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Review article

The Role of Game-Based Interventions in Developing Fundamental Movement Skills in Down Syndrome

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Abstract: This scoping review aimed to examine the role of game-based interventions in developing fundamental movement skills (FMS) among individuals with Down syndrome (DS) and to identify their relevance to pediatric rehabilitation. A scoping review was conducted using Scopus, ScienceDirect, Springer Nature Link, and Google Scholar. Following screening, eligibility assessment, and reviewer consensus, 12 studies published between 2019 and 2025 were included in the final synthesis. The findings suggest that game-based interventions may contribute to im-provements in balance, locomotor skills, object control, coordination, visual-motor integration, and lower-limb function. Four intervention models were identified: structured play-based exercise, adapted sports games, exergames/virtual reali-ty, and serious games. Intervention outcomes appeared to be influenced by duration, intensity, supervision, task speci-ficity, and accessibility. Several studies also reported cognitive, motivational, and behavioral benefits that may support participation and engagement. Game-based interventions represent a promising rehabilitation-oriented approach that may support motor development, functional mobility, and independence in individuals with DS. How-ever, the available evidence remains limited and heterogeneous. Further high-quality longitudinal studies are needed to establish optimal intervention parameters and long-term effectiveness.

Keywords: game-based interventions, Down syndrome, fundamental movement skills,

1. Introduction

Down syndrome (DS) is a genetic disorder that results in suboptimal intellectual growth. Children with DS have impaired motor development. This delay is produced by physiological conditions such as hypotonia and hypermobility of joints, as well as physical structures that impact movement stability and body control [1] . It becomes more difficult to perform basic motor skills, including walking, running, jumping, turning, and bending, as well as complex movements like kicking, catching, and throwing.

Fundamental movement skills (FMS) are required for involvement in school learning and physical activity with peers [2]. Children with Down syndrome are more likely to become obese and have cardiovascular diseases as they grow older [3]. As a result, FMS for children with DS is not only concerned with school but also with daily activities, as well as with increasing self-confidence and independence. Enjoyable physical activity is one option. Game-based activities are components of play that aim

to improve fundamental movement skills. These activities are packaged in an engaging and ecologically friendly manner, allowing children with DS to explore their experiences.

Fundamental movement skills (FMS) are essential for motor recovery, functional mobility, involvement, and long-term independence in children with Down syndrome from the standpoint of rehabilitation. Limitations in activities of daily living (ADL), school involvement, and community engagement are often caused by deficiencies in balance, locomotor skills, postural control, coordination, and object handling. As a result, task-oriented, repetitive, and motivating methods that promote motor learning and functional skill acquisition are becoming more and more important in pediatric rehabilitation and physiotherapy therapies. Because game-based therapies incorporate controlled motor practice with feedback, incentive, social engagement, and customized task progression, they may be useful rehabilitation techniques in this setting.

Game-based activities might enhance motivation and motor skills [4] . Children with DS are naturally quite active, and engaging game activities allow for maximal active engagement. Lastly, direct feedback is provided, allowing children to respond to their actions and feelings. Children with DS require solutions through entertaining activities that use an appropriate gaming approach. Yet, this possibility has not been generally acknowledged in earlier studies.

Despite their frequent interchangeability, the phrases "play-based activities," "game-based interventions," "exergames," and "serious games" refer to different ideas. Play-based activities are joyful movement experiences that are mainly meant to promote social connection, involvement, and discovery. In order to attain therapeutic, educational, or motor-development results, game elements are purposefully included into organized, goal-directed programs known as game-based therapies. Exergames are digital gaming environments that incorporate physical exercise as a component of gameplay. Serious games are made especially for uses other than amusement, such as education, cognitive training, behavior modification, and rehabilitation. Differentiating between these ideas is crucial as each strategy may focus on various motor-learning mechanisms and rehabilitative goals.

Although studies have found a link between interest and games, recreational games promote balance, while organized games increase motor skills and athletic movement [5–8]. However, some of these studies concentrated on broad surveys, short-term improvement, and cognitive enhancement, with no solutions for future follow-up. As a result, they cannot be considered to have any practical effect on children, coaches, teachers, or caregivers. While the theoretical difficulties are evident, they are still unclear, needing further in-depth investigations to unravel these issues and allow future research to establish cohesive goals.

