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Effectiveness of Core Stability and Trunk-Focused Exercise Interventions on Balance, Postural Control and Gross Motor Function in Children with Down Syndrome: A Systematic Review

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Abstract: ***Children with Down syndrome commonly present with hypotonia, ligamentous laxity, delayed postural control, and poor trunk stability, which adversely affect balance, gross motor function, and functional independence. Core stability and trunk-focused exercise interventions have been increasingly incorporated into pediatric physiotherapy to address these motor impairments; however, consolidated evidence regarding their effectiveness remains limited. This systematic review assessed the influences of core stability and trunk control exercises on balance, posture, and overall motor skills among children with Down syndrome. A comprehensive search of PubMed, ScienceDirect, and Google Scholar was conducted according to PRISMA guidelines for English language studies. Included were interventions such as Swiss ball exercises, Pilates, neurodevelopmental therapy-based trunk exercises, stretch-shortening cycle trampoline drills, and treadmill-based practice. Six studies, including randomized trials and experimental designs, met the inclusion criteria. Due to the differing methodologies and assessment tools, the results were synthesized narratively rather than statistically. Across all studies, core-oriented programs showed large improvements in static and dynamic balance, core muscle power, postural control, and gross motor coordination activities. The best clinical outcomes were obtained by interventions that combined trunk strengthening with lower limb or walking training. The results provide compelling evidence that incorporating well-structured core and trunk exercises into physiotherapy regimen can significantly enhance motor abilities and daily independence for children with Down syndrome.***

Keywords: Down syndrome, gross motor coordination, Swiss ball, Pilates, pediatric rehabilitation.

1. Introduction

Down syndrome (DS) arises from a genetic anomaly involving an additional copy of chromosome 21 and represents one of the most prevalent chromosomal conditions linked to cognitive and motor challenges. Young individuals with DS often exhibit distinctive physical and neuromuscular traits—including reduced muscle tone, loose ligaments, excessive joint flexibility, and delayed development of postural regulation. These characteristics commonly lead to difficulties in maintaining balance, stabilizing the trunk, and coordinating movements, thereby impeding milestones like sitting upright, standing independently, walking, and reaching for objects. Inadequate control of the trunk not only restricts autonomy in physical tasks but also influences engagement in everyday routines, educational activities, and social exchanges. The capacity to manage the alignment and motion of the torso relative to the pelvis—commonly referred to as core stability—is essential for effective posture and purposeful movement. It establishes a solid foundation that supports coordinated use of the arms and legs and promotes smoother, more efficient motor execution. Rehabilitation approaches for children have increasingly incorporated trunk-centered strategies such as core strengthening routines, Swiss ball–based activities, Pilates, and neurodevelopmental therapy (NDT) protocols targeting trunk regulation. Such programs are designed to activate deep abdominal and spinal musculature, heighten body awareness through sensory feedback, and refine communication between nerves and muscles. Although multiple standalone investigations have noted beneficial effects of these methods in children with DS, findings remain fragmented and lack consensus for clinical application. Consequently, this systematic review seeks to comprehensively evaluate and integrate current research on how trunk-oriented and core-focused exercise regimens impact balance, postural regulation, and large-movement capabilities in this population. The findings are expected to support evidence-based physiotherapy practices and guide future research toward optimized rehabilitation protocols for this population.

2. Literature Survey

Children with down syndrome commonly exhibit hypotonia, ligamentous laxity and delayed postural control which negatively affect trunk stability, balance and gross motor development. Several studies have investigated the effectiveness of the core stability and trunk focused exercises interventions in addressing these impairments.

