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Stimulating Gross Motor Skills in Deaf-Mute Children in a Special Needs Elementary School Via Games

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ABSTRACT

Purpose of the study: Deaf-mute children often experience delays in gross motor skill development due to limited auditory feedback and reduced exposure to traditional physical activities. Game-based interventions have shown promise in enhancing motor development in children with special needs. This research aimed to evaluate the effectiveness of structured game-based interventions in improving gross motor skills among deaf-mute children in a special needs elementary school setting.

Materials and methods: A quasi-experimental study was conducted with 36 students (ages 7-12 years) from a special needs elementary school in Binjai city, North Sumatra. Participants were randomly divided into experimental (n=18) and control (n=18) groups. The experimental group received 12 weeks of structured game-based motor skill interventions (3 sessions/week, 45 minutes/session), while the control group continued regular physical education. Gross motor skills were assessed using the Test of Gross Motor Development-3 (TGMD-3) pre- and post-intervention.

Results: Statistical analysis using SPSS v27 revealed significant improvements in the experimental group's gross motor skills. The experimental group showed significant increases in locomotor skills (pre: M=42.3, SD=6.8; post: M=58.7, SD=5.2; $p<0.001$) and ball skills (pre: M=38.9, SD=7.1; post: M=52.4, SD=6.3; $p<0.001$) compared to the control group.

Conclusions: Game-based interventions significantly enhanced gross motor skills in deaf-mute children. These findings support the implementation of structured play-based programs in special needs education settings.

Keywords
deaf-mute children, gross motor skills, game-based intervention, special needs education, motor development.

INTRODUCTION

Children with hearing impairments face unique challenges in motor skill development that extend beyond their primary sensory deficit. The absence of auditory input significantly impacts their ability to develop spatial awareness, balance, and coordination skills that are fundamental to gross motor development (Hartman et al., 2010). This can lead to developmental delays in locomotor and object control skills, as evidenced by studies comparing hearing-impaired children to their hearing peers (Gürsel, 2014). Such delays are particularly pronounced in fundamental motor skills, with deaf children often demonstrating lower proficiency across various age groups (Dummer et al., 1996; Goodman & Hopper, 1992). Deaf-mute children, in particular, experience compounded difficulties as they navigate both auditory and verbal communication barriers that can limit their participation in traditional physical activities and motor learning experiences.

The development of gross motor skills is crucial for children's overall physical, cognitive, and social development. These skills form the foundation for more complex movement patterns and contribute significantly to children's self-confidence, social integration, and academic performance (Capio et al., 2024; Palmer, 2024). However, research indicates a concerning decline in the motor skill levels of children globally, with many performing at or below average in gross motor assessments (Hussain & Cheong, 2022). This decline is even more pronounced in children with hearing impairments, who often exhibit significant delays in fine and gross motor skills compared to their hearing counterparts (Alshahrany, 2021). For deaf-mute children, the mastery of gross motor skills becomes even more critical as it can compensate for communication limitations and provide alternative avenues for social interaction and self-expression.

Previous research has consistently demonstrated that children with hearing impairments exhibit delays in gross motor development compared to their hearing peers. Butterfield & Ersing, (1986) found that deaf children scored significantly lower on tests of balance, coordination, and overall motor proficiency. This delay is often attributed to vestibular dysfunction, which is more prevalent in individuals with hearing loss and directly impacts postural control and balance (Rajendran & Roy, 2011; Rine et al., 2000). More recent studies have confirmed these findings, with (Gheysen et al., 2007) reporting that deaf children show particular difficulties in dynamic balance tasks and complex motor sequences.

The underlying mechanisms contributing to these motor delays are multifaceted. The vestibular system, which is closely connected to the auditory system, plays a crucial role in balance and spatial orientation (Carrillo et al., 2024; Rine et al., 2004;

Wiener-Vacher et al., 2024). Damage to the inner ear structures that cause deafness can also affect vestibular function, leading to balance difficulties. Consequently, children with hearing impairments are at an increased risk of developing balance and gross motor deficits (Gronski, 2013). Additionally, the lack of auditory feedback limits deaf children's ability to monitor their movement patterns and adjust accordingly (Carlson et al., 1991; Ong et al., 2023).