According to observational data, physical activity has been incidental and situational, depending on the preferences of children with Down syndrome. The exercises conducted are confined to imitating animal movements, walking around the garden, and playing guessing games to stimulate cognitive function. Concerns occur as children with Down syndrome grow older and gain a sense of independence in activities such as washing, eating, and socializing. Children with Down syndrome cannot yet manage their independence. Furthermore, some caregivers, teachers, and coaches are unfamiliar with specialized testing and measurements for children with Down syndrome and require references related to game-based interventions to develop fundamental movement skills. This is similar to earlier research, which indicates the need for a sports approach tailored to children with Down syndrome, such as creating games and adapting current sports to specific situations [3].

However, scientific investigations on game-based exercise or physical activity models have not provided a complete understanding of their application and unique effects on children with Down syndrome. A scoping review of studies is required to better investigate this issue. A peer review is an attempt to explain the phenomena of existing original and systematic research by summarizing and synthesizing the results, providing meaning beyond simply testing the effectiveness of a method, and attempting to unravel the potential and limitations of existing research [9].

Because they integrate structured motor practice with motivational, social, and cognitive affordances, game-based therapies are a promising strategy. When compared to therapy-only repetitious exercise, game-based exercises can boost engagement, perseverance, and enjoyment. Additionally, group arrangements can foster social modeling and reciprocal encouragement. Play modifies the learning environment by increasing repetitions, focusing attention on objectives, giving instant feedback, and enabling task constraints to be adjusted to individual aptitude. This is not just because games are interesting. To ascertain if these conditions result in long-lasting motor improvements in children with DS and severe intellectual deficits, long-term follow-up is necessary.

Based on the method explanation above, the primary purpose of this study is to map in depth the role of game-based activities in developing fundamental movement in Down syndrome, with a focus on the following research questions (RQ):

RQ1: Why use game-based interventions to develop fundamental skills?

RQ2: What types of game models are used to develop skills?

RQ3: How effective are game-based interventions in developing fundamental movement skills?

RQ4: What research instruments are used in game-based interventions?

RQ5: What are the challenges in implementing game-based interventions?

RQ6: What are the potential opportunities for further research on the implementation of game-based interventions?

This approach is anticipated to advance the review beyond merely descriptive mapping by elucidating the connections between particular game characteristics and the motor-learning mechanisms in Down syndrome (DS). Consequently, the synthesis differentiates among (a) forms of intervention, which include structured play, adapted sports, exergames, virtual reality, and serious games; (b) targeted domains of Fundamental Motor Skills (FMS), such as balance, locomotor movement, object control, coordination, and functional strength; (c) mediating mechanisms, which encompass motivation, repetition, feedback, task constraints, social interaction, and motor-cognitive integration; and (d) conditions of implementation, including duration, frequency, supervision, accessibility, and severity of disability.

2. Materials and Methods

Study Design

A literature review strategy was employed in this study utilizing a scoping review approach. The scoping review approach is deemed suitable given that evidence pertaining to game-based interventions for developmental disabilities is scattered across various disciplines, including rehabilitation, adapted physical education, sport science, special education, and technology-enhanced learning. The objectives included not only the assessment of intervention effectiveness but also the mapping of concepts, clarification of intervention boundaries, identification of mechanisms, summarization of instruments, and the exposure of methodological gaps. In contrast to a

focused effectiveness review, this design facilitates the organization of heterogeneous studies into a clear conceptual framework that can inform future experimental research [10], [11].

Eligibility Criteria

(1) Original empirical studies, conference proceedings, and literature reviews published between 2019 and 2025; (2) studies with accessible full texts and abstracts; (3) English-language publications; and (4) studies indexed in Scopus, ScienceDirect, Springer Nature Link, or Google Scholar were the requirements for inclusion. Studies that reported results pertinent to the motor, cognitive, behavioral, or rehabilitation domains and looked at game-based interventions, exergames, serious games, virtual reality, adapted sports, or similar approaches involving people with Down syndrome or intellectual disabilities were included.

Studies published outside of the 2019–2025 period, publications in languages other than English, records without full text accessibility, editorials, commentaries, letters, protocols, and non-scientific publications, and studies not directly related to the review objectives were all excluded. During full-text evaluation, studies that reported overlapping participant samples, duplicate datasets, or repeated intervention results were closely scrutinized to prevent duplication of evidence. The more thorough and methodologically sound publication was kept where overlap was found. Although they were not synthesized as primary evidence, literature reviews were utilized to highlight research gaps and give contextual information. The evidence synthesis in the findings section was only directly influenced by original empirical research.

