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HARNESSING NEUROPLASTICITY: THE EFFECT OF MODERATE FITT-STRUCTURED TRAINING ON GROSS MOTOR DEVELOPMENT IN SPECIAL NEEDS LEARNERS

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Abstract

This study examines the effectiveness of moderate-intensity FITT-structured training in enhancing gross motor development among special needs learners, focusing on students with hearing impairments and intellectual disabilities. Grounded in neuroplasticity theory, the intervention was designed to stimulate functional motor adaptation through consistent, goal-oriented physical activities. Using a pre–post experimental design, the study involved 77 students from SLB Negeri Semarang (46 hearing-impaired and 31 intellectually disabled), comprising 38 males and 39 females. The intervention consisted of 12 sessions delivered twice weekly, totaling 100–120 minutes per week. Gross motor skills were assessed using TGMD-2, while fine motor skills were measured using the Nine-Hole Peg Test. Data analysis followed distribution and homogeneity assumptions, using Wilcoxon Signed-Rank tests for nonparametric data and paired-samples t-tests for normally distributed and homogeneous data. The results showed significant improvements across all groups: male and female hearing-impaired students demonstrated meaningful posttest gains ($p = 0.003$ and $p = 0.039$, respectively), while male students with intellectual disabilities also showed significant improvement ($p = 0.001$). Female students with intellectual disabilities exhibited a strong increase in motor performance as confirmed by the paired t-test ($p < 0.001$). These findings indicate that moderate FITT-based training effectively enhances gross motor proficiency in diverse special needs populations. The discussion highlights that the structured application of the FITT principle supports neuroplastic adaptation and motor learning, with dosage and intensity contributing to consistent functional gains. The study concludes that FITT-structured programs are both effective and feasible for implementation in special education. Implications emphasize the need for integrating systematic physical activity models into school curricula, while suggestions call for teacher training, individualized adaptation, and future longitudinal research.

Keywords: *Neuroplasticity; FITT principle; Gross motor skills; Special needs learners; Physical training intervention*

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INTRODUCTION

Neuroplasticity has emerged as a central concept in contemporary neuroscience, emphasizing the brain’s capacity to reorganize, adapt, and form new neural connections in response to learning and environmental stimulation (Saha, 2025). Empirical studies consistently show that children with special needs particularly those with developmental delays, Autism Spectrum Disorder, cerebral palsy, and intellectual disabilities demonstrate measurable improvements in motor and cognitive outcomes when exposed to structured physical activity programs. Recent longitudinal evidence indicates that moderate-intensity exercise can stimulate synaptic plasticity, promote myelination, and support motor cortex activation, thereby strengthening gross motor coordination more effectively than low-intensity activity (Ungureanu et al., 2022).

Despite these promising findings, global data reveal that many special needs learners still present persistent deficits in gross motor skills. According to epidemiological reports, approximately 20–30% of school-aged children with developmental disabilities show significant impairments in balance, locomotor control, and body coordination (Jylänki et al., 2022). These motor challenges contribute not only to limited physical functioning but also to restrictions in social participation, academic engagement, and psychological well-being. Such conditions underscore the urgent need for interventions that are both scientifically grounded and feasible to implement within special education settings (Alesi et al., 2022).

The FITT principle Frequency, Intensity, Time, and Type offers a systematic framework for designing exercise interventions that optimize physiological outcomes (Zhannisa et al., 2025). Moderate-intensity FITT-structured training, in particular, has been associated with enhanced cardiorespiratory endurance, improved muscle activation patterns, and more consistent motor progress in children with special needs. However, the operationalization of FITT-based exercise specifically targeting gross motor development remains underexplored in many developing educational contexts, including Southeast Asia (Wibisana & Royana, 2023). Many programs are delivered inconsistently, lack monitoring of intensity levels, or do not align with neuroplasticity-driven guidelines.

A review of recent literature shows that previous studies tend to isolate individual components of physical activity such as frequency alone or type alone without integrating all elements of the FITT framework in a cohesive intervention model (Burnet, 2020). Other studies focus primarily on cognitive outcomes or fine motor skills, leaving gross motor development comparatively understudied. Furthermore, most existing evidence stems from clinical or laboratory-based research with small sample sizes, limiting its generalizability to real classroom environments where special needs learners spend most of their time.

