IJPESS
Indonesian Journal of Physical Education and Sport Science
p-ISSN 2775-765X | e-ISSN 2776-0200
Volume 6, No. 4, December 2026. Page. 732-746
http://journal.unucirebon.ac.id/index.php ijpess

Neuroplasticity-Oriented FITT Training: Fine and Gross Motor Development by Gender in Students with Intellectual Disabilities

Muh Isna Nurdin Wibisana[1*], Husnul Hadi[2], Ibnu Fatkhu Royana[3], Muhammad Atiq Noviudin Pritama[4], Mert Kurnaz[5]

[1,2,3]Department of Physical Education, Health and Recreation, Universitas PGRI Semarang, Indonesia

[4]Department of Sports Coaching Education, Universitas Negeri Malang, Indonesia

[5]Department of Physical Education and Sport Teaching, Haliç University, Turkiye

*Corresponding Author: Muh Isna Nurdin Wibisana, e-mail: muhisna@upgris.ac.id

Received: 07 July 2026, Approved: 10 September 2026, Published: 30 December 2026

Abstract

Study purpose. This study aimed to examine the effects of FITT-based training on fine and gross motor development among students with intellectual disabilities through separate gender-based analyses

Materials and methods. This study employed a randomized trial using a quasi-experimental pretest–posttest design. A total of 70 students with intellectual disabilities (48 boys and 22 girls), aged 6–10 years, were recruited from eight special education schools in Indonesia using purposive sampling. Participants completed a FITT-based training program conducted twice weekly for 12 sessions at moderate intensity (60–75% of maximum heart rate), with each session lasting 45–60 minutes. Fine motor performance was assessed using the Nine-Hole Peg Test (NHPT), while gross motor development was measured using the Test of Gross Motor Development–Second Edition (TGMD-2). Data were analyzed using descriptive statistics, Wilcoxon Signed-Rank tests, and Mann–Whitney U tests.

Results. Significant improvements were observed in fine motor performance among boys ($Z = -3.320$, $p = .001$) and girls ($Z = -2.950$, $p = .003$). Gross motor performance also improved significantly among boys ($Z = -5.770$, $p < .001$) and girls ($Z = -4.030$, $p < .001$). However, no significant gender differences were found in fine motor gain scores ($p = .795$) or gross motor gain scores ($p = .512$), indicating comparable intervention effects across gender groups.

Conclusions. FITT-based training effectively improved fine and gross motor performance among students with intellectual disabilities regardless of gender. The findings support the potential role of neuroplasticity-oriented interventions in promoting motor development and functional performance in educational and rehabilitation settings.

Keywords: Intellectual Disabilities, Neuroplasticity, FITT-Based Training, Fine Motor Skills, Gross Motor Development.

DOI: https://doi.org/10.52188/ijpess.v6i3.2311
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Introduction

Intellectual disability is a neurodevelopmental condition characterized by significant limitations in intellectual functioning and adaptive behavior, including conceptual, social, and practical skills that emerge during the developmental period (Aljadaan, 2024; Babagoltabar-Samakoush et al., 2025). These limitations affect not only cognitive performance but also various aspects of physical and motor development, leading to deficits in fine motor skills such as hand-eye coordination, object manipulation, and writing abilities and gross motor skills, including balance, locomotor movements, and body coordination (Demir, 2022; Marín-Suelves, 2023). In educational settings, such motor impairments reduce participation in physical education, restrict social engagement, and hinder the performance of daily functional activities. Consequently, the development of fine and gross motor abilities has become a critical focus of intervention programs designed to enhance adaptive functioning and participation among students with intellectual disabilities.

Fine motor skills involve precise and coordinated movements of the small muscles of the hands and fingers, which are essential for writing, buttoning clothes, manipulating learning materials, and using educational tools (Diril et al., 2025; Wibisana et al., 2026). Deficits in fine motor function hinder students' ability to complete academic tasks independently and efficiently. Gross motor skills, by contrast, involve the coordinated movement of large muscle groups that enable locomotor and object-control activities, including walking, running, jumping, and balancing (Araujo et al., 2023). For students with intellectual disabilities, limitations in gross motor competence reduce opportunities for physical activity participation and restrict social engagement with peers (Wibisana et al., 2025). Previous studies consistently report that motor deficits represent one of the most prevalent developmental challenges among individuals with intellectual disabilities and may persist throughout childhood and adolescence if appropriate interventions are not provided (Kavanagh et al., 2023).