Procedures

The research procedure was structured systematically as follows:

a. To rationalize the issue, the authors conducted a needs assessment through interviews with practitioners and teachers who work directly with children with Down syndrome.
b. An exploratory document analysis of relevant articles was performed to uncover discrepancies and pragmatics in prior studies and to validate the data underlying the problem.
c. Developing a problem formulation to focus and meaningfully engage the discussion.
d. Creating Boolean keywords: "serious games" OR "active video games" OR "games-based exercise" OR "virtual reality exercise." "Fundamental motor skills" OR "FMS" OR "gross motor skills" OR "motor competence" OR "motor skills." "Down syndrome" OR "children with Down syndrome" OR "DS children." ("games-based exercise" OR "exergames" OR "active video games") AND ("fundamental motor skills" OR "gross motor skills" OR "motor competence") AND ("Down syndrome" OR "trisomy 21"). A number of databases, including Sco-pus, ScienceDirect, Springer Nature Link, and Google Scholar, were searched
e. 158 records from Scopus, ScienceDirect, Springer Nature Link, and Google Scholar were found in the first search. 150 distinct records remained for title and abstract screening after 8 duplicate records were eliminated. 60 records were then eliminated as they didn't fit the relevancy requirements. Ninety records were evaluated in full. 42 records were eliminated after eligibility evaluation because they did not meet the inclusion requirements. Due to language barriers, accessibility issues, or inadequate relevance to the review's goals, an additional 36 rec-

ords were eliminated. Twelve papers were ultimately included in the final synthesis after meeting all qualifying requirements.The next stage was further filtered using the inclusion criteria, eliminating 60 and finding 90 articles.

f. The next stage was further filtered using abstract text and full downloadability criteria, eliminating 42, resulting in 48 articles.

g. The next stage was further filtered, focusing on English language and open access, eliminating 36, finding 12 articles, and then proceeding to download the RIS data in PDF format.

h. The next stage was more detailed, reading all the downloaded data in full. Articles that were irrelevant to the topic were removed, resulting in a final data set of 12 articles.

i. The study team decided that the last stage, which included 12 publications, was qualified. The suggested reporting elements for systematic reviews-scoping reviews (PRISMA-Scr) analysis [12] are used to show this for clarity: Two reviewers separately performed title screening, abstract screening, and full-text eligibility evaluation to improve methodological rigor and reduce selection bias. Throughout the screening procedure, each reviewer used the predetermined inclusion and exclusion criteria. The research team discussed and came to a resolution to settle disagreements over study eligibility. A third reviewer was consulted to support the final judgment in cases where consensus could not be reached right away. During the selection of studies, this process enhanced uniformity, dependability, and transparency..

