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Original Article

# Impact of *Brain Gym®* on health outcomes of toddlers born with low birth weight: a randomized trial

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## Abstract

***Background*** Low birth weight (LBW) children are at risk of developmental delay, including impaired motor skills, cognitive function, and stress regulation. *Brain Gym®* activities have been shown to improve motor coordination, attention span, and fine motor skills in preschool and primary school-aged children. Evidence for the use of *Brain Gym®* is limited for infants and toddlers with medical vulnerabilities such as low birth weight (LBW), who are at increased risk of developmental delay and heightened stress sensitivity.

***Objective*** To evaluate the impact of *Brain Gym®* exercises on cognitive function, motor skills (fine and gross motor), and cortisol levels in children aged 12-23 months with a history of LBW compared to a control group.

***Methods*** A randomized controlled trial (RCT) was conducted in Sragen, Indonesia, involving 80 low birth weight (LBW) children aged 12 to 23 months. Participants were randomly allocated into two groups: an experimental group receiving *Brain Gym®* intervention and a control group.The experimental group received *Brain Gym®* exercises combined with routine baby massage, while the control group received only baby massage. Cognitive and motor development were assessed using the *Denver Developmental Screening Test* (DDST), while stress biomarkers were measured through salivary cortisol levels using enzyme-linked immunosorbent assay (ELISA). Assessments were conducted at baseline (pre-intervention) and after the 8-week intervention period. The evaluators who administered the DDST and laboratory staff analyzing cortisol were blinded to group allocation.

***Results*** The primary outcomes of this study were motor skills, cortisol levels, and cognitive function. At baseline, there were no significant differences between the *Brain Gym®* group and the control group in fine motor, gross motor, or cognitive function scores, as assessed by the DDST. After the intervention, between-group comparisons revealed no statistically significant differences in gross motor, fine motor, cortisol, or cognitive function outcomes. Within-group analysis showed that gross motor scores in the *Brain Gym®* group significantly increased after the intervention (P=0.038), while fine motor scores demonstrated a non-significant trend toward improvement (P=0.110). Cortisol levels in the *Brain Gym®* group significantly decreased (P=0.009), whereas the control group exhibited no significant changes in gross motor (P=0.548), fine motor, or cortisol levels (P=0.118). Cognitive function scores remained statistically unchanged in both groups.

***Conclusion*** Our findings suggest that *Brain Gym®* exercises can improve gross motor function and reduce stress in LBW children. These findings highlight the potential of early interventions in enhancing development, but should be interpreted cautiously due to the modest sample size and short intervention period. Future studies should focus on the long-term effects and the mechanisms underlying these improvements. **[Paediatr Indones. 2025;65:400-10; DOI: https://doi.org/10.14238/pi65.6.2025.400-10 ].**

***Keywords:*** *brain gym; motor improvements; cortisol reduction; cognitive effect; early-intervention policy*

Low birth weight (LBW), defined by the *World Health Organization* (WHO) as a birth weight of less than 2,500 grams regardless of gestational age, remains a significant global public health concern.[1] Approximately 15% to 20% of all births worldwide fall into this category, with the highest prevalence reported in developing

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countries, particularly in South Asia and Sub-Saharan Africa.[2] Indonesia is among the countries where LBW continues to present a major challenge in neonatal and infant health. Data from *Riset Kesehatan Dasar 2018/ Riskesdas 2018* (*Indonesia's 2018 Basic Health Research*) showed that the national prevalence of LBW was 6.2%, with some provinces, including Central Java, exhibiting rates above the national average.[3]

Children born with LBW are more vulnerable to a range of complications that can extend far beyond the neonatal period.[4] Studies have consistently demonstrated that infants with LBW are at greater risk of experiencing delayed milestones, especially within the first two years of life, a critical period for brain development.[5] Furthermore, research indicates that LBW infants may have dysregulated stress responses, making them more sensitive to environmental stimuli and less adaptive to change.[6] If left unaddressed, these developmental vulnerabilities may have lifelong consequences on the individual's educational attainment, employment opportunities, and overall quality of life.[7] Given these risks, early intervention is vital to support the optimal development of LBW infants. Interventions that target this period can significantly improve cognitive and motor outcomes, especially among high-risk populations.[8]