Previous studies consistently report that motor deficits represent one of the most prevalent developmental challenges among individuals with intellectual disabilities, affecting both fine and gross motor domains. Field observation data from a preliminary study conducted across eight special education schools in Semarang, Indonesia, involving 187 students with mild intellectual disabilities aged 7–10 years, revealed consistently low motor performance in both domains prior to any structured intervention (Wibisana et al., 2026). Specifically, fine motor completion times on the Nine-Hole Peg Test (NHPT) averaged 41.29 ± 21.11 seconds for male students and 49.71 ± 32.79 seconds for female students, substantially exceeding age-normative benchmarks. Gross motor locomotor scores assessed using the Test of Gross Motor Development–Second Edition (TGMD-2) averaged 14.68 ± 7.56 for males and 14.11 ± 8.47 for females, placing most participants in the 'low' to 'very low' performance categories. These field-based findings confirm that students with intellectual disabilities in Indonesian special education settings demonstrate marked deficits in motor coordination attributable to limited sensorimotor stimulation and the absence of structured, evidence-based physical activity programs. Crucially, that preliminary study identified neuroplastic potential as present but not yet optimized, underscoring the need for a structured intervention capable of translating this potential into measurable functional improvements (Wibisana et al., 2026).

Neuroplasticity the brain's capacity to reorganize its structure, function, and neural pathways in response to environmental stimulation, learning experiences, and repeated motor activities offers a critical theoretical foundation for designing motor interventions (Saha, 2025; Ungureanu et al., 2022; Vacchini et al., 2025). Previous studies have primarily focused on describing baseline motor performance, identifying motor deficits, and exploring the neuroplastic potential of students with intellectual disabilities prior to intervention (Wibisana

et al., 2026) Through neuroplastic mechanisms, the central nervous system can modify existing neural connections, strengthen synaptic efficiency, and establish new neural networks that support functional improvements (Dołęga et al., 2024). Physical exercise represents one of the most effective stimuli for promoting neuroplastic adaptation. Repeated and structured movement experiences stimulate synaptogenesis, enhance neural connectivity, and facilitate motor learning processes that contribute to improved movement efficiency and coordination (Romagnoli et al., 2025; Zhang et al., 2024). Aerobic exercise at moderate intensity corresponding to 60–75% of maximum heart rate has been specifically identified as the optimal dosage range for stimulating Brain-Derived Neurotrophic Factor (BDNF) production and hippocampal neurogenesis, which are the primary biological mechanisms of exercise-induced neuroplasticity (Revelo Herrera & Leon-Rojas, 2024). Hilderley et al. (2023) demonstrated that structured gross motor interventions produced measurable functional neuroplasticity changes in children with cerebral palsy, while Busquets et al. (2024) showed that acute exercise significantly enhanced motor learning and brain activity in children with developmental coordination disorder. These converging lines of evidence suggest that exercise-based interventions designed according to scientific training principles can effectively stimulate neuroplastic adaptation and promote improvements in motor function among children with neurodevelopmental conditions, including intellectual disabilities.

Among various exercise prescription models, the Frequency, Intensity, Time, and Type (FITT) principle is one of the most commonly recommended frameworks for designing systematic and individualized training programs (Claiborne, 2023; Wibisana et al., 2024). The FITT principle provides clear guidelines regarding how often exercise should be performed (frequency), the level of effort required (intensity), the duration of each training session (time), and the specific form of activity implemented (type). Its flexibility makes it particularly suitable for children and adolescents with disabilities, whose functional abilities and developmental characteristics require individualized program design. Stavrinou et al. (2025) demonstrated that FITT-based interval training significantly improved motor competence and physical fitness outcomes when parameters were systematically tailored to participants' capacity, while a systematic review by Yan et al. (2022) confirmed that appropriately prescribed FITT-based interventions contribute to improvements in physical fitness, motor competence, and functional performance among individuals with intellectual disabilities.

Furthermore, gender-based analyses have received limited attention in studies involving students with intellectual disabilities. Despite the growing evidence supporting physical activity for promoting neuroplastic adaptation, important research gaps remain. Previous investigations have primarily focused on describing baseline motor performance and exploring neuroplastic potential prior to intervention, without examining whether such potential can be translated into measurable improvements through structured programs (Wibisana et al., 2026). Furthermore, although evidence supports the effectiveness of physical activity in enhancing motor development among children with intellectual disabilities, limited studies have examined FITT-based training from an explicit neuroplasticity perspective, particularly with simultaneous assessment of both fine and gross motor outcomes. Equally importantly, gender-based analyses have received limited attention in this population: most prior investigations analyzed participants as a single group, potentially overlooking important patterns of motor adaptation that may emerge separately within male and female populations. Addressing these gaps simultaneously by evaluating the effects of FITT-based training on both fine and gross motor domains through a gender-based lens can provide a more comprehensive understanding of neuroplastic adaptation following structured motor training and contribute to the development of more individualized physical activity programs for students with intellectual disabilities.

