

Development and Effectiveness of a Music-Synchronized Rhythmic Movement Learning Model for Children with Mild Intellectual Disabilities

Ary Artanty^{1*}, Sugeng Purwanto², Farida Mulyaningsih³, Ahmad Lani⁴,
Luthfie Lufthansa⁵, Laila Nur Rohmah⁶, Rickadesti Ramadhana⁷ Yulianto
Dwi Saputro⁸

¹²³Department of Physical Education, Faculty of Sport Science, Universitas Negeri Yogyakarta, Indonesia

⁴⁵⁶⁸Faculty of Exact Studies and Sports, Universitas Insan Budi Utomo, Indonesia

⁷Faculty of Science and Technology, Universitas PGRI Yogyakarta, Indonesia

HOW TO CITE:

Ary Artanty, Sugeng Purwanto, Farida Mulyaningsih, Ahmad Lani, Luthfie Lufthansa, Laila Nur Rohmah, Rickadesti Ramadhana, Yulianto Dwi Saputro (2026) Development and Effectiveness of a Music-Synchronized Rhythmic Movement Learning Model for Children with Mild Intellectual Disabilities

International Journal of Special Education, 41(22s), 620-632

OPRYRIGHT STATEMENT:

Copyright: © 2026 Authors.

Open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

ABSTRACT:

This study developed and evaluated a music-synchronized rhythmic movement learning model for children with mild intellectual disabilities. A research and development design based on the ADDIE framework was employed. The study involved a needs analysis with 11 physical education teachers, validation by seven experts, a small-scale trial with 12 children, a large-scale trial with 30 children, and an effectiveness trial with 20 children. The intervention comprised 16 sessions conducted over eight weeks. Locomotors and non-locomotors skills were assessed using selected components of the TGMD-2 and BOT-2. The model demonstrated high content validity (overall Aiken's $V=0.95$), feasibility (95.4%), and practicality (96.1%). Locomotors scores increased significantly from 22.40 ± 4.28 to 31.75 ± 3.62 , $t(19)=13.82$, $p<.001$, $d_z=3.09$. Non-locomotors scores also improved from 15.30 ± 3.12 to 22.85 ± 2.64 , $t(19)=11.47$, $p<.001$, $d_z=2.56$. The model was valid, practical, and potentially effective for improving motor skills among children with mild intellectual disabilities. Controlled studies are needed to confirm these preliminary findings.

Keywords: intellectual disability; locomotors skills; music synchronization; non-locomotors skills; rhythmic movement.

1. Introduction

Fundamental movement skills provide an essential foundation for children's participation in physical activity, play, sport, and everyday functional tasks (Yang et al., 2025). These skills commonly comprise locomotors movements, such as running, hopping, jumping, galloping, and sliding, as well as non-locomotors or stability-related movements involving balance, bending, turning, swaying, and controlled body positioning (Clive, 2017). Adequate motor

competence can support children's independence, confidence, social participation, and engagement in active lifestyles (Guo et al., 2024). For children with intellectual disabilities, however, the acquisition of these skills is frequently constrained by limitations in intellectual functioning and adaptive behavior, together with difficulties in attention, information processing, motor planning, and coordination, balance, and movement execution. A systematic review and meta-analysis reported

that children with intellectual disabilities were 65% more likely to demonstrate low motor competence than their typically developing peers (Heussler et al., 2023). This disparity highlights the importance of developmentally appropriate and systematically structured movement-learning opportunities.

Poor motor competence may have consequences extending beyond performance in physical education. Children who experience persistent difficulty performing fundamental movements may participate less frequently in active play and structured physical activity, thereby receiving fewer opportunities to practice and refine their skills. Recent evidence indicates that motor competence is positively associated with physical activity among children with intellectual disabilities and/or autism spectrum disorder, although the available evidence remains limited and varies according to the movement domain and participant characteristics (Taylor et al., 2024). Consequently, improving locomotor and non-locomotor abilities may contribute not only to better movement execution but also to greater participation, autonomy, and long-term engagement in physical activity. Schools, particularly special schools, therefore represent an important setting in which children can receive repeated, supported, and meaningful motor-learning experiences.

Physical education and adapted physical activity interventions can improve the motor and functional abilities of children with intellectual disabilities when instruction is aligned with their learning characteristics. Özkan and Kale, for example, found that structured physical education activities contributed positively to motor development and quality of life in children with intellectual disabilities (Özkan & Kale, 2023). Similarly, adapted rhythmic gymnastics has been associated with improved physical fitness among children with intellectual and developmental disabilities (Xu et al., 2020). A systematic review of physical education for students with intellectual disabilities also identified positive outcomes across motor,

physical, psychological, and social domains, while emphasizing the need for program that are appropriately adapted to the characteristics of the participants (Tijera Iborra et al., 2023). More recently, a systematic review and meta-analysis concluded that exercise-training program can improve motor skills in individuals with intellectual disabilities, although variation in program content, duration, assessment, and methodological quality limits the generalizability of the findings (Zarei et al., 2024).