Interventions such as Pilates, Swiss ball-based core exercises and neurodevelopmental treatment (NDT) based trunk control programs have demonstrated significant improvements in static and dynamic balance, trunk muscle strength and gross motor coordination control leading to better postural alignment and functional performance. Additional studies have reported that dynamic interventions such as trampoline – based stretch – shortening cycle training

and treadmill walking further improve postural control, lower – limb strength and gait performance in children with down syndrome. combined training approaches integrating core strengthening with gait or lower – limb exercises were found to produce superior functional outcomes compared to single – modality intervention. overall existing literature supports the inclusion of structured core stability and trunk – focused exercises as essential components of pediatrics physiotherapy programs to enhance balance, postural control and gross motor function in children with down syndrome.

3. Problem Definition

Young individuals with Down syndrome often experience low muscle tone, overly flexible ligaments, excessive joint mobility, and slower development of postural regulation, which together result in weak core control, compromised equilibrium, and limited large-movement abilities. these impairment negatively affect the performance of functional activities such as sitting, standing, walking and postural transitions thereby limiting functional independence and participation in daily activities. Although physiotherapy plays a key role in managing these motor deficits, conventional rehabilitation programs often lack specific emphasis on structured core stability and trunk – focused exercises.

Although multiple investigations have highlighted beneficial outcomes from core stability and trunk-centered programs, the current body of evidence remains inconsistent—largely due to differences in research methodologies, training approaches, and assessment tools. This absence of cohesive, standardized findings hinders the development of definitive clinical recommendations for using such strategies with children who have Down syndrome. Hence, a thorough and structured analysis of published work is essential to clarify how effectively these exercise-based approaches enhance balance, posture regulation, and overall motor performance in this group.

4. Methodology

Study design

This systematic review was conducted based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines.

Selection of studies

The initial search using predefined keywords yielded 20 articles, which were then screened and organized based on the established inclusion and exclusion criteria. Of these, only six met all the required conditions and were ultimately selected for inclusion in the review.