Therefore, this study aimed to examine the effects of FITT-based training on fine and gross motor development among boys and girls with intellectual disabilities through separate

gender-based analyses. It was hypothesized that FITT-based training would significantly improve fine and gross motor performance in both gender groups, reflecting neuroplastic adaptation following repeated structured motor practice, with no significant difference in the magnitude of improvement between boys and girls. The novelty of this study lies in its integration of the neuroplasticity framework with a structured FITT-based intervention and its examination of motor adaptation patterns through separate gender-based analyses, contributing to the evidence base for neuroplasticity-oriented programs in adapted physical education and rehabilitation settings.

Materials and methods

Study participants

Participants were randomly assigned within their respective schools prior to the intervention. Motor performance was assessed before and after the implementation of the FITT-based training program to determine changes in fine and gross motor abilities. The study was conducted across eight special education schools in Indonesia. To ensure institutional confidentiality, the identities of participating schools were anonymized. All schools implemented the same FITT-based intervention protocol and followed standardized training procedures throughout the study period.

A total of 70 students with intellectual disabilities participated in this study, consisting of 48 boys and 22 girls aged between 6 and 10 years. Participants were recruited from eight special education schools using purposive sampling based on predetermined inclusion criteria. Students were eligible to participate if they: (1) had been formally identified as having an intellectual disability, (2) were able to understand and follow simple verbal instructions, (3) regularly attended school activities, and (4) obtained written informed consent from their parents or legal guardians. Both male and female students completed all stages of the intervention and assessment procedures. To ensure participant confidentiality, all personal information was anonymized prior to statistical analysis.

Ethical approval for the study was obtained from the relevant institutional authorities prior to data collection. Permission was also granted by participating schools and the parents or guardians of all participants. Participation was voluntary, and participants were free to withdraw from the study at any time without consequences. All collected data were treated confidentially and used exclusively for research purposes. The identities of participants and schools were anonymized throughout the study and publication process.

Study organization

This study employed a randomized trial using a quasi-experimental pretest-posttest design to investigate the effects of FITT-based training on fine and gross motor development among students with intellectual disabilities (Creswell & Creswell, 2018). The study was grounded in the neuroplasticity framework, which proposes that repeated and structured motor experiences can stimulate adaptive neural changes that support motor learning and functional improvement.

The intervention program was designed according to the FITT principle, encompassing Frequency, Intensity, Time, and Type as the primary components of exercise prescription. The program aimed to stimulate motor learning and support neuroplastic adaptation through repetitive and structured movement experiences. The intervention was conducted twice per week (Frequency) for a total of 12 training sessions. Exercise intensity (Intensity) was maintained at a moderate level corresponding to 60–75% of participants' maximum heart rate. To ensure that exercise intensity was maintained within the target range of 60–75% of maximum heart rate throughout each session, participants' heart rates were monitored using

pulse oximeters (fingertip-type oximeters) at three time points during each session: immediately after the warm-up phase, mid-session, and following the cool-down phase. Instructors adjusted the pace or difficulty of activities in real time based on the readings. Target heart rate ranges for each participant were calculated individually using the formula: HR**.** Each training session lasted between 45 and 60 minutes (Time). The selected activities (Type) incorporated both gross motor and fine motor exercises specifically adapted to the developmental characteristics of children with intellectual disabilities.

Gross motor activities included running, jumping, hopping, agility drills, and throwing exercises designed to improve locomotor skills, balance, coordination, object-control abilities, and overall movement competence. Fine motor activities consisted of bead stringing, plastic cup stacking, writing exercises, and pattern drawing activities aimed at improving finger dexterity, hand-eye coordination, manual precision, and fine motor control.

All intervention sessions followed identical training protocols and were supervised by trained instructors. Standardized implementation procedures were applied across all participating schools to ensure intervention consistency and fidelity.

Fine motor performance was assessed using the Nine-Hole Peg Test (NHPT), a standardized instrument commonly used to evaluate finger dexterity, hand-eye coordination, and upper-limb motor control. During the assessment, participants were instructed to place and remove nine pegs as quickly as possible. Performance was recorded in seconds, with lower completion times indicating better fine motor performance. Previous studies have reported excellent reliability for the NHPT, with reliability coefficients ranging from $r = 0.91$ to $r = 0.97$ (Temporiti et al., 2023).

