significantly	Not reported	91%
Griffin et al. (2013)	Obesity		Enjoyment and Commitment	Commitment to Physical Activity Scale (CPAS)	Significant difference in participants' enjoyment of and commitment to physical activity.	Not reported	Not reported
Jette et al. (1977)	Obesity	Physical work capacity test (V02 max was predicted)	Self image Concept and personality	A progressive cycleergometer exercise test. Self Concept Test, IPAT 16 Personality Factors, Eysenck Personality Inventory, Mooney Problem Check List, Draw Self-Person List, and The	Decreases in resting and exercise heart rates and increases in physical work capacity. There were no measurable changes in personality assessment	Not reported	Not reported

				Minnesota Multiphasic Personality Inventory-2 (MMPI-2)			
Korsten-Reck et al.(1994)	Obesity	Physical performance (spiroergometry)		Physical examination, spiroergometry	Improvements in performace capacity	Not reported	Not reported
Lofrano-Prado et al. (2022)	Obesity	Aerobic capacity, resistance and strength, flexibility, coordination, and agility	Self image Concept; depressive symptoms; HRQoL	Body Shape Questionnaire (BSQ), Binge Eating Scale (BES), Eating Attitudes Test (EAT), Beck Depression Inventory (BDI), Pediatric QoL Inventory (PedsQL)	Both interventions were effective in improving quality of life, symptoms of depression, bulimia and binge eating	Not reported	75%
Seabra et al. (2016)	Obesity	Cardiorespiratory fitness (VO2max)	Perceived psychological status; Self-esteem; self-perception; HRQoL	Ttreadmill exercise test;A reduced version of the children's attraction to physical activity scale; self-esteem scale of Rosenberg; The self-perception profile for children; The Pediatric Quality of Life Inventory version 4.0	Improvements in several indicators of health status among obese boys. Soccer has the potential as an effective tool for the prevention and reduction of childhood obesity	Not reported	Not reported

HRQoL: Health-related quality of life.

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