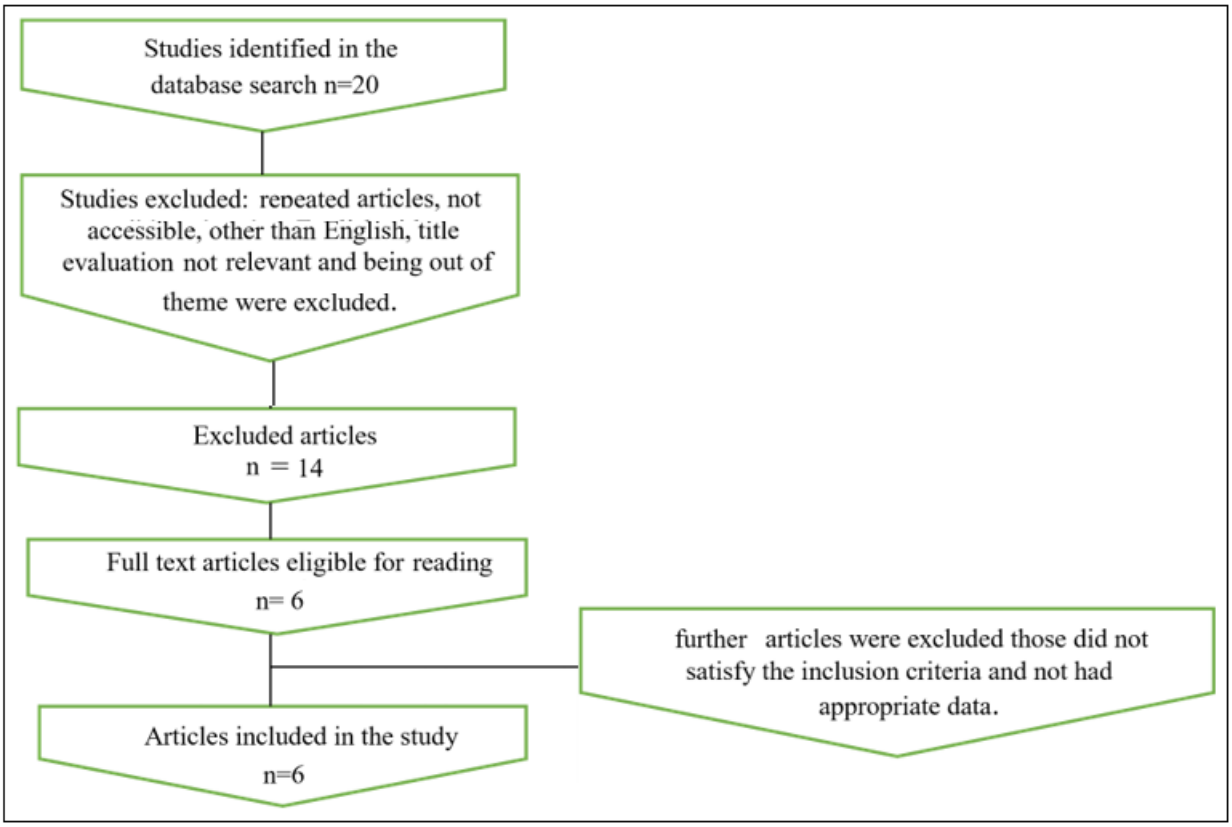

Table 1: Summary of studies included

Author	Study design	Participants	Objective of the study	Results obtained	Conclusion
Allaa Al Nemr & Shimaa Reffat et al.,	Experimental Study	40 children. 8 – 10 years with Down syndrome	To investigate the Effect of Pilates Exercises on Balance and Gross motor co- Ordination in Children with Down syndrome.	Dynamic balance (biodex), Gross motor coordination (BOT- 2), Quality of Life (PedsQL)	Pilates exercises To a designed Physical therapy Program can Produce more significant improvements in balance, Gross motor coordination & Quality of life.
A.R. Azab, W S Mahmoud, M.A Basha, S.M. Hassan, E.N. Morgan, A.E. Elsayed, F.H. Kamel, R.K. Elnaggar et al.,	Randomized Controlled Trail (RCT)	32 children. 7 – 9 years with Down syndrome	To investigate The effect of a 3 Month Trampoline based stretch Shortening cycle Exercise Program on Muscle strength and postural control in children with down syndrome.	Lower limb Muscle Strength (hip, knee, ankle Muscles) Increased in the Stretch Shortening cycle Exercise group When compared with control Group.	SSC exercises Are effective in Enhancing Muscle strength & postural Control in Children with Down syndrome.
Dr Vidhi Shah, Anuj Lahoti, Tushar J Palekar, Shradha Chanageri, Neha Chitale, Nazia Lateef Amorhi et al.,	Experimental Study	30 children aged 8 - 12 years	To evaluate the effect of core stability exercises using A Swiss ball on Balance and Core muscle Strength in Children with Down syndrome.	Dynamic Balance, Static balance and core muscle strength improved.	Incorporating Swiss ball based Core stability exercises into physiotherapy programmes for children with down syndrome supports enhanced functional mobility and may help to reduce the risk of falls.
Miho Park, Joengseon Kim, Changseon Yu And Hyoungwon Lim et al.,	Randomized Controlled Trail (RCT)	20 children with Developmental Disabilities	To determine Whether a Neurodevelopmental Treatment based Trunk control Exercises Intervention is Effective in Improving trunk Control and gross Motor function in Children with Developmental Disabilities	The NDT – TCE Intervention specifically Improved GMFM and Trunk control	The author propose that NDT-TCE can Significantly improve the GMFM & trunk Control