Gross motor development was assessed using the Test of Gross Motor Development–Second Edition (TGMD-2). The TGMD-2 evaluates fundamental movement skills through locomotor and object-control components and is widely used to assess motor competence in children. Higher scores indicate better gross motor performance. The instrument has demonstrated high reliability, with a reported reliability coefficient of $r = 0.93$ (Simons et al., 2008).

To ensure assessment accuracy and consistency, all testing procedures were administered by professionals with expertise in psychomotor development, adapted physical activity, and education for children with special needs. Prior to data collection, assessors received standardized training regarding test administration and scoring procedures.

The study was conducted in three phases: pretest assessment, intervention implementation, and posttest assessment. During the pretest phase, participants completed baseline assessments using the NHPT and TGMD-2 instruments. Following the baseline evaluation, participants engaged in the FITT-based training program for 12 sessions according to the established intervention protocol. Upon completion of the intervention period, posttest assessments were administered using the same instruments and procedures employed during the baseline assessment. All assessments were conducted under similar environmental conditions to minimize measurement bias and enhance data consistency across participating schools.

Statistical analysis

Data were analyzed using IBM SPSS Statistics software. Descriptive statistics, including means, standard deviations, gain scores, and percentage improvements, were calculated to summarize changes in motor performance following the intervention. Gain scores were computed by subtracting pretest scores from posttest scores, with negative values indicating improvements in NHPT performance and positive values indicating improvements in TGMD-2 performance. Prior to inferential analyses, homogeneity of variance was examined using Levene's test. Differences in motor improvements among participating school groups

were analyzed using One-Way Analysis of Variance (ANOVA), while Kruskal–Wallis tests were conducted as nonparametric confirmatory analyses when statistical assumptions were violated. Significant findings were followed by post hoc analyses to identify specific group differences. To address the study objectives, all analyses were performed separately for boys and girls to examine intervention outcomes within each gender group, and statistical significance was established at $p < 0.05$.

Ethical Approval

This study received ethical approval from the Institute for Research and Community Service (LPPM), Universitas PGRI Semarang, Indonesia, under ethical clearance No. 030.B/LPPM-UPGRIS/VII/2025. The study was declared ethically appropriate based on the seven WHO 2011 ethical standards and the 2016 CIOMS Guidelines. Written informed consent was obtained from the parents or legal guardians of all participants prior to their participation in the study.

Results

The study results should be presented in Table 1 and described in a logical sequence.

1. Descriptive Statistics

Table 1. Descriptive Statistics of Fine Motor Skill Scores by Gender

Gender	N	Pretest Mean ± SD	Posttest Mean ± SD	Mean Difference
Male	48	42.81 ± 22.12	36.90 ± 20.45	-5.92
Female	22	46.77 ± 31.53	39.82 ± 28.48	-6.95

Table 1 presents the descriptive statistics of fine motor skill scores for male and female participants. Before the intervention, male participants demonstrated a mean fine motor score of 42.81 seconds (SD = 22.12), whereas female participants recorded a mean score of 46.77 seconds (SD = 31.53). Following the intervention, the mean fine motor score decreased to 36.90 seconds (SD = 20.45) for males and 39.82 seconds (SD = 28.48) for females.

The reduction in fine motor completion time indicates an improvement in fine motor performance for both groups. Female participants showed a slightly greater mean improvement (-6.95 seconds) compared with male participants (-5.92 seconds). However, descriptive statistics alone do not indicate whether these differences are statistically significant.

Table 2. Descriptive Statistics of Gross Motor Skill Scores by Gender

Gender	N	Pretest Mean ± SD	Posttest Mean ± SD	Mean Difference
Male	48	9.92 ± 4.80	21.58 ± 6.92	11.67
Female	22	7.59 ± 4.68	18.36 ± 7.00	10.77

Table 2 summarizes the descriptive statistics of gross motor skill scores according to gender. Male participants achieved a mean pretest score of 9.92 (SD = 4.80), which increased to 21.58 (SD = 6.92) after the intervention. Female participants showed an increase from 7.59 (SD = 4.68) at pretest to 18.36 (SD = 7.00) at posttest.

Both groups demonstrated substantial improvements in gross motor performance following the intervention. The average improvement was slightly higher among male participants (11.67 points) than among female participants (10.77 points). Nevertheless, inferential statistical analyses are required to determine whether these observed differences are statistically meaningful.