One such approach that has gained popularity in recent years is *Brain Gym®*, which is based on the theory that simple, intentional movements can stimulate brain function, enhance neural connections, as well as improve learning and coordination.9 *Brain Gym®* is grounded in the brain-body learning theory which posits that coordinated physical movements - particularly those that involve crossing the body's midline - can improve neurological organization and facilitate cognitive, motor, and emotional development.[10] This theory emphasizes the integration of the brain's three dimensions: laterality (left-right), focus (front-back), and centering (top-bottom), which are believed to correspond to different learning and physiological functions. In toddlers, whose neural pathways are still maturing, structured movement patterns such as those used in *Brain Gym®* are proposed to support synaptic plasticity, especially in brain regions related to motor planning and sensory integration.[11]

Particular relevance are cross-lateral movements, such as "cross crawl" exercises, which require simultaneous activation of opposite limbs (e.g., right arm with left leg).[12] These movements are thought to stimulate communication between the brain's left and right hemispheres via the corpus callosum, thereby enhancing bilateral motor coordination and fine motor skill development.[13] These mechanisms provide a theoretical rationale for using *Brain Gym®* to address both developmental delays and psychophysiological stress responses in toddlers with low birth weight, who are known to be at elevated risk for such challenges.[14]

Originally developed to assist school-aged children with learning difficulties, *Brain Gym®* has since been adapted for use in various populations, including individuals with developmental delay, attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and even elderly populations experiencing cognitive decline.[15] *Brain Gym®* exercises typically involve a series of movements such as cross crawls, lazy eights, and hook-ups that are designed to activate both hemispheres of the brain, enhance sensory integration, and promote emotional regulation.[9] *Brain Gym®* activities improved motor coordination and concentration in preschool children.[16] Similarly, a study conducted in a primary school setting reported enhancements in attention span and fine motor control following regular *Brain Gym®* sessions.[17]

Despite its potential, the adoption of *Brain Gym®* in Indonesia's early childhood health strategies remains limited, and few studies have evaluated its effectiveness within the Indonesian population. To address this gap, we aimed to investigate the potential effect of *Brain Gym®* exercises on multiple domains of development - namely, cognitive function, fine motor skills, gross motor skills, and stress levels - among children aged 12-23 months with a history of LBW in Sragen Regency.

Our study investigates the impact of *Brain Gym®* on both fine and gross motor abilities, considering that these domains are often compromised in children born with LBW. We also assessed whether regular implementation of *Brain Gym®* activities can help reduce stress levels in these children, as measured through validated developmental, behavioral assessment tools and saliva test. By addressing these interrelated areas of early childhood development, our study might offer evidence-based insights that support the integration of *Brain Gym®* as a non-pharmacological intervention within public health frameworks, particularly those aimed at improving the developmental outcomes of high-risk infant populations in low-resource settings.

## Methods

This study employed a quantitative approach using a randomized controlled trial (RCT) design to evaluate the effect of *Brain Gym*® exercises and baby massage on improving cognitive function, fine and gross motor skills, as well as stress levels in infants aged 12-23 months, gestational age >37 weeks, and a history of LBW. Participants were randomly assigned to either the *Brain Gym*® intervention group or the baby massage control group, by block randomization (block=4); a random-sequence was generated in Excel by an independent statistician and allocations were concealed in sequentially numbered opaque envelopes. Using G**Power 3.1*, $\alpha=0.05$, power=0.80, and effect size (f)=0.30 (from pilot data on fine-motor score change), the minimum required sample was 72. We recruited 80 toddlers from local healthcare centers and community health services (posyandu) in Sragen, to allow for 10% attrition; 40 subjects were assigned to either the experimental or control group. Exclusion criteria were infants with congenital diseases (such as seizures or heart problems) or disabilities that may hinder participation in the intervention.

Cognitive function was assessed using the *Denver Developmental Screening Test* (DDST), which evaluates attention, memory, and problem-solving abilities. This tool measures infants' ability to engage with their environment and perform tasks that are appropriate for their developmental stage. Infant stress levels were assessed by measuring cortisol levels in saliva. Specimens were collected before and after the intervention period to evaluate changes in stress levels associated with the *Brain Gym*® and baby massage interventions. Our study investigates the impact of *Brain Gym*® on both fine and gross motor abilities, considering that these domains are often compromised in children born with LBW. We also assessed whether regular implementation of *Brain Gym*® activities can help reduce stress levels in these children, as measured through the DDST for developmental and behavioral assessment, and salivary cortisol analysis for physiological stress measurement. By addressing these interrelated areas of early childhood development, our study offers evidence-based insights supporting the integration of *Brain Gym*® as a non-pharmacological intervention within public health frameworks, particularly those aimed at improving the developmental outcomes of high-risk infant populations in low-resource settings.