Inclusion and Exclusion Criteria

This review considered studies that met the following criteria children diagnosed with Down syndrome who participated in interventions focusing on core stability, trunk control, or balance-enhancing exercises such as Swiss ball training, Pilates, neurodevelopmental treatment (NDT)-based trunk control, trampoline-based stretch–shortening cycle activities, or combined strength and treadmill programs. Eligible studies evaluated outcomes related to postural control, balance, trunk muscle strength, or gross motor function, and included randomized controlled trials, clinical intervention studies, or cross-sectional designs published published in refereed journals, with complete texts available exclusively in English with clearly defined methodologies were considered. Studies were excluded if they involved adults with Down syndrome, participants with neurological conditions unrelated to Down syndrome, or focused solely on cognitive or behavioral outcomes without motor or postural measures. Non-interventional papers, such as theoretical reviews, case reports, or editorials lacking original data, were also excluded. In addition, studies without accessible full texts, incomplete methodologies, or insufficient detail regarding intervention protocols and outcome measures were omitted. These selection standards helped identify rigorous and pertinent research focused explicitly on how core- and trunk-oriented exercise programs influence motor skills and postural abilities in children with Down syndrome.

5. Result

Six studies satisfied the eligibility requirements, among them randomized controlled trials, clinical intervention studies, and cross-sectional designs. Each study focused on children diagnosed with Down syndrome and assessed the impact of different core-strengthening approaches and trunk-focused interventions such as Swiss ball training, Pilates-based exercises, neurodevelopmental treatment (NDT)-based trunk control programs, interventions included trampoline-based stretch–shortening cycle (SSC) drills and treadmill-based practice. Consistently across all studies, participants showed marked gains in postural steadiness, equilibrium, core muscle power, and large-movement coordination.

Children who performed core stability exercises using unstable surfaces, such as Swiss balls, showed enhanced dynamic balance, trunk control, and core muscle activation. Pilates interventions led to marked improvements in gross motor coordination and functional balance performance. NDT-based exercises aimed at improving torso regulation significantly increased core steadiness and overall motor

performance, particularly in sitting and reaching tasks. Trampoline SSC training enhanced lower-limb strength and reactive postural control, while treadmill training promoted improvements in gait pattern, stepping ability, and overall motor development. Combined interventions that integrated core strengthening with lower-limb or treadmill exercises produced superior functional outcomes compared to single-modality approaches. Despite variations in intervention duration, frequency, and outcome measures, all studies reported positive effects of trunk focused training. Collectively, the evidence indicates that core stability and trunk focused exercises effectively improve balance, postural control, and motor performance in children with Down syndrome, underscoring their importance in pediatric physiotherapy programs aimed at enhancing physical function and independence.

6. Discussion

The findings of this systematic review highlight the significant role of core stability and trunk-focused exercise interventions in improving balance, postural control, and gross motor function in children with Down syndrome. Across the reviewed studies, consistent evidence supports the effectiveness of interventions such as Swiss ball exercises, Pilates-based training, neurodevelopmental treatment (NDT)-based trunk control exercises, trampoline-based stretch–shortening cycle (SSC) activities, and treadmill training in enhancing motor and postural performance. These improvements can be attributed to the strengthening of deep stabilizing muscles, increased proprioceptive feedback, and improved neuromuscular coordination, all of which are crucial for maintaining functional posture and performing daily motor tasks efficiently.

Children with Down syndrome typically present with hypotonia, ligamentous laxity, and delayed postural control, which contribute to challenges in maintaining upright stability and coordinated movement. The included studies demonstrated that targeted trunk and core training can effectively compensate for these deficits by facilitating better activation of the transversus abdominis, multifidus, pelvic floor, and hip stabilizer muscles. Exercises performed on unstable surfaces, such as Swiss balls, further enhance sensorimotor integration and postural reflexes by stimulating vestibular and proprioceptive systems. Similarly, Pilates-based interventions emphasize controlled breathing, alignment, and muscle endurance, which translate into improved trunk stability and functional coordination.

NDT-based trunk control exercises were particularly beneficial for improving segmental trunk stability and gross motor function, especially in seated and reaching tasks. These interventions align with the principles of motor control and neuroplasticity, which suggest that repetitive, purposeful, and task-specific movements promote cortical reorganization and functional recovery. Likewise, trampoline-based SSC training effectively improved lower-limb strength and reactive postural adjustments, while treadmill training enhanced gait patterns and dynamic balance through repetitive locomotor practice and sensory input.

