Evaluating Effectiveness of Brain Gym on Children's Fine and Gross Motor Skills: A Randomized Controlled Trial

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Abstract. Motor development is a crucial aspect of early childhood growth, influencing daily activities and long-term physical capabilities. Brain Gym, a series of simple movement-based exercises, has been proposed to enhance motor skills, yet its effectiveness remains underexplored through rigorous randomized controlled trials (RCTs). This study aimed to evaluate the impact of Brain Gym on fine and gross motor development in children. A total of 80 healthy preschool children aged 4–6 years were recruited from local preschools in Sragen Regency, Central Java, Indonesia, using purposive sampling. Participants were randomly assigned to either a Brain Gym group (n = 40) or a control group receiving standard physical exercises (n = 40). The intervention was conducted over eight weeks (January–March 2024) with two 30-minute sessions per week. Motor proficiency was assessed at baseline and post-intervention using standardized tools (BOT-2 and PDMS-2). Independent variables were Brain Gym and standard physical exercises, while dependent variables were fine and gross motor skills. Data normality was tested with the Shapiro–Wilk test, followed by paired and independent t-tests, two-way mixed ANOVA, and effect size analysis (Cohen's d). Results showed that the Brain Gym group significantly outperformed the control group in gross motor skills (mean change = 8.9, $p < 0.001$, $d = 0.92$) and fine motor skills (mean change = 7.2, $p < 0.001$, $d = 0.85$). A significant group × time interaction was observed ($F(1,78) = 12.47$, $p = 0.001$). No adverse events were reported. This RCT provides robust evidence supporting Brain Gym as an effective and feasible early childhood intervention to enhance motor development.

1 Introduction

Motor development in early childhood is a critical foundation for physical, cognitive, and social-emotional growth [1]. Fine and gross motor skills enable children to perform essential

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daily tasks, engage in play, and participate in academic activities [2]. Deficits in motor proficiency have been linked to learning difficulties, reduced physical activity, and lower self-esteem. Given these implications, evidence-based interventions that enhance motor skills are vital for supporting early childhood development.

Brain Gym, a movement-based program designed to improve neural connectivity and motor coordination, has been increasingly adopted in educational and therapeutic setting. The program consists of structured exercises that aim to enhance brain-body integration, potentially leading to improved motor and cognitive performance [3] Despite its popularity, empirical support for Brain Gym remains limited, with few high-quality randomized controlled trials (RCTs) examining its efficacy [4]. To better understand how Brain Gym may influence child development, it is important to distinguish between fine and gross motor domains.

Motor skills are categorized into fine motor skills (e.g., grasping, drawing) and gross motor skills (e.g., running, jumping), both of which are essential for functional independence and school readiness [5]. Research indicates that early motor competence predicts later academic achievement, particularly in mathematics and reading. Additionally, children with well-developed motor skills exhibit greater social participation and emotional regulation [6].

Given these associations, interventions targeting motor development are crucial. Traditional approaches, such as structured physical education and occupational therapy, have demonstrated effectiveness . However, alternative programs like Brain Gym require further rigorous evaluation to determine whether they offer comparable or superior benefits [7].

Brain Gym is rooted in the concept of "educational kinesiology," which posits that specific movements enhance neural communication and learning efficiency. Proponents suggest that these exercises improve attention, coordination, and stress regulation. While some studies report positive effects on motor and cognitive outcomes, others have found no significant advantages over conventional physical activities [7].

The scarcity of robust RCTs on Brain Gym, with many existing studies suffering from methodological limitations. Given these gaps, there is a need for well-designed trials to assess whether Brain Gym provides unique benefits for motor skill development in young children.

This RCT aimed to evaluate the effectiveness of Brain Gym in improving fine and gross motor skills in children aged 4–6 years, compared to standard physical exercises. Motor proficiency was assessed using the Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) and the Peabody Developmental Motor Scales, Second Edition (PDMS-2), both validated and widely used measures.

The findings contribute to the growing literature on movement-based interventions in early childhood. If Brain Gym proves effective, it could be integrated into preschool programs as a supplementary motor development tool. Conversely, if no additional benefits are found, the results would support prioritizing evidence-based physical activities over unverified interventions. This study employs a randomized controlled trial to provide high-quality evidence on the causal effects of Brain Gym on both fine and gross motor development in preschool-aged children.