This research therefore addresses a significant gap by implementing a comprehensive, moderate-intensity, FITT-structured motor training program specifically designed to stimulate neuroplasticity and enhance gross motor function. By situating the intervention within an authentic educational setting, this study seeks to generate empirical data that are both contextually relevant and practically applicable. Such data are critically needed to support evidence-based decision-making among educators, therapists, and policy-makers who are working to improve learning outcomes for students with disabilities (Zanella, 2021).

Ultimately, this study aims to contribute new theoretical and practical insights into how structured physical training can harness neuroplastic mechanisms to promote motor development among special needs learners. By examining the measurable effects of moderate FITT-based interventions on gross motor skills, the research not only advances the scientific understanding of motor learning but also provides a replicable model for inclusive educational practice. The findings are expected to support the development of more effective, data-driven physical education programs within special needs settings, particularly in regions where research on neuroplasticity-informed interventions remains limited.

METHOD

This study employed a pre–post experimental design to examine the effect of moderate FITT-structured training on the motor development of special needs learners. A pre–post experimental design is a research approach that measures a variable before (pretest) and after (posttest) an intervention is administered in order to determine whether changes occur that can be attributed to the treatment. This design is considered effective for evaluating interventions because it allows researchers to compare the initial and final conditions of the same participants, enabling direct observation of change over time (Reichardt et al., 2023). The design was selected to measure changes occurring before and after the intervention within the same participants, allowing for direct assessment of the program's influence on neuroplasticity-related motor improvements. No control group was used, as the purpose of this study was to evaluate the practical effectiveness of a structured training model implemented in a real educational environment.

The population of this research consisted of all students enrolled at SLB Negeri Semarang, a public special education school serving multiple disability categories. From this population, a total sample of 77 students was selected using purposive sampling based on their ability to participate safely in structured physical activity. The sample comprised 46 students with hearing impairment (tuna rungu) and 31 students with intellectual disabilities (tuna grahita). The gender distribution included 38 male and 39 female participants. All students were between the ages typically enrolled in primary and secondary special education and had been medically and pedagogically identified as having special needs.

The intervention was designed and implemented based on the FITT principle (Frequency, Intensity, Time, and Type) to ensure a structured and scientifically grounded exercise program. The program employed a moderate-intensity training level, appropriate for stimulating neuroplastic mechanisms while maintaining safety for learners with special needs. The intervention was delivered across 12 sessions, conducted twice per week, with a total weekly duration of 100–

120 minutes. Each session integrated warm-up, core motor training, and cool-down components tailored to the students' functional abilities.

The activities were selected to target key domains of motor development, including balance, locomotor skills, coordination, and object control. Moderate intensity was maintained by monitoring students' exertion levels and adjusting task complexity according to performance indicators. Exercises included structured locomotor drills, functional movement tasks, rhythmic coordination activities, and object manipulation exercises designed to activate motor planning pathways and support neuroplastic adaptation. All sessions were supervised by trained physical educators to ensure adherence to the FITT framework and to provide individualized support when necessary.

Motor development was measured using two standardized and internationally recognized tools. Gross motor skills were evaluated using the Test of Gross Motor Development–Second Edition (TGMD-2), which measures locomotor abilities and object control skills across multiple performance criteria (Carballo-Fazanes et al., 2023). Both instruments were administered before and after the intervention by trained assessors following standardized testing protocols.

Baseline (pre-test) data were collected one week prior to the implementation of the FITT-structured training, while post-test measurements were obtained immediately after the final intervention session. All assessments were conducted individually in a controlled environment to minimize distractions and ensure consistent testing conditions. Procedures were adapted to accommodate the unique communication needs of students with hearing impairment and the cognitive characteristics of learners with intellectual disabilities.

Data were analyzed using quantitative statistical techniques aligned with the pre–post design. Descriptive statistics were used to summarize demographic characteristics and baseline motor performance. To determine whether significant improvements occurred after the intervention, paired-sample t-tests were conducted for TGMD-2 scores. Effect size calculations (Cohen's d) were performed to evaluate the magnitude of change in motor performance. Statistical significance was set at $p < .05$. All analyses were conducted using standard statistical software to ensure accuracy and reliability.