Despite these encouraging findings, conventional movement instruction may not fully address the specific learning needs of children with mild intellectual disabilities. These learners often require short and explicit instructions, visual or auditory cues, movement demonstrations, task repetition, gradual progression, immediate feedback, and predictable lesson structures. Activities that are insufficiently adapted may impose excessive cognitive demands or fail to sustain attention and motivation. Moreover, merely providing opportunities for physical activity does not guarantee meaningful improvement in motor competence. The instructional design must help learners recognize when to initiate a movement, regulate its speed, maintain an appropriate sequence, and coordinate different body segments. Accordingly, a learning model that provides an external temporal structure while maintaining enjoyable and repetitive practice may be particularly beneficial.

Rhythmic movement offers a promising pedagogical approach because it integrates motor practice with timing, repetition, pattern recognition, and coordinated body action. Rhythm can organize movement into predictable temporal units, while repeated movement sequences may help learners anticipate the next action and maintain continuity of performance. When music is synchronized with movement, its beat can function as an external auditory cue that supports the initiation, timing, pacing, and sequencing of motor responses. Rhythm- and music-based interventions are understood to

promote auditory–motor coupling and movement entrainment, allowing individuals to align bodily actions with recurring temporal cues (Braun Janzen et al., 2022). From an instructional perspective, music may also increase enjoyment, attention, and willingness to repeat tasks—conditions that are important for sustained motor practice.

Recent empirical evidence supports the educational potential of combining rhythm, music, and movement. A rhythmic music program consisting of structured motor activities improved walking, running, jumping, throwing, dynamic balance, coordination, and flexibility among young children with Down syndrome (Mazeed, 2023). Rhythmic movement exercises have also demonstrated positive effects on the attention of students with intellectual disabilities, suggesting that rhythmic activities may simultaneously support engagement and task-focused behavior (Elyasi et al., 2023). In addition, structured music–movement pedagogy was recently found to produce greater improvement in motor performance, particularly bilateral coordination and dynamic balance, than conventional play among children with mild-to-moderate intellectual disabilities (Intani et al., 2025). Evidence from other neurodevelopmental populations similarly indicates that music- and movement-based interventions can facilitate motor coordination, synchronization, social engagement, and behavioral participation (Kanzari et al., 2025). Although these populations are not identical, the findings provide a plausible basis for examining music-supported motor learning among children with mild intellectual disabilities.

Nevertheless, several limitations remain in the current literature. First, many studies have evaluated general exercise, games, dance, rhythmic gymnastics, or music therapy rather than a pedagogically specified learning model designed for use in special-school physical education. Second, existing programs frequently focus on physical fitness, balance, attention, or broad motor competence without explicitly integrating locomotors and non-locomotors

learning outcomes. Third, music is sometimes used only as background stimulation rather than being deliberately synchronized with the timing and sequence of the target movements. Fourth, relatively few studies have combined systematic model development, expert validation, teacher-oriented implementation procedures, field-based practicality testing, and an evaluation of effectiveness. These limitations reduce the extent to which existing interventions can be adopted consistently by teachers in authentic special-school settings.

The present study addresses these gaps by developing a music-synchronized rhythmic movement learning model specifically tailored to the cognitive, behavioral, and motor-learning characteristics of children with mild intellectual disabilities. The proposed model positions musical rhythm as an instructional scaffold rather than merely as accompaniment. Movement patterns, musical tempo, repetition, task complexity, demonstrations, and feedback are organized progressively to support children in coordinating locomotors and non-locomotors actions. The model is also designed as a practical instructional resource that can be implemented by teachers in special schools, thereby connecting theoretical principles of rhythmic auditory cueing with everyday pedagogical practice.

Accordingly, this study aimed to develop and evaluate the validity, practicality, and effectiveness of a music-synchronized rhythmic movement learning model for improving the locomotors and non-locomotors skills of children with mild intellectual disabilities. The study was expected to produce both an empirically evaluated learning model and practical guidance for teachers delivering adapted physical education in special-school contexts.

2. Methodology

Study Design

This study employed a research and development design to develop and evaluate a music-synchronized rhythmic movement

learning model for children with mild intellectual disabilities. The development process followed the ADDIE framework, comprising five sequential stages: analysis, design, development, implementation, and evaluation. The study produced a structured learning model and an accompanying teacher guidebook. The overall procedure involved a needs analysis, initial product design, expert validation, small-scale and large-scale field trials, practicality assessment, product revision, and an effectiveness trial.