2 Methods

This study employed a randomized controlled trial design with two parallel groups: an experimental group receiving the Brain Gym intervention (n = 40) and a control group performing standard physical exercises (n = 40). The study population consisted of preschool children aged 4–6 years, and participants were recruited from local preschools in Sragen Regency, Central Java, Indonesia. Inclusion criteria were healthy children within the specified age range whose parents provided informed consent. Exclusion criteria included any diagnosed neuromotor disorders, prior experience with Brain Gym programs, or medical conditions limiting participation in physical activity. Randomization was achieved using a computer-generated block randomization method (block size = 4) to ensure balanced group allocation, with outcome assessors blinded to group assignments throughout the study.

The intervention protocol spanned 8 weeks with twice-weekly 30-minute sessions. The Brain Gym group performed structured midline movements (Cross Crawl, Lazy 8s), energy exercises (Brain Buttons, Hook-Ups), and coordination drills (Elephant Trunk, Double Doodle) under the guidance of certified instructors. The control group engaged in matched-duration standard physical activities including gross motor exercises (running, jumping), fine motor tasks (bead threading, drawing), and structured play (obstacle courses). Both interventions were delivered in small groups of 5-6 children to ensure proper supervision and engagement.

Motor skill outcomes were assessed at baseline and post-intervention using two standardized tools: the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2) and Peabody Developmental Motor Scales-2 (PDMS-2). The BOT-2 evaluated gross motor skills (running speed, balance) and fine motor skills (manual dexterity), while the PDMS-2 measured stationary skills, locomotion, grasping, and visual-motor integration. All assessments were conducted by trained evaluators who remained blinded to group allocations.

Prior to statistical analysis, data normality was verified using Shapiro-Wilk tests ($p>0.05$ for all variables). For normally distributed data, paired t-tests examined within-group changes from pre-to post-intervention, while independent t-tests compared between-group differences. Effect sizes were calculated using Cohen's d, with values of 0.2, 0.5, and 0.8 representing small, medium, and large effects respectively. All analyses were conducted using SPSS v.28 with significance set at $p<0.05$ (two-tailed).

Ethical approval was granted by the Health Research Ethics Committee of Universitas Aisyiyah Surakarta (No. 260/X/AUEC/2024). Given that the participants were children, additional ethical considerations were applied. Written informed consent was obtained from parents or legal guardians prior to participation, and verbal assent was sought from the children in an age-appropriate manner. All procedures were designed to ensure minimal risk, with interventions consisting of safe, non-invasive physical activities under the supervision of trained instructors. Participation was entirely voluntary, and children were allowed to withdraw at any time without penalty. Privacy and confidentiality were maintained by anonymizing all data, and results were reported in aggregate form. These measures were implemented to uphold the ethical principle of protecting vulnerable populations in research.

3 Results And Discussion

3.1 Result

Total of 80 preschool children aged 4 to 6 years participated in the study, with 40 assigned to the Brain Gym group and 40 to the control group. As shown in **Table 1**, both groups were comparable in terms of age (Brain Gym: 5.1 ± 0.6 years; Control: 5.0 ± 0.7 years, p = 0.45). Gender distribution was also balanced, with slightly more boys than girls in both groups. Statistical tests confirmed no significant baseline differences in demographic characteristics, suggesting successful randomization.

Table 1 Participant Characteristics

Variabel	Brain Gym (n=40)	Control (n=40)	*p-value*
Age	5.1 ± 0.6	5.0 ± 0.7	0.45

Gender	22 / 18	21 / 19	0.83

The Shapiro-Wilk test results **Table 2** indicated that all motor skill outcome variables (fine and gross motor pre- and post-test scores) were normally distributed ($p > 0.05$), fulfilling the assumptions required for parametric testing.

Table 2 Normality Test

Variabel	***p-value***
Fine Motor Pre-test	0.112
Fine Motor Post-test	0.186
Gross Motor Pre-test	0.095
Gross Motor Post-test	0.144

Within-group comparisons using paired t-tests **Table 3** showed significant improvements in both fine and gross motor skills in the Brain Gym group after the 8-week intervention. Fine motor scores increased from 75.2 ± 5.3 to 82.4 ± 4.8 ($p < 0.001$, $d = 0.85$), and gross motor scores increased from 73.5 ± 6.1 to 82.4 ± 5.7 ($p < 0.001$, $d = 0.92$). These changes represent large effect sizes, indicating substantial developmental gains. In contrast, the control group showed minor, statistically non-significant improvements (fine motor: $p = 0.08$; gross motor: $p = 0.09$), with small effect sizes ($d < 0.3$).