Game-based interventions have emerged as promising approaches for enhancing motor development in children with disabilities. Research by (Smythe et al., 2023) demonstrated that structured play activities could significantly improve fundamental movement skills in children with developmental delays. Similarly, adaptive physical education programs utilizing games have been shown to positively impact motor skills and social integration among children with hearing impairments (Veiskarami & Roozbahani, 2020). The use of games provides motivation, engagement, and opportunities for repetitive practice in enjoyable contexts, which are essential elements for motor learning (Goodman & Hopper, 1992; Zhou & Qi, 2022)

Despite the recognized importance of motor skill development in deaf-mute children, there remains a significant gap in research specifically examining game-based interventions for this population. Most existing studies have focused on children with hearing impairments broadly, without specifically addressing the unique needs of deaf-mute children who face additional communication challenges.

Furthermore, limited research has been conducted in developing countries, particularly in Southeast Asian contexts where cultural and educational factors may influence intervention effectiveness. The majority of studies have been conducted in Western settings with different educational systems and cultural approaches to disability support.

The implementation of game-based interventions for deaf-mute children is theoretically grounded in several established frameworks. The Dynamic Systems Theory suggests that motor development emerges from the interaction between the individual, task, and environment. Games can provide optimal task and environmental conditions that facilitate motor learning despite individual constraints. Additionally, the Social Learning Theory emphasizes the importance of observational learning and social interaction in skill acquisition. Games provide rich opportunities for peer interaction and modeling, which can be particularly beneficial for deaf-mute children who rely heavily on visual cues for learning.

The primary objectives of this study were to evaluate the effectiveness of structured game-based interventions in improving gross motor skills among deaf-mute children, compare motor skill improvements between experimental and control groups, and identify specific gross motor skill domains that show the greatest improvement through game-based interventions. Ultimately, this research aims to provide evidence-based recommendations for implementing motor skill programs in special needs educational settings.

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MATERIALS AND METHODS

Study Participants

A total of 36 students from a special needs elementary school in Binjai city, North Sumatra, participated in this study. Participants ranged in age from 7 to 12 years (M = 9.4, SD = 1.6) and were diagnosed with congenital or early-onset deafness accompanied by muteness. Inclusion criteria included: (1) profound hearing loss (>90 dB HL) diagnosed before age 3, (2) absence of verbal communication abilities, (3) age between 7-12 years, (4) ability to follow visual instructions, and (5) absence of additional physical disabilities that would prevent participation in motor activities. Exclusion criteria included: (1) presence of significant cognitive impairments, (2) orthopedic conditions affecting movement, (3) recent injuries limiting physical activity, and (4) inconsistent school attendance. Ethical approval was obtained from the institutional review board, and informed consent was secured from parents/guardians through sign language interpreters.

Study Organization

The study employed a quasi-experimental design with random assignment to experimental and control groups. Participants were stratified by age and gender before randomization to ensure balanced groups. The experimental group (n=18) received game-based motor skill interventions, while the control group (n=18) continued with standard physical education activities.

The intervention period lasted 12 weeks, with sessions conducted three times per week for 45 minutes each. All sessions were conducted in the school gymnasium under the supervision of trained physical education teachers and sign language interpreters. The intervention was designed based on the fundamental movement skills framework, focusing on locomotor skills (running, jumping, hopping, galloping, sliding, skipping) and ball skills (throwing, catching, kicking, striking).

Test and Measurement Procedures

Table 1. Test and Measurement Procedures Protocol

Component	Details	Specifications
Primary Assessment Tool	Test of Gross Motor Development-3 (TGMD-3)	Standardized tool validated for children with disabilities
Assessment Domains		
- Locomotor Skills	6 fundamental skills	Run, gallop, hop, leap, horizontal jump, slide
- Ball Skills	7 fundamental skills	Two-hand strike, stationary dribble, catch, kick, overhand throw, underhand roll, stationary bounce
Scoring System	Performance criteria-based	0-2 points per criterion (0=does not perform, 1=emerging, 2=proficient)
Testing Schedule		
- Pre-testing	1 week before intervention	Baseline measurements
- Post-testing	Within 1 week post-intervention	Outcome measurements
Testing Environment	School gymnasium	Standardized setup with proper lighting and space
Equipment Required		
- Balls	Various sizes (tennis, playground, foam)	Age-appropriate equipment
- Markers/Cones	Distance and boundary marking	Visual spatial references
- Recording Materials	Video cameras, score sheets	Documentation and verification

