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Physical Capacity in Children with Down Syndrome: A Narrative Review

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Abstract

Background: Down syndrome is the most common chromosomal aberration, characterized by widespread developmental challenges including motor delays, muscle hypotonia, and reduced physical capacity. Physical limitations are frequently compounded by congenital heart defects, occurring in nearly 50% of individuals with Down syndrome, which further compromise exercise tolerance and quality of life. Despite the clinical significance of physical capacity in this population, research specifically addressing children aged 14 years and younger remains limited.

Aim: This narrative review synthesizes current evidence on physical capacity in children with Down syndrome aged 14 years and younger, focusing on cardiorespiratory fitness, muscle strength, motor coordination, and executive function. The objective is to identify effective therapeutic interventions and provide recommendations for optimizing functional independence and quality of life in this population.

Material and Methods: A comprehensive literature search was conducted using PubMed and Google Scholar electronic databases, limited to studies published within the last five years. Inclusion criteria were restricted to participants aged 14 years and younger. Search terms included 'Down syndrome', 'children', 'pediatric', 'exercise tolerance', 'cardiorespiratory fitness', 'physical capacity', and 'functional capacity'. Eight studies met the inclusion criteria and were included in this review.

Results: Targeted respiratory interventions, including proprioceptive neuromuscular facilitation (PNF) and inspiratory muscle training (IMT), combined with aerobic exercise significantly improve respiratory muscle strength (maximal inspiratory pressure and expiratory pressure), chest wall expansion, and walking capacity in children with Down syndrome. However, children with Down syndrome demonstrate substantially reduced walking capacity compared to typically developing peers (mean difference of 105.6 m in the 6-minute walk test), directly limiting physical, social, and school functioning. Motor deficits extend beyond basic strength impairments to include compromised sensorimotor integration and impaired postural control under dual-task conditions, with motor dual-task costs ranging from -57.3% to -167% depending on cognitive load. Higher body mass index correlates strongly with reduced gross motor skill proficiency ($r=-0.729$, $p<0.001$). Directed sport training effectively improves lower and upper limb strength, dynamic balance, and core stability.

Conclusions: Physical capacity limitations in children with Down syndrome result from a complex interplay of respiratory weakness, impaired motor-cognitive integration, and weight-related factors. Effective therapeutic approaches require structured respiratory training combined with aerobic exercise, domain-specific motor and cognitive interventions recognizing independent developmental trajectories, and integrated weight management strategies. Sport-based or task-oriented training programs show promise for enhancing functional capacity and quality of life. Future research should examine long-term developmental trajectories and the efficacy of multimodal interventions, particularly in younger age groups.

Keywords: Down syndrome, physical capacity, cardiorespiratory fitness, motor coordination, respiratory function, children, exercise training

1. Introduction

Down syndrome (DS), the most common chromosomal aberration in humans, is associated with a broad spectrum of developmental challenges, encompassing the cognitive, motor, and physiological domains. Children with trisomy 21 demonstrate common delays in achieving developmental milestones, including sitting, speech, running, and adaptation(Baumer et al., 2024). The characteristic motor phenotype in this population includes muscle hypotonia, which results in excessive joint mobility and weakened muscle strength, directly translating into deficits in postural balance and motor coordination (Brugnaro et al., 2022; Rodríguez-Grande, Vargas-Pinilla, et al., 2022). These problems manifest already in early childhood (0-3 years), delaying the acquisition of fundamental skills, such as independent walking, which in turn determines the subsequent level of functional independence. Simultaneously, according to a 2022 meta-analysis, evidence for the effectiveness of exercise therapy in improving motor skills in this age group is weak (Baumer et al., 2024; Rodríguez-Grande, Buitrago-López, et al., 2022).