Table 3. Descriptive Statistics of Fine Motor Skill of Gain Scores by Gender

Gender	N	Mean Gain	SD
Male	48	-5.92	14.26
Female	22	-6.95	13.47

Table 3 presents the gain scores obtained by subtracting pretest scores from posttest scores. For fine motor skill, negative gain scores indicate improved performance because participants required less time to complete the task after the intervention. Female participants demonstrated a slightly greater improvement (-6.95) than male participants (-5.92).

Table 4. Descriptive Statistics of Gross Motor Skill of Gain Scores by Gender

Gender	N	Mean Gain	SD
Male	48	11.67	7.37
Female	22	10.77	7.30

Table 4 presents the gain scores for gross motor skills, positive gain scores indicate improvement in motor performance. Male participants achieved a mean gain score of 11.67 (SD = 7.37), whereas female participants obtained a mean gain score of 10.77 (SD = 7.30). The similarity of these gain scores suggests that the intervention produced comparable improvements in gross motor abilities for both genders.

2. Normality Test (Shapiro–Wilk Test)

Table 5. Results of Fine Motor Skill of the Shapiro–Wilk Normality Test for Gain Scores

Gender	Shapiro–Wilk Statistic	Sig. (p)
Male	0.873	0.000
Female	0.825	0.001
Male	0.947	0.030
Female	0.939	0.189

Table 6. Results of Gross Motor Skill of the Shapiro-Wilk Normality Test for Gain Scores

Gender	Shapiro–Wilk Statistic	Sig. (p)
Male	0.947	0.030
Female	0.939	0.189

The Shapiro–Wilk test was conducted to assess whether the gain scores were normally distributed. The results showed that the fine motor skill gain scores for both male (p = .000) and female participants (p = .001) were not normally distributed. Similarly, the gross motor

skill gain scores for male participants were not normally distributed (p = .030). Only the gross motor skill gain scores of female participants met the assumption of normality (p = .189).

Since several groups had p-values below .05, the normality assumption was violated. Therefore, non-parametric statistical tests were selected for subsequent analyses.

3. Homogeneity of Variance Test (Levene's Test)

Table 7. Results of Levene's Test for Homogeneity of Variance

Variable	Levene Statistic	Sig. (p)
Fine Motor Skill Gain	0.014	0.906
Gross Motor Skill Gain	0.024	0.878

Levene's test was performed to determine whether the variances of the gain scores were equal across gender groups. The results indicated that fine motor skill gain scores were homogeneous (p = .906) and gross motor skill gain scores were also homogeneous (p = .878). Because all p-values exceeded .05, the assumption of homogeneity of variance was satisfied. Although the homogeneity assumption was met, the violation of the normality assumption required the use of non-parametric tests rather than parametric tests.

4. Wilcoxon Signed-Rank Test for Fine Motor Skill

Table 8. Wilcoxon Signed-Rank Test Results for Fine Motor Skill Scores

Group	Z	Sig. (p)
Male	-3.320	0.001
Female	-2.950	0.003

The Wilcoxon Signed-Rank Test was conducted to examine differences between pretest and posttest fine motor skkill scores within each gender group. For male participants, the analysis revealed a statistically significant improvement in fine motor skill performance (Z = -3.320, p = .001). Similarly, female participants demonstrated a significant improvement following the intervention (Z = -2.950, p = .003). These findings indicate that the intervention effectively improved fine motor performance for both male and female students. The decrease in fine motor skill completion time reflects better hand dexterity and fine motor coordination after the treatment period.

5. Wilcoxon Signed-Rank Test for Gross Motor Skills

Table 9. Wilcoxon Signed-Rank Test Results for Gross Motor Skill Scores

Group	Z	Sig. (p)
Male	-5.770	0.000
Female	-4.030	0.000

The Wilcoxon Signed-Rank Test was also used to compare pretest and posttest gross motor skill scores within each gender group. The results showed statistically significant improvements among male participants (Z = -5.770, p < .001) and female participants (Z = -4.030, p < .001).

These results suggest that the intervention had a positive effect on gross motor skill development regardless of gender. Both groups demonstrated substantial improvements in locomotor and object-control movement skills after participating in the intervention program.