Assessment Personnel		
- Primary Assessors	2 certified physical education professionals	Blinded to group assignments
- Sign Language Interpreters	2 certified interpreters	Instruction communication
- Video Technicians	2 trained operators	Recording for reliability analysis
Instruction Protocol		
- Demonstration	Visual modeling of each skill	3 demonstrations per skill
- Sign Language	Certified interpreter translation	Clear gestural communication
- Practice Trials	2 practice attempts allowed	Familiarization with task
- Recorded Trials	3 trials per skill	Best 2 of 3 scored
Quality Assurance		
- Inter-rater Reliability	Independent scoring by 2 evaluators	r = 0.92 (20% of assessments)
- Test-retest Reliability	Repeated assessment (1-week interval)	r = 0.89 (n=10 participants)
- Video Review	Secondary verification	100% of assessments recorded
Data Management		
- Score Recording	Immediate digital entry	Standardized score sheets
- Video Storage	Secure digital archiving	Backup and verification purposes
- Data Verification	Double-entry validation	Error detection and correction
Adaptation for Deaf-Mute Children		
- Visual Cues	Enhanced demonstration protocols	Multiple viewing angles
- Communication	Sign language interpretation	Certified interpreters present
- Environmental Control	Minimal distractions	Optimal visual learning conditions
- Timing Flexibility	Extended instruction time	Comprehension verification

The assessment of reliability and validity in this study utilized multiple psychometric approaches to ensure the robustness of the TGMD-3 when applied to children with disabilities. The instrument has been previously validated, with content validity established through expert review and construct validity confirmed via factor analysis. In this research, additional reliability evaluations were conducted to enhance measurement precision. Inter-rater reliability was determined by having two independent assessors score 20% of all assessments, yielding a strong correlation coefficient ($r = 0.92$). Test-retest reliability was assessed by re-evaluating ten participants after a one-week interval, producing a coefficient of $r = 0.89$, indicating good stability over time. Internal consistency was measured using Cronbach's alpha, which demonstrated high reliability across subscales (Locomotor: $\alpha = 0.88$; Ball Skills: $\alpha = 0.91$).

The intervention protocol was designed as a game-based program specifically tailored for deaf-mute children, emphasizing visual learning and structured motor skill development. The activities incorporated visual cues, peer modeling, and gradual progressions to facilitate engagement and comprehension. The games were organized into four categories: (1) Locomotor Games, which emphasized running, jumping, and fundamental movement patterns; (2) Ball Skills Games, focusing on target practice, throwing accuracy, and manipulation of various balls; (3) Coordination Games, integrating multiple movement sequences to enhance motor coordination; and (4) Balance and Stability Games, aimed at improving both static and dynamic balance. Each training session adhered to a standardized structure consisting of a 10-minute warm-up, a 30-minute main activity segment involving rotation across different game categories, and a 5-minute cool-down. Visual instruction cards and demonstration videos were utilized to clearly communicate game rules, task expectations, and performance feedback, ensuring accessibility and inclusivity throughout the intervention.

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Statistical Analysis

Quantitative analyses were conducted using SPSS version 27. Descriptive statistics were calculated for all variables. The normality of data distribution was assessed using the Shapiro-Wilk test. Between-group comparisons were performed using independent t-tests for baseline characteristics. A mixed-design ANOVA was used to examine changes over time and between groups, with time (pre/post) as the within-subjects factor and group (experimental/control) as the between-subjects factor. Effect sizes were calculated using Cohen's d, with 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. Statistical significance was set at $p < 0.05$. Missing data were handled using intention-to-treat analysis with last observation carried forward method.