Research Setting and Participants

The study was conducted in eight special schools (*Sekolah Luar Biasa* [SLB]) in Malang City, East Java, Indonesia. The needs-analysis stage involved 11 physical education teachers from 11 special schools. They were selected purposively because they taught physical education to children with intellectual disabilities and had at least two years of relevant teaching experience.

Seven experts participated in product validation, comprising six subject-matter experts and one instructional-media expert. Their areas of expertise included adapted physical education, rhythmic movement, fundamental motor skills, special education, music, and instructional media. Each expert possessed at least a master's degree and five years of professional or academic experience in the relevant field.

The field-testing stages involved different groups of children who did not participate in more than one testing stage. The small-scale trial involved 12 children from SLB Putra Jaya and SLB Putra Pancasila. The large-scale trial involved 30 children from SDLB Sumber Dharma, SLB YPAC Kota Malang, SLB C Autis Kedungkandang, and SLB Sathiten. The effectiveness trial involved 20 children from SLB Bhakti Luhur. The participants were 8–12 years old and had been identified by their schools as having mild intellectual disabilities.

Participants were selected purposively according to the following inclusion criteria: (1) having a documented identification of mild intellectual

disability in the school record; (2) being enrolled as an active student at a participating special school; (3) being able to follow simple verbal, visual, or demonstrative instructions; (4) being physically capable of participating in rhythmic movement activities; (5) having no medical restrictions that prohibited moderate physical activity; and (6) having written parental or guardian consent. Children were excluded if they had an acute illness, uncontrolled medical condition, severe physical limitation, or additional condition that prevented them from safely completing the intervention or motor assessments.

Development Procedure

The learning model was developed using the five ADDIE stages: analysis, design, development, implementation, and evaluation. The analysis stage identified students' motor-learning needs and instructional challenges through observations, document analysis, and interviews with 11 physical education teachers. During the design stage, locomotor and non-locomotor activities were organized into 16 progressive, music-synchronized sessions conducted twice weekly for eight weeks, with each session lasting 45 minutes. The model incorporated simple instructions, demonstrations, visual cues, repetition, feedback, reinforcement, rest periods, and individual adaptations. The initial model and teacher guidebook were then validated by six subject-matter experts and one instructional-media expert using a four-point scale and Aiken's V (≥ 0.75). After revision, a small-scale trial involving 12 children from two special schools and a large-scale trial involving 30 children from four schools were conducted to assess feasibility, fidelity, practicality, engagement, and safety. Finally, effectiveness was evaluated through a one-group pretest–posttest design involving 20 children with mild intellectual disabilities, whose locomotor and non-locomotor skills were measured using selected TGMD-2 and BOT-2 components before and after the intervention.

Research Instruments

Five instruments were used in the development and effectiveness stages. A semi-structured interview guide gathered information from 11 physical education teachers regarding students' motor characteristics, current teaching practices, facilities, barriers, and expectations. Expert-validation questionnaires were completed by six subject-matter experts and one instructional-media expert to assess the model and guidebook in terms of content, instructional clarity, movement progression, synchronization, suitability, safety, feasibility, language, and media quality. Feasibility and practicality were evaluated through structured observations and teacher questionnaires using a four-point scale. Locomotor skills—including running, galloping, hopping, leaping, horizontal jumping, and

sliding—were measured using the TGMD-2 locomotor subtest and scored according to established performance criteria. Non-locomotor skills, postural control, balance, and bilateral coordination were assessed using selected BOT-2 items, with higher scores indicating better motor performance.

3. Results

Participant Characteristics

Twenty children with mild intellectual disabilities participated in the effectiveness trial and completed the pretest and posttest assessments. The participants consisted of 13 boys (65.0%) and seven girls (35.0%), ranging from 8 to 12 years of age. Their mean age was 9.85 years ($SD=1.39$). The largest age group comprised children aged nine years (25.0%).

Table 1. Characteristics of participants in the effectiveness trial

Characteristic	n	%
Boys	13	65.0
Girls	7	35.0
8 years	4	20.0
9 years	5	25.0
10 years	4	20.0
11 years	4	20.0
12 years	3	15.0
Total	20	100.0

Analysis Stage: Needs-Analysis Findings

The needs analysis involved 11 physical education teachers from special schools in Malang City. All teachers reported that their students had difficulty following movement sequences and that a structured rhythmic movement learning model and teacher

guidebook were needed. Ten teachers (90.9%) identified balance difficulties among their students. Nine teachers (81.8%) rarely incorporated music into physical education lessons, while eight teachers (72.7%) reported limited access to appropriate instructional media.