Collectively, these results confirm that a stable trunk acts as the foundation for all functional movements. Strengthening core musculature provides proximal stability that allows for distal limb mobility and coordination- an essential principle in pediatric physiotherapy. The observed improvements in gross motor coordination, dynamic balance, and functional activities such as standing, walking, and reaching emphasize the transferability of these gains to everyday life. Furthermore, combined intervention approaches, such as pairing core training with treadmill walking or lowerlimb strengthening, yielded superior results, indicating that comprehensive, multi-dimensional programs are more effective than single modality interventions.

However, despite these encouraging findings, several methodological limitations were identified. Many studies had small sample sizes, short intervention durations, and lacked follow-up assessments, limiting the generalizability of results. Variations in exercise intensity, frequency, and outcome measures also made it difficult to compare results across studies. Additionally, few studies employed blinded assessments or randomized allocation procedures, which may introduce bias. The absence of standardized protocols highlights the need for well-designed randomized controlled trials (RCTs) to determine optimal intervention parameters and establish consistent clinical guidelines.

From a clinical perspective, the outcomes of this review provide practical insights for physiotherapists and pediatric rehabilitation specialists. Incorporating structured core stability and trunk-focused exercises into individualized therapy plans can significantly improve postural control, balance, and motor performance in children with Down syndrome. Therapists should emphasize progressive, play based, and functionally relevant exercises that maintain motivation and engagement. Moreover, integrating these exercises with other therapeutic modalities such as gait training, strength conditioning, or aquatic therapy may yield additional functional benefits.

In summary, this systematic review reinforces the importance of core stability and trunk-focused interventions as integral components of pediatric physiotherapy for children with Down syndrome. These exercises not only enhance physical function and independence but also contribute to better quality of life by improving participation in daily and recreational activities. Future research should prioritize well-designed randomized controlled trials involving more participants and extended monitoring periods durations, and standardized outcome measures to strengthen the evidence base and guide best clinical practices.

7. Conclusion

This systematic review concludes that core stability and trunk-focused exercise interventions—such as Swiss ball training, Pilates, neurodevelopmental treatment (NDT)based trunk control, trampoline-based stretch–shortening cycle activities, and treadmill training- are effective in improving postural stability, trunk muscle muscle power, stability, and large-movement coordination in children with Down syndrome. Such training routines enhance proximal stability, neuromuscular control, and functional performance, thereby

promoting greater independence and participation in daily activities. Incorporating structured core stability training into pediatric physiotherapy programs is strongly recommended to address the motor and postural deficits commonly seen in this population. Future investigations should prioritize large-scale randomized controlled trials employing consistent protocols, extended monitoring periods, and quantifiable outcome assessments to confirm these results and develop practice guidelines grounded in robust evidence.

8. Future Scope

The present review emphasizes the advantages of core stability and trunk-focused exercise programs to improve balance, postural control, and gross motor skills in children with Down syndrome. Nevertheless, more research is warranted, especially larger randomized controlled trials applying a uniform intervention framework with clear definition of the exercise dosage, intensity, session frequency, and program duration. Furthermore, long-term studies will be required to assess whether the improvements are maintained over time and whether initiating core training early in development provides sustained functional benefits across all stages of development.

Further studies may explore the comparative effectiveness of different core stability approaches, such as Swiss ball training, Pilates, NDT-based trunk control, aquatic therapy, and technology-assisted rehabilitation. Research should also investigate the integration of core stability programs with other therapeutic modalities, including gait training, strength conditioning, and sensory integration therapy, to optimize functional outcomes. Additionally, the development of age-specific, play-based core training protocols and the inclusion of caregiver-guided home programs could enhance accessibility, compliance, and real-world application of these interventions in pediatric rehabilitation

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