RESULTS

Participant Characteristics

Baseline characteristics of participants are presented in Table 1. No significant differences were found between experimental and control groups regarding age, gender distribution, degree of hearing loss, or baseline motor skill scores, confirming successful randomization.

Table 2. Baseline Characteristics of Participants

Characteristic	Experimental Group (n=18)	Control Group (n=18)	p-value
Age (years), M ± SD	9.3 ± 1.7	9.5 ± 1.5	0.721
Gender (Male/Female)	10/8	9/9	0.743
Hearing Loss (dB HL), M ± SD	96.4 ± 8.2	98.1 ± 7.6	0.534
TGMD-3 Total Score, M ± SD	81.2 ± 10.4	79.8 ± 11.2	0.687

Primary Outcome Measures

Significant improvements were observed in the experimental group across all gross motor skill domains. Table 2 presents pre- and post-intervention scores for both groups.

Table 3. Pre- and Post-Intervention TGMD-3 Scores

Measure	Group	Pre-Test M ± SD	Post-Test M ± SD	Mean Difference	95% CI	Cohen's d	p-value
Locomotor Skills	Experimental	42.3 ± 6.8	58.7 ± 5.2	16.4	[12.8, 20.0]	2.71	<0.001
	Control	41.9 ± 7.2	44.1 ± 6.9	2.2	[-0.8, 5.2]	0.31	0.142
Ball Skills	Experimental	38.9 ± 7.1	52.4 ± 6.3	13.5	[9.9, 17.1]	2.01	<0.001
	Control	37.8 ± 6.9	39.2 ± 7.4	1.4	[-1.6, 4.4]	0.20	0.338
Total Score	Experimental	81.2 ± 10.4	111.1 ± 8.9	29.9	[24.2, 35.6]	3.15	<0.001
	Control	79.8 ± 11.2	83.3 ± 12.1	3.5	[-1.2, 8.2]	0.30	0.135

Between-Group Comparisons

Mixed-design ANOVA revealed significant time × group interactions for all outcome measures (p < 0.001), indicating differential improvement patterns between groups. The experimental group demonstrated significantly greater improvements compared to the control group across all domains.