One of the most significant factors limiting physical capacity in this patient group is congenital heart defects (CHD), which occur in nearly 50% of individuals with Down syndrome. The most frequently encountered anomaly is an atrioventricular septal defect (AVSD). Although advances in cardiac surgery have significantly improved survival rates, these individuals remain at risk for developing pulmonary hypertension and other hemodynamic complications, which may permanently reduce exercise tolerance (Dimopoulos et al., 2023). Physical capacity is inextricably linked to cardiovascular fitness, and endurance training plays a key role in optimizing physiological processes and exercise adaptation. Regular physical activity not only improves oxygen parameters but also constitutes an important element in the prevention of heart disease and lipid disorders, which is particularly important in populations at cardiovascular risk (Charzewski & Starzyk, 2025).

Given the complexity of the somatic and functional conditions in trisomy 21, the purpose of this narrative review is to synthesize current knowledge on physical capacity in children with Down syndrome. The work focuses on assessing components of cardiorespiratory fitness, muscle strength, and coordination, while identifying effective therapeutic interventions that may improve the quality of life of this patient group. The selection of the age group up to 14 years was prompted by the need to fill a research gap concerning this developmental stage, which-although crucial for shaping advanced motor abilities before the puberty period-remains insufficiently explored in the literature.

2. Material and methods.

A comprehensive literature search was conducted using the PubMed and Google Scholar electronic databases. To ensure the current relevance of the findings, the review was limited to studies published within the last five years (from 01.01.2021 to 01.11.2025). The inclusion criteria were restricted to participants aged 14 years and younger. This specific age cutoff was selected to address the current paucity of research in this developmental stage, which deserves

particular attention. The search strategy utilized the following keywords and phrases: 'Down syndrome', 'children', 'pediatric', 'exercise tolerance', 'cardiorespiratory fitness', ‘physical capacity’, and 'functional capacity'. Ultimately, a total of 8 studies met the inclusion criteria and were included in this review.

3. Results

A summary of the eight studies included in this narrative review, encompassing their study design, sample characteristics, assessment tools, and intervention duration, is presented in Table 1. Figure 1 presents a graphical representation of the thematic classification of the studies.

Study, Year	N (DS/Total)	age of children with DS (y)	Study Type	Primary Outcome	Assessment Tools	Duration (weeks)
(Elshafey & Alsakhawi, 2022)	40/40	7-10	RCT	Respiratory function	MIP, MEP, 6MWT	12
(Mohamed et al., 2021)	45/45	10-13	RCT	Respiratory function	Respiratory Pressure Meter, Ratio of upper to lower chest wall	12
(Klotzbier et al., 2022)	12/36	8-12	Comparative	Motor & cognitive	MABC-2, TMT	N/A
(Klotzbier et al., 2020)	12/36	8-12	Comparative	Motor & cognitive	Trail Walking Test (TWT)	N/A
(Yılmaz & Mirze, 2024)	22/72	7-11	Comparative	Physical fitness	Various fitness tests	N/A
(Mahnoor et al., 2024)	169/169	6-11	Cross-sectional	Physical fitness	SAMU-DISFIT, TGMD-2	N/A
(Alhammad et al., 2024)	30/68	6-12	Cross-sectional	Walking capacity	6MWT, PedsQL	N/A
(Puszczałowska-Lizis et al., 2025)	60/60	11-13	Cross-sectional comparative	Physical performance in trained vs untrained boys with DS	Eurofit Special Test battery	N/A

Table 1. Characteristics of Included Studies on Physical Capacity in Children with Down Syndrome