Nutritional status was assessed based on body mass index (BMI) and dietary patterns, evaluated using the energy adequacy level (EAL). The EAL assessment was conducted through a 24-hour dietary recall obtained from caregivers or parents, recorded for the previous day's food and beverage intake. The recall data were collected by a trained nutritionist using standardized interview guidelines to ensure accuracy. The total daily energy intake was then analyzed using *Daftar Komposisi Bahan Makanan/ DKBM* (the *Indonesian Food Composition Table*) and compared with the *Recommended Dietary Allowance* (RDA) according to the child's age and sex, as defined by the Ministry of Health of Indonesia.

The EAL was expressed as a percentage of the recommended intake and categorized as follows: <70%=deficit, 70-89%=moderately adequate, 90-119%=adequate, ≥120%=excessive. This classification was used to determine the children's overall dietary adequacy prior to the intervention and to ensure group comparability between the *Brain Gym*® and control groups.

Subjects were divided into an intervention group (n=40) receiving *Brain Gym*® training and a control group(n=40) receiving baby massage. Participants in the intervention group attended 20-minute *Brain Gym*® sessions twice weekly for four weeks. Sessions were conducted in small groups, facilitated by a trained physiotherapist, and involved the participation of each child's mother. The *Brain Gym*® program aimed at stimulating gross and fine motor skills, concentration, and emotional regulation. The intervention was based on the official *Brain Gym*® international protocols. Intervention fidelity was ensured through the use of a standardized manual and direct supervision by the lead researcher. The control group received baby massage sessions lasting 15 minutes per session, twice weekly for four weeks. Massages were performed by subjects' mothers, under the supervision of experienced physiotherapists, using standard baby massage techniques widely used in Indonesia's primary healthcare settings. Sessions were conducted in the same environment as the intervention group to ensure equal attention and contextual consistency. No *Brain Gym®* components were included. Therefore, differences between groups can be attributed specifically to the effects of the *Brain Gym®* intervention.

Data were collected at two time points: pre-intervention (baseline) and post-intervention (after 2 months). Subjects underwent DDST testing to assess cognitive and motor skills, and salivary cortisol specimens were collected to assess stress levels. Blinding was applied in a limited manner. Outcome assessors were blinded to group allocation to minimize detection bias during pretest and posttest evaluations. However, due to the behavioral nature of the intervention and the need for direct engagement, parents/caregivers and intervention facilitators were not blinded. Data analysts *Brain Gym®* were not involved in the intervention implementation and received anonymized data only, ensuring objective data analysis. The lack of blinding among parents and facilitators may introduce potential performance bias. To address this, the research team provided scripted instructions to both caregivers and community health workers during intervention sessions. Furthermore, objective measures, such as the DDST were administered using standardized procedures to enhance measurement validity and reliability.

Quantitative data were analyzed using *SPSS* software. Descriptive statistics (mean, standard deviation) were used to summarize the demographic characteristics and baseline measurements for both groups. Paired T-tests were employed to compare pre- and post-intervention scores within each group. Two-way mixed ANOVA was used to examine between-group differences and the interaction effects of time and group. The significance level was set at $P<0.05$.

This study was approved by the Health Research Ethics Committee of Universitas Aisyiyah, Surakarta. Written informed consent was obtained from parents or legal guardians prior to participation. The confidentiality and privacy of participants were strictly maintained throughout the research process.

## Results

The demograhic characteristics of subjects included age, gender, nutritional status based on body mass index (BMI), and dietary patterns assessed using the energy adequacy level (EAL) (**Table 1**). The EAL was calculated from a 24-hour dietary recall conducted on the previous day, then compared with the recommended daily intake according to age and sex. Testing was conducted to ensure that there were no significant differences between the experimental group and the control group before the intervention

We compared pre-test and post-test DDST scores in the experimental and control groups to evaluate the impact of *Brain Gym®* on cognition. Data normality, within-group effect (before and after the intervention), and differences between groups were analyzed, as shown in **Table** 2.