Table 2. Needs-analysis findings from physical education teachers

Finding	n	%
Students had difficulty following movement sequences	11	100.0
Students had difficulty maintaining balance	10	90.9
Teachers rarely used music in physical education	9	81.8
Teachers required a structured learning model	11	100.0
Teachers required a practical guidebook	11	100.0
Schools had limited instructional media	8	72.7

These findings supported the development of a structured model incorporating clear instructions, demonstrations, repetitive practice,

progressive movement difficulty, musical cues, visual markers, and practical guidance for teachers.

Development Stage: Expert Validation

The initial model and teacher guidebook were evaluated by six subject-matter experts and one instructional-media expert. All assessed components exceeded the predetermined minimum Aiken's V criterion of 0.75. Coefficients ranged from 0.92 to 0.98, with an

overall coefficient of 0.95. Music synchronization received the highest validity coefficient ($V=0.98$). Content relevance, movement progression, and media quality also demonstrated high validity. Language received the lowest coefficient ($V=0.92$), although it remained substantially above the acceptance criterion.

Table 3. Content validity of the learning model

Assessed aspect	Aiken's V	Interpretation
Content relevance	0.96	Highly valid
Learning objectives	0.94	Highly valid
Movement progression	0.95	Highly valid
Music synchronization	0.98	Highly valid
Safety	0.93	Highly valid
Language	0.92	Highly valid
Media quality	0.95	Highly valid
Overall	0.95	Highly valid

Based on the expert recommendations, several minor revisions were made before field testing. These included simplifying instructional language, clarifying movement illustrations, adjusting the progression of several movement combinations, refining musical-tempo guidance, and strengthening the safety instructions in the teacher guidebook.

Implementation Stage

The small-scale trial involved 12 children from two special schools. The model obtained an overall feasibility score of 95.4% and was classified as highly feasible. Safety received the highest score (98.0%), followed by student engagement (95.5%), instructional clarity (94.5%), and ease of implementation (93.8%).

Table 4. Results of the small-scale trial

Aspect	Mean score	Percentage	Interpretation
Instructional clarity	3.78	94.5	Highly feasible
Student engagement	3.82	95.5	Highly feasible
Safety	3.92	98.0	Highly feasible
Ease of implementation	3.75	93.8	Highly feasible
Overall	3.82	95.4	Highly feasible

The small-scale trial indicated that the learning activities were understandable, engaging, and safe for children with mild intellectual disabilities. Minor revisions were made by simplifying complex movement combinations and allowing additional repetition before increasing the musical tempo. The revised model was implemented with 30 children across four

special schools. The combined score across practicality, teacher satisfaction, student participation, and implementation fidelity was 96.1%, indicating that the model was highly practical. Teacher satisfaction received the highest percentage (97.0%), while student participation received the lowest (95.0%). Nevertheless, all evaluated components were within the highly practical category.

Table 5. Results of the large-scale trial

Aspect	Mean score	Percentage	Interpretation
Practicality	3.86	96.5	Highly practical
Teacher satisfaction	3.88	97.0	Highly practical
Student participation	3.80	95.0	Very high

Implementation fidelity	3.84	96.0	Very high
Overall	3.85	96.1	Highly practical

These results demonstrated that trained physical education teachers could implement the model consistently using the guidebook. The movement activities, musical accompaniment, equipment requirements, time allocation, and safety procedures were also considered appropriate for special-school settings.

Inter-Rater Reliability

Two trained assessors evaluated the recorded motor performances. Inter-rater score consistency was examined using an intraclass

correlation coefficient. The TGMD-2 and BOT-2 scores demonstrated excellent inter-rater reliability, with coefficients exceeding 0.90. The findings indicated that the scoring procedures were applied consistently by the two assessors.

Table 6. Inter-rater reliability of the motor assessments

Instrument	ICC
TGMD-2 locomotors score	0.942
BOT-2 non-locomotors and postural-control score	0.931

Evaluation Stage: Effectiveness of the Learning Model

The normality of the difference between pretest and posttest scores was examined using the

Shapiro–Wilk test. The differences were normally distributed for both locomotors ($p=.287$) and non-locomotors ($p=.174$) scores. Therefore, paired-samples t-tests were used to examine changes following the intervention.

Table 7. Normality of paired differences

Outcome	Shapiro–Wilk (p)	Interpretation
Locomotors-score difference	.287	Normally distributed
Non-locomotors-score difference	.174	Normally distributed

Following the 16-session intervention, the mean TGMD-2 locomotors score increased from 22.40 (SD=4.28) at pretest to 31.75 (SD=3.62) at posttest. This represented a mean

improvement of 9.35 points. The mean BOT-2 non-locomotors and postural-control score increased from 15.30 (SD=3.12) to 22.85 (SD=2.64), representing a mean improvement of 7.55 points.