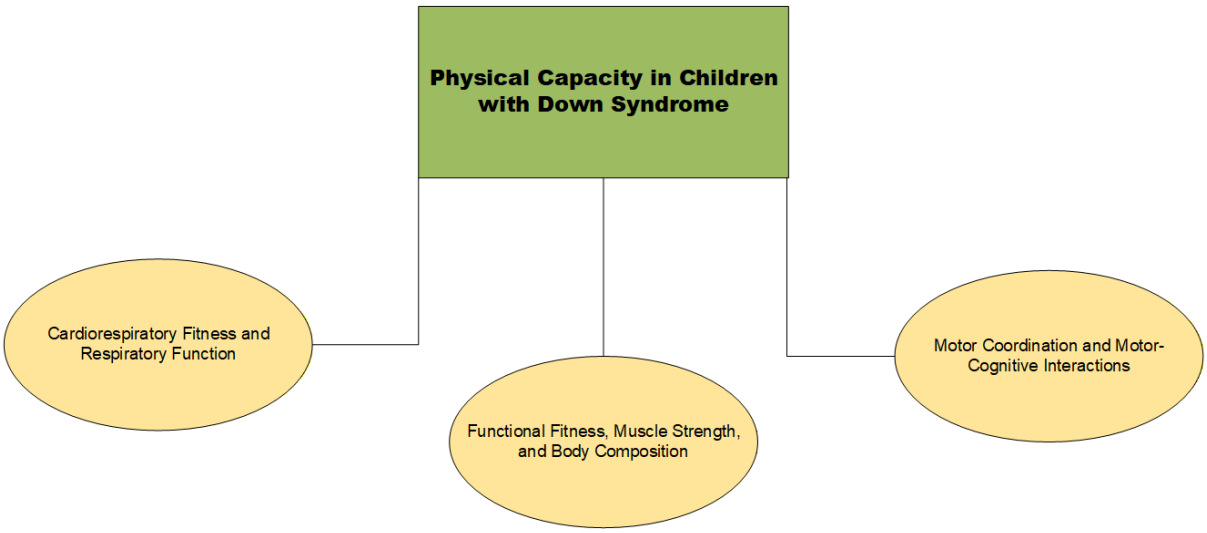

Fig. 1. Conceptual framework of physical capacity domains in children with Down syndrome.

3.1 Cardiorespiratory Fitness and Respiratory Function

Cardiorespiratory fitness and respiratory function constitute key components of physical fitness in children with Down syndrome, and their limitations result, among other factors, from muscle hypotonia and anatomical abnormalities of the chest wall.

Mohamed et al. conducted a randomized controlled trial (RCT) with 45 children with DS aged 10-13 years, comparing the effectiveness of two respiratory rehabilitation methods: Proprioceptive neuromuscular facilitation (PNF) of respiratory muscles in group A and Respiratory muscle training (RMT) in group B, with a third group serving as control (C) (Mohamed et al., 2021) . All children additionally performed aerobic exercises on a cycle ergometer for 12 weeks (5×/week, 20 min/session). The results showed that both methods significantly improved respiratory muscle strength-maximum inspiratory pressure (MIP) and expiratory pressure (MEP), chest wall expansion, spirometric parameters (VC, FEV_1, PEFR, MVV), and the distance covered in the 6-minute walk test (6MWT). Group C also demonstrated improvement in these parameters, however without significant difference in FEV_1 and MVV. A comparison of the results of both groups is presented in Table 2. The authors explain the higher efficacy of PNF by the combined action of quick stretching and resistance, as well as stimulation of muscle mechanoreceptors compared to resistance alone to the respiratory muscles in IMT.

Elshafey and Alsakhawi, in an analogous 12-week RCT, confirmed these observations, examining the additive effect of IMT to aerobic exercises (Elshafey & Alsakhawi, 2022). Forty children with Down syndrome were divided into two groups—A performed aerobic exercise only, while B additionally performed IMT, 3 times a week for 30 minutes. Group B achieved significantly greater gains in MIP, MEP, 6MWT distance, and muscle strength and endurance tests (curl-up, dumbbell press, trunk lift, standing long jump) compared to the group performing aerobic exercise alone; detailed results are provided in Table 2. Importantly, improvement in

respiratory function translated to overall physical fitness; the authors suggest that strengthening respiratory muscles may have such an effect through increased core stability in these patients.