Based on the analysis in **Table 3**, after two months of intervention, the mean cognitive function score in the experimental group further increased to 93.49 (SD 4.51), while in the control group it reached 92.48 (SD 4.66). The between-group comparison at this stage also showed no significant difference ($P=0.334$). The Wilcoxon signed-rank test within each group indicated that the change in cognitive scores from pre-test to post-test after two months was not significant in the experimental group ($P=0.154$) or in the control group ($P=0.468$). The mean difference (Δ) in score changes between the two groups was 2.375 (SD 8.39) in the experimental group and 0.968 (SD 6.51) in the control group, with the Mann–Whitney U test results showing no significant difference ($P=0.570$). Overall, although there was an increase in mean cognitive function scores in both groups, the improvement was not statistically significant either within groups or between groups. This indicates that the Brain Gym intervention over two months did not produce a differential effect on cognitive function compared to the control condition.

We assessed whether the *Brain Gym®*intervention had an effect on children's fine motor abilities, which include small movements such as reaching, grasping, and manipulating objects, by comparing pre-test and post-test scores within each group and analyzing the differences between groups. Since the data were not normally distributed ($P<0.05$), non-parametric tests were used in the subsequent analyses. The results are

**Table 1**. Characteristics of subjects by group

| Characteristics | Experimental group (n=40) | Control group (n=40) | P value |
|---|---|---|---|
| Age, n (%) | | | 0.854[ba] |
| 12-15 months | 15 (37.5) | 4 (35.0) | |
| 16-19 months | 13 (32.5) | 12 (30.0) | |
| 20-23 months | 12 (30.0) | 14 (35.0) | |
| Mean age (SD), months | 15.87 (3.03) | 15.85 (3.42) | |
| Weight, n(%) | | | 0.870[a] |
| 1500-1799 gr | 15 (37.5) | 15 (37.5) | |
| 1800-2099 gr | 10 (25.0) | 15 (37.5) | |
| 2100-2399 gr | 10 (25.0) | 8 (20.0) | |
| 2400-2499 gr | 5 (12.5) | 2 (5.0) | |
| Mean (SD), gr | 1975.05 (318.5) | 1955.8 (295.38) | |
| BMI, n(%) | | | 0.128[cb] |
| Overweight | 4 (10.0) | 4 (10.0) | |
| Normal | 27 (67.5) | 26 (65.0) | |
| Underweight | 9 (22.5) | 10 (25.0) | |
| Mean BMI (SD) | 0.221 (1.59) | - 0.279 (1.30) | |
| Dietary pattern (EAL), n (%) | | | 0.041[b] |
| Normal | 26 (65.0) | 27 (67.5) | |
| Inadequate | 14 (35.0) | 13 (32.5) | |
| Mean EAL (SD), UNITS | 92.45 (4.814) | 94.70 (4.863) | |

[a]Man Whitney test, [b] ndependent T-test; Source: Primary Data

**Table 2**. Analysis of cognitive testing within and between groups, pre- and post-intervention

| Cognitive | Experiment | Control | Independent sample test (P value) |
|---|---|---|---|
| Mean pre-test (SD) | 91.12 (7.47) | 91.51 (4.22) | 0.462[b] |
| Mean post-test (SD) | 93.49 (4.51) | 92.48 (4.66) | 0.334[b] |
| Paired sample test (pre - post) | 0.154[a] | 0.468[a] | - |
| Δ (post - pre) | 2.375 (8.39) | 0.968 (6.51) | 0.570[b] |

[a]Wilcoxon signed-rank test, [b]Mann-Whitney U test

shown in **Table 3**. Wilcoxon-signed rank test revealed no significant differences in pre- and post-test fine motor skills within each group. Mann-Whitney U test revealed no significant differences in fine motor skills improvement with intervention between groups.

Based on the analysis in **Table 4**, the mean score of fine motor skills in the experimental group before the intervention was 92.33 (SD 5.73), slightly decreased to 92.20 (SD 4.37) after one month, and further declined to 92.07 (SD 5.40) after two months of Brain Gym intervention. Meanwhile, in the control group, the baseline mean score was 91.48 (SD 5.30) and increased to 92.53 (SD 4.80) after two months. The Wilcoxon signed-rank test showed that the changes in scores from pre-test to two months post-test were not significant in the experimental group (P=1.000) or in the control group (P=0.175). The delta (Δ) value of score changes was -0.26 (SD 6.90) in the experimental group and 1.51 (SD 6.90) in the control group, with between-group comparison also showing no significant difference (P=0.303). Overall, these results indicate that the two-month Brain Gym intervention did not produce a significant effect on improving fine motor skills compared to the control group. The increases or decreases observed in both groups fell within the range of normal variation and were not statistically strong enough to be interpreted as an intervention effect.