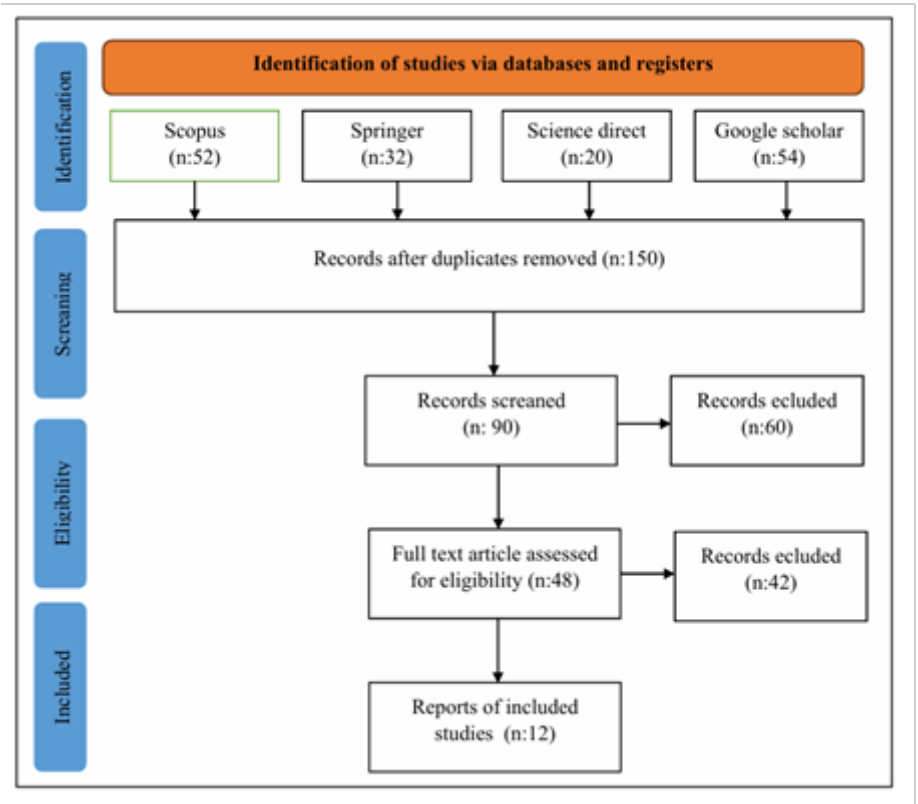

Table 1. PRISMA-Scr flowchart of the research process

Data Analysis Techniques

Publish or Perish, Mendeley, Rayyan, Google Scholar, Scopus, ScienceDirect, and Springer Nature Link were used to facilitate data administration and filtering. Duplicates were eliminated, retrieved records were transferred into reference management software, and eligibility screening was carried out in accordance with the established inclusion and exclusion criteria. Participant characteristics, intervention type, game

features, targeted basic movement skills, outcome measurements, and reported findings were the main areas of data extraction. A narrative method was used to synthesis the included papers in order to find trends in intervention models, implementation traits, measuring instruments, and results connected to rehabilitation.

The goal of the scoping review was to map the available evidence, summarize research trends, identify methodological gaps, and create an integrated framework connecting intervention characteristics, motor outcomes, cognitive outcomes, motivational factors, and implementation conditions rather than to determine pooled intervention effects. It is important to acknowledge a number of limitations. The review may have overlooked pertinent material from other sources because it was limited to accessible and English-language publications. Furthermore, direct comparison between studies was hampered by differences in research design, participant characteristics, intervention protocols, and outcome measures.

3. Results

Table 1. Publication frequency 2019-2025

No	Year	Amount	Percentage
1	2019	2	16.67%
2	2020	0	0.00%
3	2021	1	8.33%
4	2022	1	8.33%
5	2023	4	33.33%
6	2024	3	25.00%
7	2025	1	8.33%
Total		12	100%

Table 2. Research results based on PRISMA-Scr analysis

No	Title	Method	Results and Conclusion
1	The effect of structured exercise on motor skills in children with Down syndrome [13]	A 6-week randomized controlled trial design. The study included 30 children with Down syndrome. The structured exercise program focused on balance, object control, and locomotor abilities. Data were analyzed using independent t-tests and ANOVA.	The analysis revealed statistically significant differences between the two groups. To summarize, systematic exercise greatly improves balance and motor skills in children with Down syndrome.
2	Analysis of family literacy of children with Down syndrome [14]	Exploratory descriptive design. There were 161 families with Down syndrome aged 3 to 12 years. The measurements were taken using an online survey. The data was analyzed using frequencies and chi-square tests.	The findings found disparities in literacy, linguistic environment, and parental beliefs. Finally, compared to developed countries, Chilean families with Down syndrome appear to be less well-equipped, necessitating experimental and intervention research.
3	Motor development and Down syndrome [15]	The study was a peer-reviewed study that attempted to examine the motor skills of children with Down syndrome. Existing instruments modified physical activity to improve motor skills.	The key findings were that people with Down syndrome exhibit motor restrictions and developmental delays, as well as deficiencies in fine motor abilities and writing. The study revealed that there is a substantial association between motor and cognitive competencies, which supports the adoption of structured motor training. However, a standardized test for assessing motor skills in children with Down syndrome is still absent.
4	Non-pharmacological protocols and assessments to	A mixed-methods design with a randomized controlled trial. The participants were 128 individuals who had intellectual impairments.	Results showed specific improvements in eight cognitive skills related to quality of life and social interaction. In conclusion, the serious games protocol provides benefits related to well-being,