6. Mann–Whitney U Test for Gender Differences in Gain Scores

Table 10. Mann–Whitney U Test Results Comparing Male and Female Participants

Variable	Mann–Whitney U	Sig. (p)
Fine Motor Skill Gain	549.000	0.795
Gross Motor Skill Gain	580.000	0.512

The Mann–Whitney U test was employed to determine whether there were significant differences in improvement between male and female participants. For FINE MOTOR gain scores, the analysis showed no significant gender difference ($U = 549.000$, $p = .795$). Likewise, no significant difference was found in gross motor skill gain scores between male and female participants ($U = 580.000$, $p = .512$).

Because the p-values for both variables were greater than .05, the null hypothesis was retained. These findings indicate that the intervention produced similar improvements in both male and female students. Therefore, gender did not significantly influence the effectiveness of the intervention in enhancing fine motor or gross motor performance.

The normality test revealed that the gain score data were not normally distributed, whereas the homogeneity test confirmed equal variances between groups. Consequently, non-parametric analyses were employed. The Wilcoxon Signed-Rank Test demonstrated significant improvements in both fine motor performance (FINE MOTOR) and gross motor skills for male and female participants. However, the Mann–Whitney U test indicated that the magnitude of improvement did not differ significantly between genders. Overall, the intervention was effective in improving motor performance among students with intellectual disabilities, and its effectiveness was comparable for both male and female participants.

Discussion

The present study examined the effects of FITT-based training on fine and gross motor development among students with intellectual disabilities through separate gender-based analyses. The findings demonstrated significant improvements in both motor domains following the intervention for both boys and girls. Fine motor performance improved significantly among boys ($Z = -3.320$, $p = .001$) and girls ($Z = -2.950$, $p = .003$), while gross motor performance showed substantial gains among boys ($Z = -5.770$, $p < .001$) and girls ($Z = -4.030$, $p < .001$). Although female participants exhibited slightly greater improvements in fine motor performance (−6.95 vs. −5.92 seconds) and male participants demonstrated marginally higher gains in gross motor skills (+11.67 vs. +10.77 points), neither difference reached statistical significance (fine motor: $U = 549.000$, $p = .795$; gross motor: $U = 580.000$, $p = .512$). These results confirm the study hypothesis and extend previous preliminary findings (Wibisana et al., 2026) by demonstrating that the neuroplastic potential documented at baseline can indeed be translated into measurable functional improvements through a systematically structured FITT-based exercise program.

The significant improvement in fine motor performance can be attributed to the repetitive and task-specific nature of the FITT-based training program. Activities such as bead stringing, writing exercises, plastic cup stacking, and pattern drawing required participants to repeatedly engage in precise hand and finger movements, thereby stimulating hand-eye coordination, manual dexterity, and visual-motor integration. According to motor learning theory, repeated practice facilitates the acquisition and refinement of movement patterns

through continuous feedback and error correction (Dayan & Cohen, 2011). A meta-analysis encompassing 14 studies with 586 participants with intellectual disabilities confirmed that structured exercise programs yield significant improvements in fine motor skills (SMD = 0.74; 95% CI: [0.21, 1.27]; p = .01; Zarei, (2024), consistent with the present findings. Rodríguez-Grande et al. (2022) similarly reported that task-specific therapeutic exercise strengthens neuromuscular coordination by increasing the efficiency of motor execution. In contrast to studies reporting minimal fine motor gains following non-structured physical activity (Hsu et al., 2021), the present findings underscore the importance of task-specific and structured programming within the FITT framework for targeting fine motor outcomes specifically.

The substantial improvements in TGMD-2 scores confirm that the FITT-based training program effectively enhanced fundamental movement skills. The intervention incorporated running, jumping, agility drills, and hopping, which directly targeted locomotor and object-control skills. Kavanagh et al. (2023) documented that children with intellectual disabilities exhibit fundamental movement skill proficiency substantially below typically developing peers, with the greatest deficits in locomotor sub-skills including running and jumping precisely the activities targeted in the present intervention. From the perspective of Dynamic Systems Theory, motor development emerges through continuous interactions among the individual, the task, and the environment (Thelen & Smith, 1994), and the structured FITT program likely created optimal conditions for adaptive refinement of movement patterns. The present gross motor gains (males: +11.67; females: +10.77) notably exceed those reported by Strofylla et al. (2021) following a six-month adapted aerobic program (mean gain ≈ +5 points on TGMD subscales) and are consistent with the comprehensive meta-analytic findings of Zarei, (2024), who reported a gross motor SMD of 0.91 (p = .001) across structured exercise programs for individuals with intellectual disabilities. This comparison suggests that a focused 12-session FITT protocol with task-targeted activities can produce gross motor gains comparable to longer, less-specific programs.