We evaluated the impact of the *Brain Gym®* intervention on the improvement of gross motor skills (sitting, standing, walking, and other large body movements) within and between groups. The analysis was conducted using non-parametric tests due to the non-normal distribution of the data (P<0.05). The results are shown in **Table 4**. Wilcoxon-signed rank test revealed a significant improvement in gross motor

**Table 3**. Analysis of fine motor skills within and between groups, pre- and post-intervention

| Fine motor | Experiment | Control | Independent sample test (P value) |
|---|---|---|---|
| Mean pre-test (SD) | 92.33 (5.73) | 91.48 (5.30) | 0.329[b] |
| Mean post-test (SD) | 92.07 (5.40) | 92.53 (4.80) | 0.630[b] |
| Paired sample test (pre - post) | 1.000[a] | 0.175[a] | - |
| Δ (post - pre) | -0.26 (6.90) | 1.51 (6.90) | 0.303[b] |

[a]Wilcoxon signed-rank test, [b]Mann-Whitney U test

**Table 4**. Analysis of gross motor skills within and between groups, pre- and post-intervention

| Fine motor | Experiment | Control | Independent sample test (P value) |
|---|---|---|---|
| Gross motor | Experiment | Control | Independent sample test (P value) |
| Mean pre-test (SD) | 88.61 (6.54) | 89.66 (5.91) | 0.157[b] |
| Mean post-test (SD) | 91.77 (6.15) | 90.89 (5.76) | 0.211[b] |
| Paired sample test (pre-post) | 0.000[a] | 0.001[a] | - |

[a]Wilcoxon signed-rank test, [b]Mann-Whitney U test

skills within the intervention group (P=0.014), but not within the control group (P=1.00). However, Mann-Whitney U test revealed no significant difference between the groups.

Based on the analysis in **Table 5**, the mean score of gross motor skills in the experimental group increased from 88.61 (SD 6.54) at pre-test to 91.77 (SD 6.15) after two months of *Brain Gym*® intervention. The Wilcoxon signed-rank test showed that the change from pre-test to post-test at two months was statistically significant (P=0.000), with a delta (Δ) value of 3.16 (SD 2.32). This indicates that *Brain Gym*® intervention provided a meaningful improvement in gross motor skills among children with a history of low birth weight after two months of implementation. In the control group, the initial mean score of 89.66 (SD 5.91) slightly decreased to 90.89 (SD 5.76) after two months. Although the Wilcoxon test also showed statistical significance (P=0.001), the delta (Δ) value of -0.69 (SD 2.66) reflected a negative change, indicating a decline in the mean gross motor score.

Between-group comparison using the Mann-Whitney U test demonstrated a significant difference in the two-month delta change (P=0.000), although the difference in the mean scores at the two-month post-test was not significant (P=0.211). These findings suggest that the improvement in the experimental group was much greater than in the control group. Overall, the results strengthen the evidence that *Brain Gym*® is effective in enhancing gross motor skills in children aged 12-23 months with a history of low birth weight, particularly when implemented consistently over two months.

We evaluated the effectiveness of *Brain Gym*® in reducing physiological stress levels by comparing cortisol concentrations before and after the intervention. Data analysis included the Kolmogorov-Smirnov test for normality and non-parametric tests (Wilcoxon signed-rank and Mann-Whitney U) due to non-normal data distribution. Results are shown in **Table 6**.

The analysis of cortisol levels showed a statistically significant decrease in the experimental group after receiving the *Brain Gym*® intervention. The mean cortisol level decreased from 2.26 (SD 2.10) to 1.65 (SD 1.22), with a mean difference of -0.61 (SD -0.88). The Wilcoxon signed-rank test indicated that this reduction was significant (P=0.009), suggesting that *Brain Gym*® exercises have the potential to effectively reduce physiological stress in children aged 12-23 months with a history of low birth weight. In the control group, cortisol levels decreased from 2.109 (SD 1.44) to 1.89 (SD 1.43); however, this change was not statistically significant (P=0.118). This finding indicates that without intervention, a decrease in cortisol levels may occur naturally or due to other factors, but it was not consistent enough to be considered statistically meaningful.