Table 3 Paired Sample t-Test (Within-Group Comparison)

Variabel	**Pre-Test Mean ± SD**	**Post-Test Mean ± SD**	**p-value**	**Effect Size (d)**
Fine Motor (BG)	75.2 ± 5.3	82.4 ± 4.8	<0.001	0.85
Fine Motor (Ctrl)	74.9 ± 5.1	76.0 ± 5.0	0.08	0.22
Gross Motor (BG)	73.5 ± 6.1	82.4 ± 5.7	<0.001	0.92
Gross Motor (Ctrl)	74.1 ± 5.8	75.2 ± 6.0	0.09	0.21

Independent t-tests **Table 4** comparing post-intervention scores showed significant differences between the groups. The Brain Gym group outperformed the control group in fine motor skills (mean difference = 6.3 points, $p < 0.001$, $d = 1.27$) and gross motor skills (mean difference = 6.8 points, $p < 0.001$, $d = 1.21$). These improvements were not only statistically significant but also clinically meaningful. According to normative data for BOT-2 and PDMS-2, an increase of more than 5 points is generally considered indicative of a noticeable improvement in functional motor performance in daily activities. Thus, the observed gains suggest that Brain Gym contributed to improvements that are likely to be relevant for children's practical abilities, such as coordination, balance, and manual dexterity, beyond mere statistical outcomes.

Table 4 Independent Sample t-Test (Between-Group Comparison)

Variabel	**Brain Gym Post-Test**	**Control Post-Test**	**Mean Difference**	**p-value**	**Effect Size (d)**
Fine Motor	82.4 ± 4.8	76.0 ± 5.0	6.4	<0.001	1.27
Gross Motor	82.4 ± 5.7	75.2 ± 6.0	7.2	<0.001	1.21

3.2 Discussion

The results of this randomized controlled trial offer compelling evidence for the effectiveness of Brain Gym in significantly enhancing both fine and gross motor skills among preschool-aged children. The statistical significance and large effect sizes observed underscore the robustness of the findings. Such improvements are crucial during the early developmental years, where motor skills not only affect physical capabilities but also influence broader domains such as cognitive functioning and social interaction [8].

The investigation concerning the efficacy of Brain Gym interventions for enhancing motor skills in preschool-aged children yields important insights. Findings from various studies indicate that children participating in Brain Gym programs show improvements in fine and gross motor skills compared to those engaged in standard physical exercises. For instance, one study observed a statistically significant increase in fine motor skills post-Brain Gym intervention, with a p-value of 0.000, indicating a significant effect [9]. This is supported by another study that suggests structured physical activities, including Brain Gym exercises, can promote general motor proficiency and coordination in young children [10]. While these improvements are noteworthy, it's essential to consider that the benefits attributed to Brain Gym may be influenced by the principles of structured physical activity itself rather than unique mechanisms associated with Brain Gym. Research highlights that repetitive movements, regardless of being part of Brain Gym or other movement-based programs, can foster motor skill development in preschoolers [11]. Additionally, aerobic exercise has been shown to enhance cognitive and motor functions across various age groups, indicating parallels to findings associated with Brain Gym [12].

The results align with previous exploratory studies that have highlighted the potential of movement-based interventions in promoting neurodevelopmental outcomes. Previous studies have reported improvements in coordination and balance among children who regularly practiced Brain Gym. Enhanced visual-motor integration and increased classroom engagement among preschoolers who participated in structured movement programs [13]. These findings suggest that Brain Gym may operate through mechanisms that go beyond motor enhancement alone, potentially engaging attentional and executive systems.

Movement-based educational programs and questioned whether Brain Gym provides any unique benefits compared to traditional physical education [7]. However, our study contributes to resolving this ambiguity by employing a rigorous randomized controlled trial design with validated instruments like the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2) and the Peabody Developmental Motor Scales (PDMS-2). The methodological rigor of our study, including blinded assessments and random group assignment, strengthens the internal validity and helps clarify the specific benefits attributable to Brain Gym.