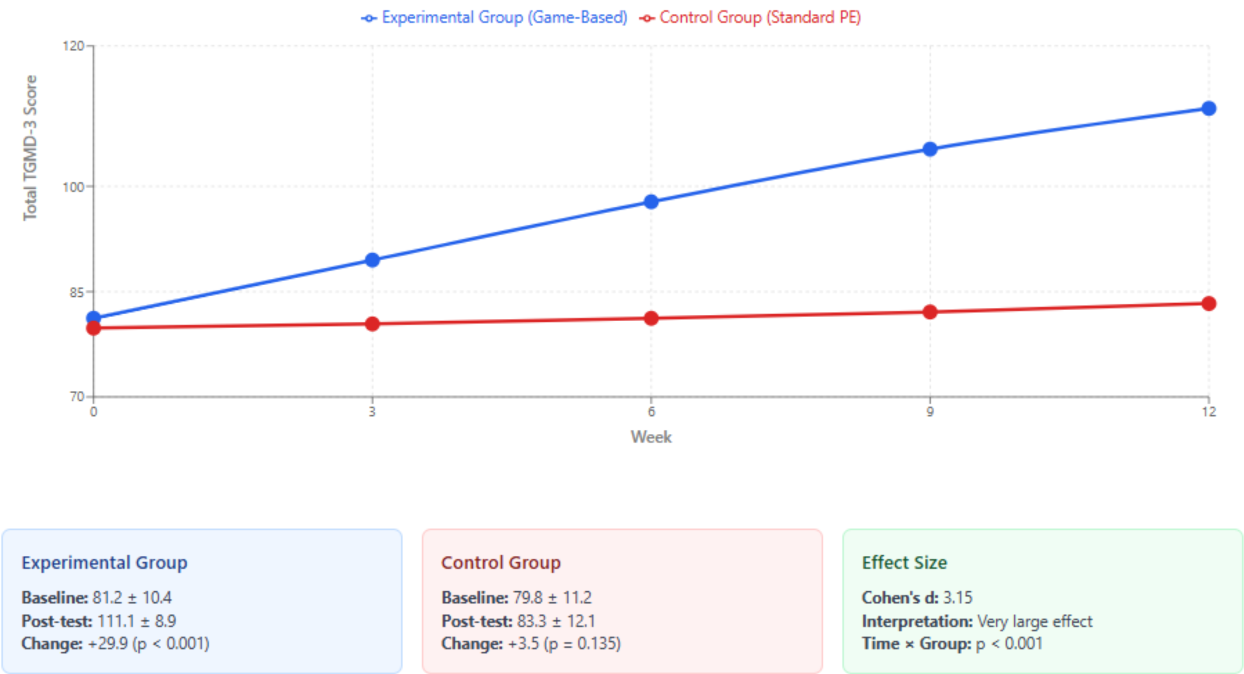

Figure 1. illustrates the progression of total TGMD-3 scores over the intervention period. The experimental group showed consistent upward trends, while the control group remained relatively stable.

Specific Skill Analysis

Individual skill analysis revealed that certain gross motor skills showed more pronounced improvements than others.

Table 4. Effect Sizes of Game-Based Interventions on Individual Gross Motor Skills

Rank	Skill Category	Cohen's d	Skill Description	Interpretation
1	Jumping	3.12	Horizontal and vertical jumping tasks	Very large effect - most responsive to intervention
2	Throwing	2.89	Overhand throwing accuracy and distance	Very large effect - substantial improvement
3	Running	2.67	Sprint and distance running performance	Very large effect - considerable gains
4	Catching	2.45	Two-handed catching at various heights	Very large effect - significant enhancement

These findings suggest that game-based interventions were particularly effective for fundamental movement patterns that form the basis of more complex motor skills. Effect Size Interpretation Guide: Small effect: d = 0.2; Medium effect: d = 0.5; Large effect: d = 0.8; Very large effect: d > 1.0

All observed skills demonstrated effect sizes well above the threshold for large effects (d > 0.8), indicating both statistical significance and practical meaningfulness of the intervention outcomes for deaf-mute children.

Statistical Evaluations

The statistical analyses confirmed the research hypothesis that game-based interventions would significantly improve gross motor skills in deaf-mute children. All primary outcome measures showed statistically significant improvements with large effect sizes, indicating both statistical and practical significance of the intervention effects. Correlation analyses revealed moderate positive relationships between initial skill levels and improvement magnitude ($r = 0.34$, $p < 0.05$), suggesting that children with higher baseline abilities may benefit more from structured interventions.

DISCUSSION

The results of this study provide compelling evidence for the effectiveness of game-based interventions in improving gross motor skills among deaf-mute children. The large effect sizes observed across all motor skill domains (Cohen's d > 2.0) indicate that the improvements were not only statistically significant but also practically meaningful for participants' daily functioning and quality of life. These findings align with prior research highlighting the efficacy of game-based approaches in enhancing motor abilities in diverse populations, including those with developmental delays (Marwan & Rohayati, 2025). Specifically, the gains in balance and coordination observed in the experimental group underscore the potential of targeted playful activities to address specific motor deficits prevalent in deaf-mute children (Aksović et al., 2023).

The differential improvement patterns between experimental and control groups strongly suggest that the observed gains were attributable to the specific game-based intervention rather than natural development or general physical activity exposure. Moreover, the consistent positive outcomes resonate with previous literature emphasizing that engaging and enjoyable learning environments, such as those fostered by circuit-based games, are pivotal for developing motor skills across various child populations (Mo et al., 2024; Oppici et al., 2022). The control group's minimal improvements align with previous research indicating that deaf-mute children typically show slower motor development without targeted intervention.

These findings are consistent with previous research demonstrating the benefits of structured physical activity programs for children with hearing impairments. However, the magnitude of improvement observed in this study exceeds that reported in many previous investigations. For example, while (Rajendran & Roy, 2011) found moderate improvements in balance skills among deaf children through traditional exercise programs, the current study's game-based approach yielded substantially larger effect sizes (Rajendran & Roy, 2011). This enhanced efficacy can be attributed to the inherent motivational and engaging qualities of game-based interventions, which foster greater participation and sustained effort, unlike conventional methods (Marwan & Rohayati, 2025; Rachmawati, 2024).