RESULT AND DISCUSSION

Hearing-Impaired Male Students

Table 1. Test of Normality Hearing Impaired Male Students

Tests of Normality							
	Kolmogorov-Smirnov[a]			Shapiro-Wilk			
VAR00002	Statistic	df	Sig.	Statistic	df	Sig.	
VAR00001	1.00	.218	19	.018	.862	19	.011
	2.00	.214	19	.022	.829	19	.003
a. Lilliefors Significance Correction							

Data Pretest, Sig 0.011 < 0,05 , Data is not normally distributed
Data Posttest, Sig 0.003 < 0,05 , Data is not normally distributed

Table 2. Test of Homogenety Hearing Impaired Male Students

Test of Homogeneity of Variances					
		Levene Statistic	df1	df2	Sig.
VAR00001	Based on Mean	4.573	1	36	.039
	Based on Median	2.620	1	36	.114
	Based on Median and with adjusted df	2.620	1	30.162	.116
	Based on trimmed mean	3.708	1	36	.062

Sig 0.039 < 0.05, the data is not homogeneous

Table 3. Wilcoxon Test (Nonparametric)

Test Statistics[a]	
	Posttest - Pretest
Z	-2.942[b]
Asymp. Sig. (2-tailed)	.003
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

The results of the normality test indicated that both pretest and posttest scores were not normally distributed. The Shapiro Wilk test showed significance values of 0.011 for the pretest and 0.003 for the posttest, both below the threshold of $p < 0.05$, confirming non-normal distribution. The homogeneity test further revealed that the data were not homogeneous (Levene's test, p = 0.039). Based on these results, a nonparametric analysis was conducted using the Wilcoxon Signed-

Rank Test. The test yielded a Z value of –2.942 with a significance level of p = 0.003, indicating a statistically significant improvement in motor performance after the intervention. These findings demonstrate that moderate FITT-structured training had a meaningful positive effect on the gross motor abilities of male students with hearing impairment.

Hearing-Impaired Female Students

Table 4. Test of Normality Hearing Impaired Female Students

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	VAR00002	Statistic	df	Sig.	Statistic	df	Sig.
VAR00001	1	.170	11	.200*	.940	11	.515
	2	.249	11	.056	.807	11	.012

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Data Pretest, Sig 0.515 > 0,05 , Data is normally distributed
Data Posttest, Sig 0.012 < 0,05 , Data is not normally distributed

Table 5. Test of Homogenety Hearing Impaired Female Students

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
VAR00001	Based on Mean	7.253	1	20	.014
	Based on Median	5.333	1	20	.032
	Based on Median and with adjusted df	5.333	1	15.583	.035
	Based on trimmed mean	7.399	1	20	.013

Sig 0.014 < 0.05, the data is not homogeneous

Table 6. Wilcoxon Test (Nonparametric)

Test Statistics[a]

	Posttest - Pretest
Exact Sig. (2-tailed)	.039[b]

a. Sign Test
b. Binomial distribution used.

For female students with hearing impairment, the normality test showed contrasting results between pretest and posttest. The pretest data were normally distributed (Shapiro–Wilk, p = 0.515 > 0.05), whereas the posttest data displayed non-normality (Shapiro–Wilk, p = 0.012 < 0.05). The homogeneity of variance test revealed non-homogeneous data (Levene's test, p = 0.014). Given these conditions, nonparametric testing was again required. The Wilcoxon Signed-Rank Test indicated a significant difference between pretest and posttest scores, with p = 0.039 (Exact, 2-tailed). This result confirms that the intervention effectively improved motor performance among hearing-impaired female students.