	improve cognitive skills of people with disabilities [16]	Neuropsychological tests were employed as measurements both before and after the intervention. The data were analyzed using ANOVA and t-tests.	reduces cognitive difficulties, and improves social interaction in individuals with intellectual disabilities, mild cognitive impairment, and autism spectrum disorders.
5	Spatial profile of Down syndrome [17]	The study was designed as a methodical evaluation. Participants included 40 adolescents with Down syndrome and 40 typically developing children. Participants completed eight spatial tasks, divided into four categories: static extrinsic (water level and cart tasks), static intrinsic (ground figures and form completion), dynamic extrinsic (three mountains and dog tasks), and dynamic intrinsic (mental rotation and block design). Independent t-tests and ANOVA were used to analyze the data.	Results revealed uneven spatial ability profiles between individuals with Down syndrome and typically developing individuals. Conclusion: The Down syndrome group exhibits specific weaknesses in understanding intrinsic dynamic spatial relations (such as spatial transformations, mental rotation, and block design) and extrinsic static spatial relationships (the location of objects relative to an external framework, such as horizontality). More programmed interventions are recommended to improve spatial abilities.
6	Developing virtual-based learning for individuals with Down syndrome [18]	The design used was a developmental research study on the usability of a virtual learning environment on smartphones. Participants were 60 students with Down syndrome. Measurements were made using a questionnaire.	The results and conclusions show that the virtual learning environment platform obtained a favorable rating. This platform is substantial, straightforward, and easily accessible, with the potential to increase opportunities for persons with Down syndrome, particularly in education, the environment, employment, and social interactions. However, further improvement is required.
7	The effects of physical activity over one year on the skills of children with intellectual disabilities [19]	The design was a one-year randomized controlled trial. The study included 46 boys with Down syndrome. The device was a second-stage gross motor development test. The intervention involved a semi-structured physical activity program.	The intervention results revealed that one year of activity enhanced fundamental movement skills, indicating that the experimental group outperformed the control group. The study concluded that a physical activity intervention can considerably enhance the fundamental motor skills of children with severe Down syndrome. However, this is only apparent after a long duration of one year, not a short period of six months.
8	Comparison of Down syndrome and normal children in terms of basic motor skills: systematic and meta-analysis [20]	The design was a systematic review and meta-analysis using PRISMA principles. There were 26 articles that were relevant. To calculate the mean, data were analyzed using a multivariate maximum likelihood random effects model.	The findings and conclusions suggest that children with intellectual disabilities perform better in fundamental skills than children with regular development. The most significant variations are in balance and object manipulation skills.
9	The effect of mini basketball on motor skills in people with intellectual Disabilities [21]	The design was a quasi-experimental pretest-posttest control design. Participants: 30 boys with intellectual disabilities and coordination disorders, aged 11 years, were randomly assigned. The intervention was mini-basketball for 45 minutes, three times a week, for eight weeks. The analysis technique was a 2x2 repeated-measures ANOVA with a Bonferroni post hoc test at a significance level ($p<0.05$).	The findings revealed significant differences between the intervention and control groups. Conclusion: Mini-basketball training considerably improves motor coordination in children with intellectual disabilities and coordination issues; thus, it is recommended.
10	Motor skill impairments in children with intellectual disabilities [22]	The design was a cross-sectional study to assess fundamental movement skills. Participants were 100 children with intellectual disabilities. Measurements were made using the third-stage gross motor development test. The data analysis technique used was quantitative descriptive analysis.	The key finding is that children with disabilities have barely begun to develop their essential movement skills. It is stated that future therapies should take a constraint-based approach to explicitly target weak behaviors, with a particular emphasis on improving balance, which is the most basic movement skill weakness.

11	Motor skill impairments in children with intellectual disabilities [23]	The design employed a single experimental design. The study included six individuals with Down syndrome. The intervention consisted of cognitive modeling through an exergame based on gesture interaction with sensors. Measurements were made using the Test of Psycholinguistic Abilities (ITPA). The data was analyzed using the t-test.	The results showed no significant differences between the experimental and control groups, possibly due to the very small sample size. In conclusion, although statistically insignificant, intervention with sensor-based exergames has the potential to improve visual-motor cognitive skills.
12	Serious game design for people with intellectual disabilities [24]	The development and assessment design focused on serious games and employed a mixed methods approach. There were 22 participants in an inclusive teaching setting. The intervention utilized a web-based serious game prototype. A questionnaire was used to collect measurement data. The data analysis employed quantitative scoring.	The results showed that among participants with intellectual impairments, the web-based serious game had excellent usability, accessibility, and user approval. Positive learning experiences, task completion, and engagement were all made possible by the inclusive design. The study came to the conclusion that serious games could offer a workable platform for encouraging engagement, motivation, and skill development, but further research with bigger sample sizes is needed to determine their efficacy.

The PRISMA-ScR process led to the identification of 12 pertinent studies published from 2019 to 2025. Instead of considering the tables as independent descriptive outputs, the evidence was synthesized across various dimensions such as intervention type, target skill, mechanism, measurement, and implementation condition. This comprehensive synthesis indicates that game-based approaches have the potential to enhance fundamental motor skills (FMS) through four interconnected pathways: motor repetition, motivational engagement, task-specific constraints, and motor-cognitive feedback. These pathways elucidate the reasons for the variability in outcomes associated with the same intervention label, which can be influenced by factors such as duration, supervision, severity of disability, accessibility of the interface, and the alignment between the game task and the skill being measured.