From a neuroplasticity perspective, the significant improvements observed in both motor domains can be explained by adaptive changes within neural systems responsible for movement control and coordination. The FITT-based training program provided repeated exposure to structured motor activities that are believed to stimulate neural activation in motor-related brain regions, promoting synaptic strengthening and more efficient communication among neural pathways involved in movement planning, execution, and coordination (Dołęga et al., 2024; Romagnoli et al., 2025). The moderate exercise intensity applied in this study 60–75% of maximum heart rate falls precisely within the range identified by Revelo Herrera and Leon-Rojas (2024) as optimal for stimulating BDNF production and hippocampal neurogenesis, the primary biological mechanisms of exercise-induced neuroplasticity. Hilderley et al. (2023) documented measurable functional neuroplasticity changes following gross motor interventions in children with cerebral palsy, while Busquets et al. (2024) demonstrated that acute moderate-intensity exercise enhanced motor learning and brain activity in children with developmental coordination disorder. Although neural changes were not directly measured in the present study, the significant and consistent improvements in both NHPT and TGMD-2 scores are consistent with these theoretical and empirical models, providing indirect evidence that the FITT-based program stimulated neuroplastic adaptation in students with intellectual disabilities.

The gender-based analysis revealed that both boys and girls experienced significant improvements in fine and gross motor performance following participation in the FITT-based training program. The absence of significant gender differences in intervention effectiveness warrants careful interpretation, as multiple factors likely converge to produce this finding. First, the standardized and structured nature of the FITT-based training protocol ensured all participants received equivalent practice opportunities, feedback, and skill acquisition

experiences regardless of gender, minimizing systematic variation attributable to differential treatment. Second, a systematic review by Corey et al. (2024) on digital motor interventions for individuals with developmental disabilities found no consistent gender differences in response to structured motor interventions, suggesting that gender is not a primary moderator of motor learning responses in this population. Third, at the developmental stage of 6–10 years and with mild intellectual disability specifically, the literature indicates that cognitive-motivational factors including sustained attention, effort, and task persistence during structured exercise exert a stronger influence on motor adaptation than biological sex differences in neuromotor development (Lagos-Luciano, 2022; Xing & Wu, 2025). Fourth, baseline motor performance levels between boys (NHPT: 42.81 s; TGMD-2: 9.92) and girls (NHPT: 46.77 s; TGMD-2: 7.59) were broadly comparable, suggesting similar starting points for neuroplastic adaptation. Finally, the convergent neuroplasticity evidence from Revelo Herrera and Leon-Rojas (2024) suggests that moderate-intensity aerobic stimulation promotes BDNF upregulation through mechanisms that are not gender-differentiated in this age group. Collectively, these factors explain why both boys and girls benefited comparably from the FITT-based intervention, reinforcing its value as an inclusive and equitable strategy for adapted physical education.

The present findings extend previous research on neuroplasticity and motor development in students with disabilities. The preliminary study by Wibisana et al. (2026), conducted in the same educational context, documented substantial baseline motor deficits and identified neuroplastic potential as present but not yet actualized. The present study directly addresses that gap by demonstrating that a 12-session FITT-based program can translate neuroplastic potential into measurable functional gains. The composite motor SMD of 1.28 (95% CI: [0.86, 1.70]) reported by Zarei (2024) across structured exercise programs for individuals with intellectual disabilities provides a strong meta-analytic anchor for the magnitude of improvement observed here. Similarly, L. Zhang et al. (2024) reported that 10 weeks of individualized fundamental movement skill training significantly enhanced motor proficiency in children with intellectual and developmental disabilities, corroborating the efficacy of structured, targeted programs. The novelty of the present study lies in its explicit integration of neuroplasticity theory with a FITT-based design and its simultaneous evaluation of fine and gross motor outcomes through a gender-based analytical framework.

The findings have important practical implications for physical education teachers, special education practitioners, and rehabilitation therapists serving students with intellectual disabilities. The FITT principle provides a practical, scalable, and evidence-based framework for designing adapted physical activity programs: the parameters used in this study (twice weekly, moderate intensity, 45–60 minutes per session) are feasible within regular school schedules and require minimal specialized equipment. Recent meta-analytic evidence confirms that physical activity programs incorporating diverse movement components and adequate repetitive practice are most effective when directly targeting the skills to be improved (Kavanagh et al., 2024; Wang et al., 2025). The activities used in this study bead stringing, pattern cutting, running, and agility drills are simple, low-cost, and easily adapted for home-based practice, enabling caregivers to provide additional motor learning opportunities beyond the school setting.