Recent advances in neuroscience also provide a plausible biological explanation for our findings. Cross-lateral movements featured prominently in Brain Gym, such as the "Cross Crawl" and "Lazy 8s," are theorized to stimulate communication between the brain's hemispheres [7]. Functional MRI studies have shown that such movements activate both cerebral hemispheres and enhance interhemispheric connectivity, which is essential for motor planning, coordination, and executive function . These neural mechanisms may explain the improvements observed not only in gross motor skills but also in the fine motor domain, which requires greater precision and control [4].

The practical implications of these findings are noteworthy. Brain Gym, as an intervention, is both time-efficient and resource-friendly. Each session in our study lasted only 30 minutes and required no specialized equipment. This makes it highly adaptable to various educational and clinical settings, especially in under-resourced communities or in schools with limited access to trained physical therapists. Given these advantages, policymakers and curriculum designers may consider integrating Brain Gym as a routine component of early childhood programs.

Brain Gym, a structured series of movement-based exercises, is believed to enhance motor development in children through multiple neurophysiological pathways [7]. One of the primary mechanisms involves the stimulation of interhemispheric communication. Many Brain Gym activities, such as Cross Crawl and Lazy 8s, incorporate cross-lateral movements that engage both hemispheres of the brain simultaneously. These movements are thought to enhance the efficiency of the corpus callosum, the neural bridge between the two hemispheres, thereby facilitating improved coordination and motor planning [6]. Effective bilateral integration is critical in both fine motor activities (e.g., cutting, writing) and gross motor tasks (e.g., balancing, jumping), where coordination of limbs across the midline is essential.

Brain Gym is hypothesized to stimulate key motor control centers in the brain, including the cerebellum, motor cortex, and premotor areas. These regions are responsible for the initiation, precision, and timing of motor actions. Repetitive, intentional movements in Brain Gym may promote neuroplasticity, strengthening synaptic connections involved in both gross and fine motor execution. For example, activities such as Double Doodle and Elephant Trunk require simultaneous visual tracking and bilateral arm movement, which activate the dorsal stream of visual processing and promote visuomotor integration—a critical skill for handwriting, drawing, and catching objects [14].

Brain Gym emphasizes sensory-motor integration by combining tactile stimulation, visual tracking, and movement. This multimodal engagement can refine proprioception and kinesthetic awareness, especially vital in fine motor tasks that require precision and control [14]. Gross motor development also benefits from enhanced proprioceptive input and muscle memory, enabling more controlled and fluid whole-body movements [8].

Another mechanism involves autonomic nervous system regulation. Brain Gym exercises, such as Hook-Ups and Brain Buttons, are designed to reduce physiological stress and calm the nervous system [9]. This can downregulate sympathetic arousal and improve parasympathetic tone, thereby creating a more optimal internal state for motor learning and task execution. Calm and regulated physiological states have been shown to enhance attention, postural stability, and motor coordination in children [9].

Brain Gym contributes to the development of neuromuscular readiness, strengthening the core and stabilizing muscles that support upright posture and coordinated movement. Activities that involve rhythmic patterns and midline crossing foster motor timing and sequencing, both of which are foundational for motor skill acquisition. These changes are especially meaningful during the early years of development, when neural circuits related to movement are highly plastic and responsive to structured input [10].

Educators and pediatric therapists can particularly benefit from incorporating Brain Gym into their daily routines. The structured movements can serve not only as physical warm-ups but also as preparatory exercises that enhance focus and readiness for cognitive tasks such as reading, writing, and problem-solving. Furthermore, its group-based delivery fosters social interaction, cooperation, and emotional regulation—skills that are equally vital during early childhood development.

The intervention's simplicity also offers opportunities for parental involvement. Caregivers could be trained to implement Brain Gym at home, promoting continuity of intervention outside formal education environments. This home-school consistency could further amplify developmental outcomes and engage families in the child's motor and cognitive journey.

Improvements in children's attention span and behavioral regulation following a structured Brain Gym protocol. Although these were not primary endpoints in our study, anecdotal observations from teachers and parents noted better engagement and reduced restlessness among children in the intervention group. Future trials should include these variables to better understand the holistic benefits of Brain Gym [7].