4. Discussion

RQ1: Why use game-based interventions to develop fundamental skills?

Fundamental movement skill crisis

Individuals with Down syndrome and intellectual disabilities face developmental and engagement difficulties throughout their lives [15,20]. Individuals with Down syndrome face a variety of barriers, including motor skill impairments, specialized skill issues, and functional limitations. Children with Down syndrome and intellectual disability (ID) routinely show weaker fundamental motor skills than their typically developing classmates. In the early phases of motor development, they are expected to exhibit motor deficits, with an average mastery of one of ten key movement skills [20]. Significant disparities exist in skills requiring complicated control, such as balance, the weakest fundamental movement skill. Furthermore, there are considerable changes in object manipulation abilities depending on contextual and cognitive factors [20,22]. This is due to limits in motor planning and motor control, which result in difficulty in coordinating bilateral or sequential movements of the legs and arms [15,22]

Game-based exercise interventions as a solution

By integrating controlled motor practice with social and incentive components, game-based therapies may offer a useful strategy for promoting motor development in people with Down syndrome. Research indicates that engaging and pleasurable activities may boost engagement and enhance balance, locomotor abilities, object

control, and general motor competence [13] Additionally, by highlighting the significance of structured movement experiences, motor-based activities may assist cognitive processes that are strongly linked to motor development, Although the ideal intervention parameters are yet unknown, a number of research suggest that longer intervention times may be linked to higher gains in fundamental movement skills [15,19]. As a result, game-based therapies might support functional independence and enhance pediatric rehabilitation programs.

Motor and Cognitive Integration

Direct gestural engagement provides cognitive stimulation for individuals with Down syndrome through a game-based approach, such as exergames that use the Kinect sensor platform [23]. A structured motor program is predicted to improve memory, inhibition control, flexibility, and cognition, all of which are necessary for organized motor abilities [15]. Specific activities, such as mini-basketball exercises, also have an impact on walking, leaping, and hopping abilities, which involve complex coordination [21]. Inclusive design with serious games based on virtual environments is designed with universal principles to accommodate the needs of users with intellectual disabilities and Down syndrome [17]. Furthermore, visual designs such as images and videos support and strengthen understanding according to the learning profile of Down syndrome [18]

RQ2: What types of game models are applied to develop skills?

Exercise program structure

The intervention model is designed to focus on fundamental movement skills within an enjoyable and group-oriented environment, emphasizing enhanced stability, object control, and locomotor movement [13] Typically, these activities are conducted three times per week for a duration of 50 minutes each, incorporating exercises such as balance walking on a beam, ball kicking, and jumping [13]. A notable benefit of this model lies in the integration of training rules within play, thereby facilitating the development of discipline, repetition, and task engagement without rendering the activity solely therapeutic in nature [13].

Adapted sports games

These games emphasize natural activities such as running, walking, jumping, and balance. This model employs a ball, necessitating difficult motor coordination [21]. The benefits of this game include its emphasis on increasing motor coordination and its ability to engage youngsters with Down syndrome. This model can be described as a mini-basketball game [21]

Exergames and virtual reality models

This model focuses on using the Kinect sensor in a platform called TANGO: H, which controls the user's body movements [23]. This game aims to improve visual-motor cognitive abilities through arm, hand, leg, and head movements [23]. The benefits of this application include improved visual integration and sequential memory, which are areas of weakness in Down syndrome [23]. This device offers real-world input and a controlled setting for rehabilitation.

Skill-based serious games

These games focus on teaching hygiene and sustainable living. While also targeting fundamental movement skills, they also train digital coordination and problem-solving skills [16,18,24]. These games enhance motivation, social interaction, and provide high-quality visual support [16,18,24].

RQ3: How effective are game-based interventions in developing fundamental movement skills?

Motor Skill Improvement

Following game-based therapies, several studies found improvements in lower-extremity functional performance, object control, balance, locomotor abilities, and coordination. However, in terms of research design, intervention length, sample size, participant characteristics, and outcome measures, the data that is currently available is still inconsistent. Consequently, even while game-based therapies show promise for improving motor development, there is currently inadequate data to assess their effectiveness or draw firm judgments about whether they are better than other intervention strategies [13]. Furthermore, the training program using mini-game baskets significantly improved coordination, specifically in backward walking, vertical hopping, and lateral jumping tests. This improvement demonstrates that sports games involving complex coordination movements have been shown to have significant positive effects [21]. Furthermore, the exercise-based program increased static balance using a modified stroke test and lower extremity functional strength using the five-times sit-to-stand test [13].