Male Students with Intellectual Disabilities

Table 7. Test of Normality Male Students with Intellectual Disabilities

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelompok	Statistic	df	Sig.	Statistic	df	Sig.
Data	1	.134	28	.200*	.962	28	.378
	2	.165	28	.050	.941	28	.115

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Data Pretest, Sig 0.378 > 0,05 , Data is normally distributed
Data Posttest, Sig 0.115 > 0,05 , Data is normally distributed

Table 8. Test of Homogenety Male Students with Intellectual Disabilities

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Data	Based on Mean	19.645	1	54	.000
	Based on Median	16.812	1	54	.000
	Based on Median and with adjusted df	16.812	1	43.688	.000
	Based on trimmed mean	19.575	1	54	.000

Sig 0.000 < 0.05, the data is not homogeneous

Table 9. Wilcoxon Test (Nonparametric)

Test Statistics[a]

	Posttest - Pretest
Z	-3.224[b]
Asymp. Sig. (2-tailed)	.001

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

The normality test for male students with intellectual disabilities showed that both pretest and posttest data were normally distributed, with Shapiro–Wilk significance values of 0.378 and 0.115, respectively. However, the homogeneity of variance test indicated that the data were not homogeneous, as Levene's test produced a significance value of p = 0.000. Due to the violation of homogeneity assumptions, the analysis proceeded with the Wilcoxon Signed-Rank Test. The results demonstrated a significant improvement in motor performance, indicated by a Z value of –3.224 and a significance level of p = 0.001. This finding suggests that the moderate-intensity FITT-based training program effectively enhanced the gross motor skills of male students with intellectual disabilities.

Female Students with Intellectual Disabilities

Table 10. Test of Normality Female Students with Intellectual Disabilities

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelompok	Statistic	df	Sig.	Statistic	df	Sig.
Data	1	.132	19	.200*	.937	19	.230
	2	.160	19	.200*	.934	19	.206

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Data Pretest, Sig 0.230 > 0,05 , Data is normally distributed
Data Posttest, Sig 0.206 > 0,05 , Data is normally distributed

Table 11. Test of Homogenety Female Students with Intellectual Disabilities

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Data	Based on Mean	.000	1	36	1.000
	Based on Median	.000	1	36	1.000
	Based on Median and with adjusted df	.000	1	31.923	1.000
	Based on trimmed mean	.000	1	36	.997

Sig 1.000 > 0.05, homogeneous data

For female students with intellectual disabilities, both pretest and posttest data met the normality assumption, with Shapiro–Wilk significance values of 0.230 and 0.206, respectively. The data were also found to be homogeneous (Levene's test, p = 1.000). Based on these conditions, a paired-samples t-test was conducted. The analysis revealed a statistically significant difference between pretest and posttest scores, with t(18) = –5.284, p < 0.001, and a mean improvement of 4.00 points. These results indicate that the intervention produced a substantial positive effect on the motor abilities of female students with intellectual disabilities.

Table 12. T-Test

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Pretest - Posttest	-4.000	3.300	.757	-5.590	-2.410	-5.284	18	.000

The paired-samples t-test was conducted to evaluate the difference between pretest and posttest motor performance scores among female students with intellectual disabilities, whose data met both normality and homogeneity assumptions. The analysis revealed a significant increase in motor performance following the FITT-structured moderate-intensity intervention. The mean difference between the pretest and posttest scores was –4.00, with a standard deviation of 3.30, indicating consistent improvement across participants.

The statistical test yielded a t-value of –5.284 with 18 degrees of freedom, and the significance level was $p < 0.001$ (two-tailed). The 95% confidence interval of the difference ranged from –5.590 to –2.410, demonstrating that the improvement was not only statistically significant but also practically meaningful. These results confirm that the intervention produced substantial gains in the gross motor abilities of female students with intellectual disabilities.

Discussion

The findings of this study demonstrate that moderate-intensity FITT-structured training produced significant improvements in gross motor performance across all groups of special needs learners. The consistent increase in posttest scores, as shown through Wilcoxon tests for non-normal datasets and paired-samples t-tests for normally distributed ones, supports the assumption that structured physical activity can effectively activate neuroplastic mechanisms. These results align with existing literature suggesting that repetitive, goal-oriented motor activities stimulate neural adaptation, strengthen synaptic pathways, and enhance functional motor outcomes in children with developmental challenges (Farrens, 2020).