Alhammad and colleagues, in a cross-sectional study, compared walking capacity (6MWT) and quality of life in 30 children with DS (6-12 years) and 38 typically developing (TD) children from Saudi Arabia (Alhammad et al., 2024). Children with DS covered an average of 262.7 m on the 6MWT, which was significantly less than in TD peers (368.3 m, mean difference = 105.6 m, $p<0.001$). After controlling for age, height, body weight, and BMI, reduced walking capacity in children with DS was independently associated with worse results on the PedsQL quality of life scale ($\beta=-2.71$, $p<0.001$), particularly in the domains of physical functioning ($\beta=-2.29$), social functioning ($\beta=-2.40$), and school functioning ($\beta=-3.71$). This study illustrates that reduced aerobic capacity directly limits the physical, social, and functional participation of children with DS.

Study, Study Group	MIP (cmH_2O) Before and After Intervention	MEP (cmH_2O) Before and After Intervention	6MWD (m) Before and After Intervention
(Mohamed et al., 2021), group A	44.26±3.43 vs 56.73±5.02	41.86±2.85 vs 55±4.15	301.20±14.71 vs 338.06±12.90
(Mohamed et al., 2021), group B	44.73±2.93 vs 53.26±3.34	42.46±2.55 vs 51.06±3.53	307.06±12.20 vs 325.66±8.58
(Elshafey & Alsakhawi, 2022), group A	86.45±5.54 vs 96.95±6.46	80.1±3.24 vs 90.95±3.79	237.6±29.34 vs 253.8±18.48
(Elshafey & Alsakhawi, 2022), group B	86.9±5.90 vs 109.55±8.02	80.4±3.10 vs 104.8±8.15	235.9±22.43 vs 267.3±19.24
(Alhammad et al., 2024), children with DS	-	-	262.7*

Table 2. Changes in Respiratory Function and Walking Capacity Following Respiratory Muscle Training and Aerobic Exercise in Children with Down Syndrome

*No intervention

3.2 Functional Fitness, Muscle Strength, and Body Composition

Functional fitness in children with DS encompasses components of muscle strength, endurance, power, flexibility, and body composition. In this subsection, three cross-sectional studies are

discussed, which provide comparative data and analyze factors conditioning physical fitness in this population.

Puszczałowska-Lizis et al. compared physical fitness in 30 boys with DS engaged in soccer training (3×/week for approximately 2 years, age 11.7±0.7 years) with 30 untrained peers with DS (Puszczałowska-Lizis et al., 2025). The Eurofit Special test battery was used for assessment, comprising: Standing Long Jump (lower limb strength), Seated Forward Bend (flexibility), 2 kg Medicine Ball Forward Push with one hand (upper limb strength), 25 m Run from a High Start (speed), Bent Knee Sit-ups in 30 seconds (endurance), and Walking on a Gymnastic Bench in the Upright Position (dynamic balance). Young soccer players achieved significantly better results in long jump, dashes, ball throws, and balance tests, whereas in the 25 m run the untrained group proved to be faster, all results were statistically significant. The authors suggest that soccer training improves primarily dynamic balance, lower and upper limb strength, and trunk muscles, which are key during play (changes of direction, kicks, ball control). The reason for the results on short distances may be the characteristics of soccer training, which translate to high speed during actual play but not necessarily in tests conducted solely on short distances. Interestingly, neither age nor BMI correlated with test results in either group, and training did not affect flexibility in young soccer players.

Yilmaz and Mirze conducted a comparative study of three groups: 22 individuals with DS, 18 with autism spectrum disorder (ASD), and 32 with moderate intellectual disability (ID) (Yılmaz & Mirze, 2024). BMI, Flexibility (sit and reach) test, Standing long jump, and medicine ball throwing were assessed. In standing long jump, the DS group achieved a rank average of 38.02, indicating higher results than the ASD group (23.92). Interestingly, no statistically significant differences were observed in flexibility and sitting height. The DS group achieved the lowest results in the remaining tests: Arm span length (rank avg. 24.16 vs 43.86 in the ASD group and 40.84 in the ID group) and medicine ball throwing (29.77 vs 30.08 in the ASD group and 44.73 in the ID group).