Despite the promising results, our study has several limitations. First, the intervention period of 8 weeks, while sufficient to detect changes in motor performance, may not fully capture the long-term sustainability of these gains. Longitudinal follow-ups at 3 or 6 months post-intervention would be necessary to determine whether motor improvements are maintained or require ongoing reinforcement.

Second, our sample was drawn from preschools in a single urban region, potentially limiting the generalizability of the findings. Children from rural settings, different socioeconomic backgrounds, or with pre-existing developmental conditions might respond differently to the intervention. Future studies should aim to replicate these findings across diverse populations.

Third, although outcome assessors were blinded to group allocations, the intervention providers (teachers or facilitators) were not, which introduces the possibility of performance bias. It is also possible that the children's awareness of participating in a "special activity" may have influenced their motivation and effort levels, thereby confounding results.

Moreover, while the BOT-2 and PDMS-2 are robust and widely accepted tools, they primarily assess gross and fine motor domains without capturing other relevant aspects such as reaction time, coordination under pressure, or dual-task performance. These limitations suggest the need for multimodal assessments in future research to provide a more comprehensive understanding of motor competence.

The theoretical underpinnings often cited to explain the improvements seen in children's motor skills through activity programs such as Brain Gym include enhanced interhemispheric communication and the neural dynamics associated with lateralized brain functions. However, caution must be exercised when attributing specific outcomes to these neurophysiological mechanisms, particularly when direct empirical assessments are absent. Some studies suggest a correlation between cross-lateral movements and interhemispheric communication—highlighting the role of the corpus callosum in facilitating coordination between the brain's hemispheres Jiang et al.[15] but the current study lacks neuroimaging or physiological data to substantiate such claims. Corpus callosum mediates motor coordination across hemispheres, underscoring its importance in integrating sensory and motor functions [15].

Consequences of developmental changes in bimanual coordination related to the maturation of transcallosal motor pathways [11]. This indicates that age-related improvements could be partially due to neural maturation rather than solely the effects of specific movement activities. Thus, the enhancement of motor skills in children observed from participating in Brain Gym activities might reflect broader developmental patterns in motor and cognitive domains, which could be consequentially similar to effects induced by other forms of physical engagement [14].

Further validate and expand upon our findings, several future directions are proposed. Long-term studies are needed to determine the persistence of Brain Gym's effects over time. This is particularly relevant for understanding whether the observed motor gains contribute to downstream benefits in academic performance or psychosocial development.

Additionally, future trials should consider employing neuroimaging or neurophysiological techniques to examine the underlying mechanisms of action. Understanding how Brain Gym affects brain structure and function could substantiate its theoretical underpinnings and provide biomarkers for intervention efficacy.

Comparative effectiveness studies are also warranted. These should explore how Brain Gym performs relative to, or in conjunction with, other evidence-based physical education programs. Such comparative studies can help educators and clinicians make informed decisions about which interventions are most appropriate for specific populations or settings.

This randomized controlled trial provides robust evidence that Brain Gym is a highly effective intervention for enhancing both fine and gross motor skills in children aged 4 to 6 years. The statistically significant improvements observed in this study highlight the value of structured, movement-based activities in early childhood development. With its simplicity, low cost, and adaptability, Brain Gym represents a promising tool for use in educational, clinical, and home settings. As research continues to explore its broader developmental benefits, Brain Gym may play an increasingly central role in comprehensive child development strategies.

This study also has several limitations that warrant attention. First, the sample was drawn from a single urban setting in Central Java, which may limit the generalizability of the findings to other regions or cultural contexts. Second, the intervention lasted only 8 weeks, preventing conclusions about the long-term sustainability of the motor skill gains. Third, no follow-up assessments were conducted after the intervention, leaving open the question of whether improvements persist over time. Finally, although outcome assessors were blinded, the teachers who delivered the intervention were not, introducing the possibility of performance bias.

4 Conclusion

This randomized controlled trial demonstrates that Brain Gym is a highly effective intervention for improving fine and gross motor skills in children aged 4 to 6 years. The significant gains observed in the Brain Gym group, compared to the control group, suggest that structured movement-based activities can accelerate motor development in early childhood. Given its simplicity, low cost, and adaptability to classroom or community settings, Brain Gym holds strong potential as a supplementary tool in early education and pediatric rehabilitation programs. Future studies should investigate its long-term effects, scalability, and integration with other evidence-based interventions to optimize developmental outcomes for children.

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