Differentiation of Outcome Domains

Motor, cognitive, motivational, and behavioral outcomes are the four categories into which the results presented in the included research may be divided. Improvements in balance, locomotor abilities, object control, coordination, and functional performance were among the motor results. Visual-motor integration, executive functioning, memory, and problem-solving skills were all associated with cognitive results. While behavioral outcomes included involvement, social interaction, self-confidence, and independence in day-to-day activities, motivational outcomes included enjoyment, engagement, and adherence to intervention programs. It is crucial to distinguish between different domains since advancements in one may not always translate into comparable advancements in another. Future research should use verified and standardized metrics to assess these results independently.

Intensity and Duration Factors

The concepts of intensity and duration ought to be viewed as fundamental mechanisms rather than as secondary aspects of the program. While brief interventions may yield immediate benefits in contexts where tasks are highly specific, sustainable alterations in fundamental movement skills (FMS) typically necessitate repeated exposure over extended durations. The information that is currently available indicates that the length of the intervention may have an impact on the degree of motor gains that are shown. While some studies showed good results after relatively short programs, others found more significant benefits after longer intervention periods. There is presently no conclusive suggestion for the ideal length, intensity, or frequency of game-based therapies due to the small number of research and variation in intervention methods. [19]. Consequently, the efficacy of game-based training is contingent upon the congruence between intervention dosage, task specificity, supervision, and the cognitive-motor profile of the child. A practical consideration is that game-based programs should provide detailed reports on session length, weekly frequency, total hours of intervention, progression guidelines, attendance, and fidelity, thereby ensuring that outcomes can be interpreted in a transparent manner [13].

These findings have implications for rehabilitation that go beyond gains in specific motor abilities. Improved lower-extremity strength, balance, coordination, and locomotor capacity may all immediately lead to increased independence in day-to-day activities, safer movement performance, and functional mobility. Improvements in basic movement abilities may have a favorable impact on bodily functions, activity performance, participation, and general quality of life within the framework of the International Classification of Functioning, Disability and Health (ICF). As a result,

comprehensive pediatric rehabilitation programs that seek to enhance both motor competence and functional independence may benefit from the use of game-based therapies. From a rehabilitation standpoint, these results imply that by offering fun, repeated, and task-oriented movement practice, game-based therapies may enhance traditional physiotherapy and pediatric rehabilitation programs. While focusing on functional mobility, balance, coordination, and participation objectives that are pertinent to daily independence, such treatments may also aid improve commitment to therapy programs.

RQ4: What research instruments are used in game-based interventions?
Coordination and Basic Motor Skills
•Test of Gross Motor Development (TGMD 2 and 3)

The TGMD assessment test measures basic motor abilities such as locomotion and object control. TGMD 3 also focuses on the examination of behavioral components. The implementation context measures the efficiency of organized intervention programs and interventions for severe intellectual disability [13,19,20]

•Korperkoordinationstest fur kinder (KTK)

This test focuses on assessing motor coordination, assessing all four subtests: walking backward, vertical hooping, lateral movement, and lateral jumping. In this context, it was used in a mini-basketball training study [21].

•Bruininks oseretsky test of motor proficiency 2 (BOT-2)

Frequently used to evaluate the balance subtest and as a supplement to the TGMD test. In this context, to evaluate basic motor impairments [22].

Balance and Functional Skills
•Modified stroke test (MST)

This test involves standing on one foot on the floor while the other leg is raised above the ankle joint with the arms placed at the sides. This test measures the ability to maintain a one-legged stance [22].

•Five times sit-to-stand test (FTSTS)

This test evaluates lower extremity strength. Participants sit in a chair with no backrest, arms engaged, and back against the chair. They then stand up and sit down five times in succession. Time is measured in seconds and represents functional leg muscular strength [13].