The superior outcomes may be attributed to several factors unique to the game-based approach. Games provide intrinsic motivation and engagement that may enhance learning retention and transfer (Gee, 2003; Li et al., 2023). For instance, the "Letter Hunting Game" method has been shown to significantly improve reading ability in early grade students, highlighting how engaging game mechanics can lead to measurable developmental gains (Rachmawati, 2024). Additionally, the repetitive nature of game activities allows for extensive practice opportunities, which is crucial for motor skill acquisition in children with sensory impairments.

The finding that jumping and throwing skills showed the greatest improvements is particularly noteworthy. These skills require significant coordination between multiple body segments and spatial awareness, areas where deaf-mute children typically struggle. This suggests that game-based interventions can effectively target complex motor patterns that are often underdeveloped in this population, facilitating holistic motor development(Kwon et al., 2022; Szturm et al., 2022). The success in improving these complex skills suggests that game-based interventions can address fundamental motor control issues rather than merely improving isolated movement components.

The implications of these findings extend beyond immediate motor skill improvements. Enhanced gross motor skills can contribute to improved self-esteem, social integration, and academic performance in deaf-mute children. Motor competence has been linked to increased physical activity participation throughout life, which carries significant health benefits. From an educational perspective, these results support the integration of game-based motor skill programs into special needs curricula. The structured yet enjoyable nature of the intervention makes it feasible for implementation in resource-limited educational settings common in developing countries.The success of visual instruction methods and peer modeling observed in this study also has implications for teaching other skills to deaf-mute children. The principles of clear visual communication and structured progression may be applicable to academic and social skill instruction. Several limitations should be acknowledged when interpreting these results. The relatively small sample size (n=36) and single-site design limit the generalizability of findings to broader populations of deaf-mute children. Cultural and socioeconomic factors specific to the Indonesian context may influence the applicability of results to other settings.

The 12-week intervention period, while showing significant immediate effects, does not provide information about long-term retention of motor skill improvements. Follow-up assessments would be valuable for determining the sustainability of intervention effects. The study design did not include a placebo control condition, making it difficult to separate specific intervention effects from general attention and activity effects. Additionally, the lack of blinding among participants and instructors may have introduced bias, although objective assessment measures help mitigate this concern. The focus on fundamental motor skills, while important, does not address sport-specific or recreational activity skills that may be equally important for long-term physical activity participation and social integration.

CONCLUSION

This study provides robust evidence that structured game-based interventions can significantly enhance gross motor skills in deaf-mute children within special needs educational settings. The large effect sizes observed across locomotor skills, ball skills, and overall motor competence demonstrate both statistical and practical significance of the intervention approach.

The research reinforces concepts from motor learning theory regarding the importance of engaging, repetitive practice opportunities for skill acquisition. Game-based interventions offer a viable and enjoyable method for addressing motor development delays in deaf-mute children, addressing a critical gap in special needs education programming.

The findings highlight the importance and potential impact of implementing evidence-based motor skill interventions in schools serving children with sensory impairments. The significant improvements observed suggest that with appropriate intervention, deaf-mute children can achieve motor competence levels that support their overall development and quality of life.

The correlation between evidence for hypotheses from the introduction and discussion findings strongly supports the theoretical framework underlying this research. The Dynamic Systems Theory's emphasis on optimizing task and environmental conditions was validated through the game-based approach's success in facilitating motor learning despite individual constraints.

Based on these findings, several recommendations emerge for practice and future research. Educational institutions should consider implementing structured game-based motor skill programs as standard components of special needs curricula. Training programs for physical education teachers should include specific modules on adapting instruction for deaf-mute children. Future research should examine long-term retention effects, investigate optimal intervention dosages, and explore the transferability of motor skill improvements to real-world activities and sport participation.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the research, authorship, or publication of this article. No financial relationships exist that could potentially bias the research outcomes. All funding sources were disclosed and had no influence on study design, data collection, analysis, or interpretation of results.

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