Table 8. Pretest and posttest motor-performance scores

Outcome	Shapiro–Wilk (p)	Interpretation
Locomotors-score difference	.287	Normally distributed
Non-locomotors-score difference	.174	Normally distributed

The paired-samples t-test demonstrated a statistically significant improvement in locomotors performance, $t(19)=13.82$, $p<.001$. The mean improvement was 9.35 points, 95% CI [7.94, 10.76]. The corresponding effect size

was very large ($d_z=3.09$). A statistically significant improvement was also found in non-locomotors performance, $t(19)=11.47$, $p<.001$. The mean improvement was 7.55 points, 95% CI [6.17, 8.93], with a very large effect size ($d_z=2.56$).

Table 9. Effectiveness of the music-synchronized rhythmic movement model

Outcome	Mean difference	95% CI	(t)	(df)	(p)	Cohen's (d_z)
Locomotors skills	9.35	[7.94, 10.76]	13.82	19	<.001	3.09
Non-locomotors skills	7.55	[6.17, 8.93]	11.47	19	<.001	2.56

Overall, the development process demonstrated that the music-synchronized rhythmic movement learning model had strong content validity, high feasibility and practicality, excellent

4. Discussion

This study developed and evaluated a music-synchronized rhythmic movement learning model for children with mild intellectual disabilities. The results demonstrated strong content validity, high feasibility and practicality, excellent inter-rater score consistency, and significant improvements in locomotors and non-locomotors performance. These findings indicate that the model was pedagogically appropriate, implementable in Indonesian special-school settings, and potentially effective for supporting children's motor development.

The needs analysis showed that teachers encountered substantial difficulties when teaching movement sequences and balance-related skills. All participating teachers expressed a need for a structured learning model and an accompanying guidebook. These findings suggest that the limitations observed in physical education were related not only to children's motor characteristics but also to the availability of instructional resources. Teachers required a program that translated movement-learning principles into clear objectives, progressive activities, musical-tempo guidance, demonstrations, feedback strategies, and assessment procedures.

This result is consistent with Cavalcante Neto et al. (2023), who demonstrated that children with intellectual disabilities can learn motor tasks but may require instructional adjustments because their acquisition patterns differ according to task complexity and learning conditions (Lopes Cavalcante Neto et al., 2023). Consequently, merely exposing students to physical activity may not be sufficient. Instruction should be organized progressively, allow repeated practice, and reduce unnecessary cognitive demands. In the present model, these requirements were addressed through short instructions, teacher demonstrations, visual markers, predictable

scoring reliability, and promising effectiveness in improving the locomotors and non-locomotors performance of children with mild intellectual disabilities.

lesson structures, and the gradual progression of movement and musical tempo.

The learning model achieved an overall Aiken's V coefficient of 0.95. All assessed aspects exceeded the acceptance criterion, indicating strong agreement among the experts regarding the model's relevance and appropriateness. The highest coefficient was obtained for music synchronization, supporting the decision to use the musical beat as an integral instructional component rather than as background accompaniment. High coefficients for movement progression, safety, media quality, and learning objectives also indicate that the model appropriately combined pedagogical, motor, musical, and child-protection considerations.

The expert-validation process resulted in several minor but important improvements, including simplified instructional language, clearer movement illustrations, more gradual combinations of locomotors and non-locomotors skills, and more specific musical-tempo recommendations. These revisions were particularly relevant for children with mild intellectual disabilities because task complexity and information load can influence motor-skill acquisition. The resulting model provided children with sufficient time to observe, process, imitate, and repeat each movement before progressing to a more demanding activity.

The small-scale trial produced an overall feasibility score of 95.4%, while the large-scale trial produced an overall practicality and implementation score of 96.1%. These results demonstrate that the model remained practical when implemented across schools with different learning environments. Safety received the highest score in the small-scale trial, while teacher satisfaction obtained the highest score during large-scale implementation. These findings suggest that the teacher guidebook, pre-

implementation training, simple equipment, and structured session format helped teachers deliver the intervention consistently.

The high implementation scores may also be attributed to the model's alignment with regular physical education practices. The program did not require sophisticated equipment or specialized clinical facilities. Teachers could adapt the movement difficulty and musical tempo to the abilities of their students. This practical flexibility is important in Indonesian special schools, where instructional facilities, teacher preparation, and access to adapted learning media may vary.

Shen et al. (2024) similarly found that an adapted physical activity program designed according to participants' functional characteristics improved fundamental motor skills among adolescents with intellectual disabilities (Shen et al., 2024). Their findings support the importance of matching instructional content and progression to the abilities of the participants. The present study extends this principle by incorporating musical synchronization and providing a structured teacher-oriented implementation guide.