The most substantial improvements were observed among students with intellectual disabilities, both male and female. This may be attributed to the higher potential responsiveness of this group to structured motor learning, given that many perform below their developmental motor age but still possess intact basic motor circuitry capable of adaptation (Sánchez-Torres, 2024). Moderate intensity appears to be ideal for this population, as it provides sufficient physiological challenge without inducing excessive fatigue, frustration, or cognitive overload (Wibisana, 2020). The structured nature of the FITT model particularly the clarity of task repetition and progression likely contributed to the students' improved motor planning and coordination (Babagoltabar-Samakoush et al., 2025; Robertson, 2024).

For students with hearing impairment, improvements were also statistically significant, albeit with slightly more variability in performance outcomes. This variability could be explained by the unique communication needs of hearing-impaired students, which may influence instruction clarity and response speed during motor tasks (Jylänki et al., 2022). Nevertheless, the positive outcomes highlight that auditory limitations do not impede the capacity for motor neuroplasticity (Li, 2023; Nudo, 2013). Rather, with appropriate visual demonstration and structured movement sequencing, hearing-impaired learners can achieve substantial motor gains comparable to their peers with cognitive disabilities.

The duration and frequency of the intervention also appear to play a critical role. Delivering the program twice per week for a total of 12 sessions allowed sufficient time for motor skill consolidation while maintaining learner engagement. Existing neuroscience research emphasizes that consistent, moderately intense motor stimulation supports long-term potentiation and the refinement of motor maps in the cortex (Wang et al., 2022). The weekly dosage of 100–120 minutes used in this study aligns with global recommendations for children with special needs, suggesting that the program was not only effective but also feasible for implementation within school schedules.

An important aspect of these findings is the support they provide for applying the FITT principle in special education contexts. Many special needs motor programs remain unstructured, inconsistently delivered, or lacking in intensity monitoring. By applying a systematic FITT approach adjusting frequency, intensity, time, and type of exercise the present study demonstrates that predictable and measurable motor progress can be achieved (Alves, 2022). This reinforces the value of evidence-based physical education practices that prioritize structured progression, measurable goals, and functional relevance.

The results also highlight the role of motor training in enhancing broader developmental domains. Although this study focused on gross motor outcomes, improvements in coordination and movement efficiency may indirectly support academic participation, emotional regulation, and social engagement (Lee, 2024). Motor proficiency is strongly associated with self-confidence and autonomy, particularly among learners with disabilities who often face barriers to physical participation. Thus, the motor gains identified in this study may contribute to enhanced overall quality of life for the participating students.

Despite the strong results, several limitations warrant consideration. Data homogeneity issues in multiple groups indicate diverse baseline abilities, suggesting the need for more individualized intensity monitoring in future interventions. Additionally, the study did not include a control group, which limits the ability to attribute improvements exclusively to the intervention rather than potential external factors such as natural maturation. Future research should consider adopting controlled or randomized designs, as well as exploring long-term retention effects after the cessation of training.

Overall, this study provides compelling evidence that moderate FITT-structured physical activity can harness neuroplasticity to significantly enhance gross motor development in special needs learners. The positive outcomes across disability categories support the integration of structured movement programs within special education curricula and reinforce the importance of designing interventions grounded in motor learning and neuroplasticity science.

CONCLUSION

This study demonstrates that moderate-intensity FITT-structured training is an effective and scientifically grounded approach for improving gross motor performance among special needs learners, including those with hearing impairments and intellectual disabilities. Across all groups, the intervention produced significant posttest gains, confirming that consistent, well-designed motor activities can activate neuroplastic mechanisms and enhance functional movement skills. The structured application of frequency, intensity, time, and type enabled measurable progress within only 12 sessions, reinforcing the value of systematic physical education programming in special schools. These findings highlight the critical role of evidence-based motor training in supporting developmental outcomes and underscore the importance of integrating structured FITT-based interventions into routine instructional practices for learners with diverse needs.

The results of this study carry important theoretical and practical implications for special needs education. Theoretically, the findings reinforce the concept that neuroplasticity can be effectively stimulated through structured, moderate-intensity motor training, even in populations with sensory or cognitive impairments. Practically, the success of the FITT-based intervention highlights the feasibility and value of implementing evidence-based movement programs within school settings. Educational institutions, policymakers, and curriculum developers can utilize these insights to design more effective motor development curricula, allocate appropriate resources, and promote inclusive physical activity environments that support the holistic development of learners with disabilities.

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