Mahnoor et al., in the largest sample, examined the relationships between BMI, physical fitness assessed by the SAMU Disability Fitness Battery (SAMU-DISFIT), and motor skills measured by TGMD-2 (Total Gross Motor Development-2 test),(Mahnoor et al., 2024). SAMU-DISFIT included assessment of body composition, motor fitness, and musculoskeletal fitness (which includes deep trunk flexibility, right hand grip strength, left hand grip, 30-second sit-up, 10 timed stand test) and cardiorespiratory fitness (which includes the 6-minute walk test). With a mean BMI of 21.24 and waist circumference of 61.33 cm, the results revealed a statistically significant negative correlation of BMI with agility (r=-0.263 for Timed Up & Go) and gross motor quality (r=-0.729), but a positive correlation with trunk flexibility (r=0.644) and hand grip strength (r=0.559 for right hand and 0.484 for left hand). The authors emphasize the problem of reduced cardiovascular and muscular fitness in children with Down syndrome and recommend frequent screening for overweight and obesity to counteract their negative effects. The further section covering TGMD-2 results is found in Section 3.3.

3.3 Motor Coordination and Motor-Cognitive Interactions

The specificity of motor deficits in DS is not limited to strength or endurance, but also includes higher functions of sensorimotor integration, postural control under dual-task conditions, and coordination of complex motor sequences. In this subsection, two studies by Klotzbier et al. and coordination aspects from Mahnoor et al.'s work are discussed.

Klotzbier et al. (2020) examined cognitive function in relation to motor demands in 12 children with DS compared with two control groups: 12 chronologically age-matched children (TD-CA) and 12 mentally age-matched children (TD-MA, 5.50±1.24 years) (Klotzbier et al., 2020). The Trail-Walking Test (TWT) was used to assess dual-task performance. In this test, 15 cones with flags were randomly placed around a 4-meter square, with a circle drawn around each cone. In the first stage of the test, participants walked along a line connecting all points; in the next stage, they stood on designated targets in the proper sequence; finally, they stood on targets in a sequence consisting of numbers and letters starting with 1-A-2 and ending with 8. Time and accuracy were assessed. Children with DS were significantly slower than TD-CA in all TWT conditions, but no significant differences were found compared to the TD-MA group in dual-task conditions, indicating comparable attentional resources to younger children. Under dual-task conditions, children with DS showed greater motor interference than cognitive interference, particularly in the high cognitive load condition (numbers & letters). In the low cognitive load condition (TWT-2), motor dual-task cost (DTC) was -57.3% while cognitive DTC was +44.6% for children with DS. In the high cognitive load condition (TWT-3), motor DTC increased substantially to -167%, while cognitive DTC was minimal at -8.97%.

In a subsequent cross-sectional study, Klotzbier et al. (2022) assessed correlations between motor performance (MABC-2: Movement Assessment Battery for Children-2) and executive functions (Trail-Making Test, TMT) in the identical group division (n=12 DS, 12 TD-CA, 12 TD-MA) (Klotzbier et al., 2022). Children with DS demonstrated significantly lower motor performance across all dimensions of the MABC-2 compared to both chronologically and mentally age-matched controls ($p<0.001$), with most falling into the "red zone" (≤5th percentile) indicating motor delays. Executive function performance assessed via the Trail-Making Test revealed severe difficulties with cognitive flexibility (TMT-B: M=128 s) in children with DS compared to controls. A crucial finding is that children with Down syndrome exhibit fundamentally different developmental trajectories where motor and cognitive domains show weak interdependence, requiring domain-specific tests for measuring motor and cognitive abilities

In the further section of Mahnoor et al.'s study, the Total Gross Motor Development-2 (TGMD-2) assessment revealed a gross motor quotient (GMQ) standard score of 6.20±1.00 and a strong negative correlation with BMI of -0.729 ($p<0.001$), indicating that higher BMI is significantly associated with lower gross motor skill proficiency (Mahnoor et al., 2024). Analysis by BMI categories showed that underweight children exhibited a negative correlation of -0.314 ($p=0.046$), while normal weight children showed a stronger negative correlation of -0.466 ($p<0.001$), demonstrating that increased body weight adversely affects fundamental motor skill performance in children with Down syndrome.