The effectiveness trial demonstrated a significant increase in locomotors performance. The mean TGMD-2 locomotors score improved by 9.35 points following the 16-session intervention. The size of the within-participant change was very large. This improvement suggests that repeated and progressively structured practice supported participants in refining running, galloping, hopping, leaping, horizontal jumping, and sliding.

The improvement is consistent with Karakaş et al. (2024), who reported that a long-term adapted physical activity program improved motor proficiency in children with mild intellectual disabilities, as measured using the BOT-2. Importantly, their study also observed regression after structured activities were discontinued (Karakaş et al., 2025). This finding indicates that motor development among children with intellectual disabilities may depend

on continued opportunities for organized practice. Therefore, the present model should be incorporated into regular physical education rather than implemented only as a short-term intervention.

Motor improvements may have resulted from the combined effects of repetition, demonstration, external timing, progressive difficulty, and feedback. Repeated practice can help children become familiar with movement sequences, while demonstrations and visual markers reduce reliance on verbal explanations. Cavalcante et al. (2023) highlighted that task structure and practice conditions influence motor learning among children with intellectual disabilities (Lopes Cavalcante Neto et al., 2023). In the present study, the structured sequence may have enabled participants to concentrate on one or two movement components before combining them into more complex actions.

The musical beat may also have provided a predictable temporal reference. Children did not have to rely entirely on internally generated timing because the recurring beat indicated when movements should begin, continue, or change. This interpretation is supported by Williams et al. (2024), who found that neurologic music therapy delivered through telehealth improved motor performance in autistic children. Although autism and intellectual disability are distinct conditions, their findings demonstrate that purposeful musical cues can be incorporated into motor interventions for children with neurodevelopmental needs (Richard Williams et al., 2024).

Music-supported practice may also have encouraged participants to sustain attention and repeat tasks. When the rhythm, tempo, and movement demands were appropriately matched, the activity became predictable without becoming monotonous. The progression from 80–90 beats per minute to 100–120 beats per minute allowed participants to initially perform movements at a manageable pace and subsequently respond to more challenging temporal demands. This progression

may have supported both movement accuracy and fluency.

The improvement in locomotor outcomes also aligns with evidence from adapted sport interventions. Pierantozzi et al. (2022) found that a long-term adapted judo program improved physical fitness and motor-related outcomes among children with autism spectrum disorder (Pierantozzi et al., 2022). Although the intervention and population differed from those in the present study, both studies demonstrate the value of structured, progressive, and regularly scheduled movement practice for children with developmental needs.

Non-locomotor and postural-control performance also improved significantly. The mean BOT-2-based score increased by 7.55 points, with a very large within-participant effect. These findings suggest that the intervention supported static and dynamic balance, postural control, bilateral coordination, and the organization of body movements.

The improvement may be explained by the content of the intervention. Participants repeatedly performed bending, stretching, swaying, twisting, turning, balancing, pushing, pulling, and coordinated hand-and-foot actions. These activities required them to regulate their center of mass, maintain body position, and coordinate multiple body segments. The gradual combination of these movements with directional changes and musical tempo increased postural and coordinative demands without requiring an abrupt increase in task difficulty.

Comparable findings were reported by Kachouri et al. (2025), who found that eight weeks of motor dual-task training improved gait and mobility performance in children with intellectual disabilities (Kachouri et al., 2025). Their intervention required participants to coordinate locomotor actions with an additional motor demand. This finding supports the view that children with intellectual disabilities can improve complex movement organization when tasks are repeated,

progressively structured, and adapted to their capacities.

Balayi et al. (2022) also reported improvements in postural control and balance following an eight-week combined training program for students with intellectual disabilities (Balayi et al., 2022). Together with the present findings, this evidence suggests that balance and coordination should not be treated merely as fixed limitations associated with intellectual disability. These abilities may respond positively to appropriately designed and sustained motor interventions.

The high inter-rater reliability obtained for TGMD-2 and BOT-2 scores further supports the consistency of the assessment procedures. Both coefficients exceeded 0.90, indicating excellent agreement between the two assessors. This was likely facilitated by assessor training, standardized instructions, video recording, and the use of observable performance criteria. Nevertheless, high inter-rater reliability indicates scoring consistency rather than proving that the selected tasks captured every dimension of locomotor and non-locomotor competence.

The main novelty of this study lies in the systematic integration of musical synchronization into an instructional model developed specifically for children with mild intellectual disabilities. The model was not limited to testing an exercise program. It connected needs analysis, expert validation, teacher training, field testing, guidebook development, implementation-fidelity assessment, and motor-outcome evaluation. Music was used as a temporal scaffold directly aligned with the intended movements rather than as passive background stimulation.