• Development coordination disorder questionnaire (DCDQ)

This questionnaire aims to identify individuals with Down syndrome, which is characterized by impaired neurodevelopment and motor skills. Parents complete this questionnaire. The assessment in this questionnaire includes three aspects, namely general coordination, movement control, and fine movements [21]

RQ5: What are the challenges in implementing game-based interventions?
Methodological challenges

The primary methodological challenge identified is the utilization of small samples, heterogeneous disability profiles, or single-case experimental designs in several studies, which in turn restricts generalizability [19,23,24]. Descriptions of participants are frequently inadequate for assessing whether outcomes vary according to factors such as age, sex, severity of Down syndrome (DS), level of intellectual disability, baseline motor competence, comorbidities, or previous physical activity experiences [13]. Furthermore, the duration of follow-up periods is often limited, complicating the evaluation of the persistence of gains post-intervention. Additionally, the absence of a universally standardized assessment battery specifically designed for DS leads to the frequent appropriation of instruments from broader contexts related to intellectual disability or child motor development [15,22]. While these limitations do not invalidate the evidence presented, they necessitate careful interpretation and enhanced transparency in reporting.

Implementation Challenges

To obtain meaningful benefits, low cognitive capacities require long-term therapies, such as those lasting a year rather than six weeks or six months [19]. Children with Down syndrome struggle to execute unfamiliar tasks that demand motor and cognitive abilities; therefore, coaches, teachers, or mentors play an important role [24]. Furthermore, some teachers lack the knowledge and confidence to give effective education, as well as training in working with disabled children [20].

Game design challenges

Some games may be too complex for children with Down syndrome, leading to questions regarding their suitability [18]. Despite low-barrier designs, accessibility concerns exist, such as people unable to scroll or click on smartphones or tablets [24]. Furthermore, technological difficulties with web-based platforms impair the learning process, such as signal troubles and the inability of some platforms to function smoothly [18]. Furthermore, game-based activities cannot be viewed as a sole solution; they must be an integral part of the curriculum and support an adequate teaching framework [24].

RQ6: What are the potential opportunities for further research on the implementation of game-based interventions?

Long-Term Interventions

In order to assess enhancements in movement and motor abilities, as well as to monitor retention over an extended period, it is recommended that upcoming programs be evaluated beyond brief trial phases and incorporate medium- to long-term follow-up assessments. Evidence indicates that certain improvements may necessitate prolonged exposure, especially in cases where participants exhibit severe intellectual disabilities or possess low baseline motor skills [19].. Conducting large-scale trials could augment the generalizability of outcomes to more specific populations of individuals with Down syndrome and intellectual disabilities [23]. Furthermore, direct comparisons among game-based interventions, traditional exercise regimens, and adapted sports models are required to ascertain which approach is most efficacious for particular fundamental movement skill domains [23].

Expanding the research sample

It is essential to include both genders to provide a more comprehensive perspective [23,24]. Studying developmental characteristics based on different ages and severity levels is essential [19]. Furthermore, an ideal comparison group is needed to control for factors such as physiological maturation [19].

Methodological Improvements

An analysis of fundamental movement skills at the behavioral component level is deemed essential, as this approach allows for the identification of specific weaknesses that can be addressed through intervention [22] It is suggested that this analysis incorporates cognitive data alongside motor-development outcomes, given the close relationship between intellectual and motor development in children with Down syndrome (DS) and intellectual disabilities [20]. It is recommended that future research employs more objective performance measures, such as running speed, jump distance, balance-system outputs, and isokinetic strength data, whenever feasible [13]. Furthermore, it is advised that game design be documented with enhanced precision, encompassing aspects such as accessibility features, progression rules, feedback formats, task adaptations, and fidelity monitoring, to enable the evaluation of the mechanisms behind improvement rather than relying on assumptions [13].

Limitations of the Available Evidence

It is important to take into account a number of the evidence's limitations. Direct comparisons across the included studies were hampered by their small sample numbers, diverse intervention methods, and range of outcome measures. Determining long-term impacts is further challenging because many studies reported brief intervention durations and few follow-up evaluations. The review may have overlooked pertinent information from other sources because it was limited to accessible, English-language publications. As a result, the results should be regarded with caution, and further high-caliber research using standardized techniques is required to bolster the body of data.

5. Conclusions

According to this scoping study, game-based therapies might be a promising rehabilitation-focused strategy for helping people with Down syndrome develop their basic motor abilities. Four forms of intervention were found: serious games, exergames/virtual reality, adaptive sports games, and organized play-based exercise. Potential advantages for balance, locomotor abilities, object control, coordination, and functional mobility are suggested by the current data. However, due to small sample numbers, a variety of outcome measures, and variations in intervention techniques, the present data is still inconsistent. As a result, the results should not be extrapolated to all people with Down syndrome and should be read with caution. Larger samples, longer follow-up times, and standardized assessment techniques should be used in future studies to enhance rehabilitative practice and increase the body of data.

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