4. Discussion

This narrative review synthesized current evidence on physical capacity in children with Down syndrome aged 14 years and younger, examining cardiorespiratory fitness, muscle strength, motor coordination, and executive function—domains critical for functional independence and quality of life in this population.

The review reveals that targeted respiratory interventions (PNF and IMT) combined with aerobic exercise significantly improve respiratory muscle strength, chest expansion, and walking capacity in children with DS (Elshafey & Alsakhawi, 2022; Mohamed et al., 2021). These improvements translate to better overall physical function and quality of life, with aerobic training demonstrating effects comparable to typically developing peers when adjusted for age. However, children with DS demonstrate substantially reduced walking capacity compared to typically developing children, directly limiting their physical, social, and school functioning (Alhammad et al., 2024).

Motor deficits in children with DS extend beyond basic strength and endurance impairments to include compromised sensorimotor integration, impaired postural control under dual-task conditions, and difficulty coordinating complex motor sequences. Under cognitively demanding tasks (such as simultaneous walking and number sequencing), children with DS prioritize cognitive processing at the expense of motor performance, demonstrating motor dual-task costs ranging from -57.3% to -167% depending on cognitive load. Critically, motor and cognitive impairments follow largely independent developmental trajectories rather than common pathways, with weak correlations between motor performance and executive function, indicating that improvements in one domain do not necessarily transfer to the other (Klotzbier et al., 2020, 2022).

The evidence additionally demonstrates that weight status significantly influences motor skill proficiency in children with DS, with higher BMI correlating strongly with reduced gross motor quotient scores ($r=-0.729$, $p<0.001$) and impaired agility (Mahnoor et al., 2024). While this relationship is not unexpected, it underscores the importance of monitoring and managing body composition alongside targeted motor interventions. Directed sport training (such as football) effectively improves lower and upper limb strength, dynamic balance, and core stability, though notably does not enhance linear speed (Puszczałowska-Lizis et al., 2025).

Study Limitations

Several limitations should be considered when interpreting the findings of this review. First, the limited number of included studies (n=8) and heterogeneous methodologies, outcome measures, and intervention protocols preclude definitive conclusions and meta-analytic synthesis. Second, most studies employed relatively small sample sizes, particularly the Klotzbier et al. investigations (n=12 per group), limiting statistical power and generalizability to broader pediatric populations. Finally, the restriction to studies published within the last five years in English-language databases may have excluded relevant research in other languages or older foundational studies. Despite these limitations, the reviewed evidence provides valuable

insights into physical capacity in children with Down syndrome and identifies directions for future research.

5. Conclusions

In summary, physical capacity limitations in children with Down syndrome reflect a complex interplay of respiratory weakness, impaired motor-cognitive integration, and weight-related factors. Effective therapeutic approaches require structured respiratory training combined with aerobic exercise to improve cardiorespiratory function and walking capacity, domain-specific motor and cognitive interventions that recognize the independent development of these systems, and integrated weight management strategies within physical activity programs to prevent obesity-related performance decline. Sport-based or task-oriented training programs that improve functional strength and dynamic balance in ecologically valid contexts show promise for enhancing daily functional capacity.

Future longitudinal research should examine long-term developmental trajectories and the efficacy of multimodal interventions tailored to individual motor-cognitive profiles, particularly in underrepresented younger age groups. Early identification of motor delays and timely intervention during critical developmental windows (ages 6-10 years) may optimize functional independence and social participation trajectories in children with Down syndrome.

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