This distinction is practically important. Music alone may not improve motor performance if the tempo is unsuitable or unrelated to the movement task. In the present model, tempo, repetition, movement complexity, instructional cues, and feedback were organized progressively. Thus, the observed improvements likely

reflected the complete instructional structure rather than music as an isolated element.

The results have several implications for adapted physical education. Teachers should begin with simple movements and slower musical tempos, provide clear demonstrations, and allow sufficient repetition before progressing. Music should have a clear beat and minimal distracting elements. Teachers should also monitor fatigue, balance, emotional responses, and movement accuracy. Progression should be based on children's performance rather than strictly following a predetermined timetable.

Despite the encouraging results, the findings require careful interpretation. The effectiveness trial used a one-group pretest–posttest design without a control group. Therefore, maturation, repeated testing, familiarity with the assessments, and additional attention from teachers may have contributed to the observed improvements. The very large effect sizes represent within-group standardized changes and should not be interpreted as controlled effects.

The sample was also limited to 20 children from one special school. The findings may not generalize to children with moderate or severe intellectual disabilities or to those with substantial physical, sensory, or behavioral needs. Furthermore, posttest measurement occurred shortly after the intervention, and the retention of motor improvement was not examined. This limitation is particularly important given evidence that motor performance may decline when structured activity is discontinued (Karakas et al., 2025).

Future studies should use randomized or quasi-experimental controlled designs involving larger

samples and multiple schools. Follow-up assessments should examine whether improvements are maintained and transferred to play, sport participation, and daily activities. Comparisons among synchronized music, non-synchronized music, and movement without music would help identify the specific contribution of auditory–motor synchronization. Future studies should also examine attention, enjoyment, confidence, social engagement, and physical activity participation alongside motor outcomes.

Overall, the findings provide preliminary evidence that the developed model is valid, practical, and potentially effective. Its combination of progressive movement practice, external rhythmic cues, teacher demonstration, repetition, and feedback appears to support locomotor learning, balance, and bilateral coordination among children with mild intellectual disabilities.

5. Conclusion

The music-synchronized rhythmic movement learning model demonstrated strong content validity, high practicality, and excellent implementation feasibility. Following 16 sessions, children with mild intellectual disabilities showed significant improvements in locomotor and non-locomotor skills, with very large within-group effect sizes. The model can therefore serve as a structured and practical resource for adapted physical education in special schools. Nevertheless, controlled studies with larger samples and follow-up assessments are required to confirm its effectiveness and the retention of motor improvements.

6. References

- Balayi, E., Sedaghati, P., & Ahmadabadi, S. (2022). Effects of neuromuscular training on postural control of children with intellectual disability and developmental coordination disorders. *BMC Musculoskeletal Disorders*, 23(1), 631. <https://doi.org/10.1186/s12891-022-05569-2>
- Braun Janzen, T., Koshimori, Y., Richard, N. M., & Thaut, M. H. (2022). Rhythm and Music-Based Interventions in Motor Rehabilitation: Current Evidence and Future Perspectives. *Frontiers in Human Neuroscience*, 15, 789467. <https://doi.org/10.3389/fnhum.2021.789467>
- Clive, B. (2017). *Athletic Movement Skills: Training for Sports Performance*. Human Kinetics.