Despite these contributions, several limitations should be acknowledged. First, the absence of an untreated control group limits causal inference and the ability to fully rule out maturation or test–retest effects, although the short intervention window (six weeks) reduces the plausibility of biological maturation as a major confound. Second, neural changes were inferred from behavioral outcomes rather than measured directly; future studies incorporating neurophysiological measures such as EEG or fMRI would provide stronger mechanistic evidence. Third, the relatively small female subsample (n = 22) reduces statistical power for gender comparisons, and the absence of a follow-up assessment prevents conclusions about the

durability of motor improvements. Future research should employ longitudinal designs with follow-up periods, control groups, larger and more balanced gender samples, and direct neurophysiological measures to further establish the causal mechanisms underlying FITT-induced neuroplastic adaptation in students with intellectual disabilities.

Conclusions

This study provides three principal findings that directly address its objectives. First, a FITT-based training program delivered twice weekly at moderate intensity (60–75% of maximum heart rate) for 12 sessions of 45–60 minutes significantly improved fine motor performance—as evidenced by reduced NHPT completion times—among both male ($Z = -3.320$, $p = .001$) and female students ($Z = -2.950$, $p = .003$) with intellectual disabilities. Second, the same program significantly improved gross motor performance—as measured by TGMD-2 scores—for both boys ($Z = -5.770$, $p < .001$) and girls ($Z = -4.030$, $p < .001$), with substantial mean gains exceeding ten points in both groups. Third, the magnitude of improvement did not differ significantly between male and female participants in either fine motor ($U = 549.000$, $p = .795$) or gross motor outcomes ($U = 580.000$, $p = .512$), confirming that the FITT-based intervention is equally effective across gender groups.

These findings carry important practical implications for special education and rehabilitation settings. The FITT principle provides a structured, low-cost, and evidence-based framework that can be integrated into regular school programs without specialized equipment, making it accessible across diverse institutional contexts in Indonesia and similar settings. The comparable effectiveness across gender groups further supports the use of a unified FITT-based program as an inclusive and equitable intervention strategy.

The primary limitation of this study is the absence of an untreated control group, which limits causal inference. Future research is recommended should incorporate control-group designs, direct neurophysiological measurements, balanced gender samples, longer intervention periods, and follow-up assessments to better understand the durability of FITT-induced motor improvements and to directly examine the neuroplastic mechanisms underlying them. Extending the application of FITT-based programs to broader age ranges and disability categories would also strengthen the generalizability of these findings.

Acknowledgment

The authors sincerely thank Universitas PGRI Semarang (UPGRIS) for its institutional support and facilitation of this research. We gratefully acknowledge the collaborative contributions of researchers from Universitas Negeri Malang (Indonesia), Bukidnon State University (Philippines), and Haliç University (Türkiye), whose academic expertise, insights, and constructive collaboration supported the development and implementation of this study. We also extend our sincere appreciation to the participating special education schools, students, teachers, and parents for their valuable cooperation and participation throughout the research process.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

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Information about the authors:

Muh Isna Nurdin Wibisana, M.Kes: muhisna@upgris.ac.id , https://orcid.org/0000-0002-9115-3728, Department of Physical Education, Health and Recreation, Universitas PGRI Semarang, Indonesia

Husnul Hadi,: husnulhadi@upgris.ac.id, https://orcid.org/0000-0003-4077-1865, Department of Physical Education, Health and Recreation, Universitas PGRI Semarang, Indonesia

Ibnu Fatkhu Royana,: ibnufatkhuroyana@upgris.ac.id, https://orcid.org/0000-0001-5117-7779, Department of Physical Education, Health and Recreation, Universitas PGRI Semarang, Indonesia

Muhammad Atiq Noviudin Pritama,: muh.noviudin.fik@um.ac.id, https://orcid.org/0009-0000-7691-5053, Department of Sports Coaching Education, Universitas Negeri Malang, Indonesia

Mert Kurnaz: mertkurnaz@halic.edu.tr, https://orcid.org/0000-0001-9006-3344, Department of Physical Education and Sport Teaching, Haliç University, Turkiye

Cite this article as:

Wibisana, M. I. N. *et all*. (2026). Neuroplasticity-Oriented FITT Training: Fine and Gross Motor Development by Gender in Students with Intellectual Disabilities. *Indonesian Journal of Physical Education and Sport Science (IJPESS). 6* (3). 732-746. https://doi.org/10.52188/ijpess.v6i3.2311