- Elyasi, M., Kashani Vahid, L., & Akbari Jafroudi, K. (2023). The Effect of Rhythmic Movements on the Attention of Students with Intellectual Disability. *Quarterly Journal of Child Mental Health*, 10(3), 100–113. <https://doi.org/10.61186/jcmh.10.3.8>
- Guo, X., Li, C., Zhang, Z., Silva, A. F., & Clemente, F. M. (2024). Can motor competence be influenced by the type of training interventions preschool children are exposed to? A randomized experimental study comparing sports games and psychomotricity activities. *Frontiers in Psychology*, 15, 1476297. <https://doi.org/10.3389/fpsyg.2024.1476297>
- Heussler, H., Kleburg, J. L., De Vries, P., & Hageman, R. (2023). Overview of the 25th SSBP International Research Symposium - A Virtual Conference. *Journal of Intellectual Disability Research*, 67(9), 805–806. <https://doi.org/10.1111/jir.13073>
- Intani, A. D., Sukoco, P., Sumaryanti, S., Abidin, D., Prayogo, G., Özman, C., Rusdiawan, A., & Ilmah, N. K. (2025). Integrating music–movement pedagogy into inclusive physical education for children with intellectual disabilities. *Pedagogy of Physical Culture and Sports*, 29(4), 369–378. <https://doi.org/10.15561/26649837.2025.0414>
- Kachouri, H., Jouira, G., Rebai, H., & Sahli, S. (2025). The effect of motor dual-task training on gait and mobility performances in children with intellectual disabilities. *Journal of Intellectual Disabilities*, 29(1), 100–116. <https://doi.org/10.1177/17446295241284722>
- Kanzari, C., Hawani, A., Ayed, K. B., Mrayeh, M., Marsigliante, S., & Muscella, A. (2025). The Impact of a Music- and Movement-Based Intervention on Motor Competence, Social Engagement, and Behavior in Children with Autism Spectrum Disorder. *Children*, 12(1), 87. <https://doi.org/10.3390/children12010087>
- Karakaş, G., Eroğlu Kolayış, I., & Bayazit, B. (2025). Effects of adapted physical activity on the motor development of children with mild intellectual disability. *International Journal of Developmental Disabilities*, 71(5), 777–787. <https://doi.org/10.1080/20473869.2024.2332751>
- Lopes Cavalcante Neto, J., Alane Silva, É., & Silva Guedes, M. (2023). Analysis of motor learning task in children with intellectual disability. *Retos*, 49, 807–812. <https://doi.org/10.47197/retos.v49.98355>
- Mazeed, H. M. (2023). A Program for Developing Some Motor Skills for Down Syndrome Children Using Music. *International Journal of Early Childhood*, 55(1), 47–68. <https://doi.org/10.1007/s13158-022-00338-7>
- Özkan, Z., & Kale, R. (2023). Investigation of the effects of physical education activities on motor skills and quality of life in children with intellectual disability. *International Journal of Developmental Disabilities*, 69(4), 578–592. <https://doi.org/10.1080/20473869.2021.1978267>
- Pierantozzi, E., Morales, J., Fukuda, D. H., Garcia, V., Gómez, A. M., Guerra-Balic, M., & Carballeira, E. (2022). Effects of a Long-Term Adapted Judo Program on the Health-Related Physical Fitness of Children with ASD. *International Journal of Environmental Research and Public Health*, 19(24), 16731. <https://doi.org/10.3390/ijerph192416731>
- Richard Williams, N., Hurt-Thaut, C., Brian, J., Tremblay, L., Pranjić, M., Teich, J., Tan, M., Kowaleski, J., & Thaut, M. (2024). Improved motor skills in autistic children after three weeks of neurologic music therapy via telehealth: A pilot study. *Frontiers in Psychology*, 15, 1355942. <https://doi.org/10.3389/fpsyg.2024.1355942>
- Shen, X., Huang, P., Nie, B., Su, M., Liu, D., Guo, Y., & Zheng, L. (2024). An Adapted Physical Activity Program for Adolescents with an Intellectual Disability: An International Classification of Functioning, Disability, and Health Perspective. *Life*, 14(10), 1314. <https://doi.org/10.3390/life14101314>
- Taylor, S. L., Downs, S. J., Rudd, J. R., McGrane, B., Melville, C. A., McGarty, A. M., Boddy, L. M., & Foweather, L. (2024). Associations between motor competence and physical activity levels of children with intellectual disabilities and/or autism spectrum disorder: Movement matters. *Journal of Intellectual Disabilities*, 28(4), 976–993. <https://doi.org/10.1177/17446295231203764>
- Tijera Iborra, A., Llin Más, J. R., & Marín-Suelves, D. (2023). Effects of Physical Education on students with intellectual disabilities. A systematic review Autores/as. *Cultura, Ciencia y Deporte*, 18(58). <https://doi.org/10.12800/ccd.v18i58.2021>
- Xu, C., Yao, M., Kang, M., & Duan, G. (2020). Improving Physical Fitness of Children with Intellectual and Developmental Disabilities through an Adapted Rhythmic Gymnastics Program in China. *BioMed Research International*, 2020(1), 2345607. <https://doi.org/10.1155/2020/2345607>
- Yang, Y., Mao, X., Li, W., Wang, B., & Fan, L. (2025). A meta-analysis of the effect of physical activity programs on fundamental movement skills in 3–7-year-old children. *Frontiers in Public Health*, 12, 1489141. <https://doi.org/10.3389/fpubh.2024.1489141>
- Zarei, H., Norasteh, A. A., Dehghani, N., Lieberman, L. J., Ertel, M. W., & Brian, A. (2024). Effects of exercise training programs on motor skills of individuals with intellectual disabilities: A systematic review and meta-analysis. *Disability and Rehabilitation*, 46(25), 6001–6010. <https://doi.org/10.1080/09638288.2024.2318486>

7. Acknowledgements (Optional)

The authors sincerely thank the participating special schools in Malang City, the physical education teachers, expert validators, students, and parents or legal guardians for their valuable participation and support throughout the study. The authors also acknowledge the Faculty of Sport and Health Sciences, Universitas Negeri Yogyakarta, for its academic and institutional support.

8. Author Declaration

The authors declare that this is original work and no conflicts of interest.