The between-group comparison using the Mann-Whitney U test revealed no significant difference in the effects between the two groups (P=0.462).

**Table 5**. Analysis of cortisol levels within and between groups, pre- and post-intervention

| Cortisol | Experiment | Control | Independent sample test (P value) |
|---|---|---|---|
| Mean pre-test (SD) | 2.26 (2.1) | 2.109 (1.44) | 0.981[b] |
| Mean post-test (SD) | 1.65 (1.22) | 1.89 (1.43) | 0.462[b] |
| Paired sample test (pre-post) | 0.009[a] | 0.118[a] | - |
| Δ (post-pre) | -0.61 (-0.88) | -0.219 (-0.01) | 0.544[b] |

[a]Wilcoxon signed-rank test, [b]Mann-Whitney U test

**Table 6**. Multivariate analysis

| Dependent variable | F pre-test (P value) | F post-test (P value) | Partial eta squared | Significant independent variables (pre/post) | Remarks |
|---|---|---|---|---|---|
| Cognitive function | 1.042 (0.391) | F= (N/A) | N/A | None/none | No significant effects observed from any tested factors |
| Fine motor skills | 1.006 (0.410) | 1.958 (0.110) | 0.468 (intercept post-test) | None/none | Tendency to improve after intervention, but not statistically significant |
| Gross motor skills | 2.682 (0.038) | 0.769 (0.548) | 0.125 (pre), 0.158 (post intercept) | Age (P=0.016), Group (P=0.037)/ None | Significant change at pre-test; non-significant at post-test |
| Stress level (cortisol) | 0.279 (0.891) | 2.306 (0.066) | 0.109 | None/BMI (P=0.027), diet (P=0.051) | Post-test shows trend toward stress reduction influenced by diet and BMI |

This means that although the experimental group demonstrated a significant reduction in cortisol levels, the comparison with the control group did not show a sufficiently large difference to be statistically meaningful. Nevertheless, these results provide preliminary evidence that *Brain Gym®* may help reduce physiological stress in young children, particularly those with a history of low birth weight, and could be considered as part of an approach to support child development stimulation.

Multivariate analysis of variance (MANOVA) was conducted to evaluate the simultaneous effects of multiple independent variables on several dependent variables. In this study, the dependent variables included cognitive function, fine motor skills, gross motor skills, and cortisol levels. The independent variables comprised child's age, dietary pattern, body mass index (BMI), and treatment group (experimental vs. control).

The MANOVA results indicate baseline (pre-intervention) differences rather than intervention effects. Specifically, there was no significant difference in cognitive function at baseline ($F=1.042$; $P=0.391$), and no valid post-test multivariate result was produced for this outcome. For fine motor skills, there was no significant baseline difference ($F=1.006$; $P=0.410$). A non-significant positive trend appeared at post-test ($F=1.958$; $P=0.110$), suggesting possible improvement after the intervention but not reaching statistical significance.

For gross motor skills, a significant baseline difference was observed ($F=2.682$; $P=0.038$). Importantly, this reflects pre-intervention group imbalance, not an intervention effect. At baseline, the control (Baby Massage) group had slightly higher gross motor scores than the *Brain Gym®* group (e.g., mean ≈ 89.66 *vs.* 88.61). Age and group membership contributed to this baseline variation. Post-test, there was no significant multivariate difference between groups ($F=0.769$; $P=0.548$).

For stress (cortisol), there was no significant baseline difference ($F=0.279$; $P=0.891$). At post-test, a near-significant trend emerged ($F=2.306$; $P=0.066$), with dietary adequacy ($P=0.051$) and BMI ($P=0.027$) contributing to variability; however, these findings did not meet the conventional $P<0.05$ threshold. Overall, the multivariate results should be interpreted as: (1) some baseline imbalance in gross motor scores favoring the control group, and (2) no statistically significant post-intervention group differences across outcomes in the MANOVA, despite univariate within-group changes (e.g., reduced cortisol in the intervention arm) reported elsewhere.

## Discussion

The primary objective of this study was to investigate the effects of *Brain Gym®* interventions on the cognitive, fine motor, gross motor, and cortisol levels of children aged 12-23 months with a history of low birth weight (LBW). Our results revealed that while no significant changes were observed in cognitive function, there were positive trends in fine motor skills. These findings provide insight into the potential benefits of *Brain Gym®* exercises in early childhood development, particularly in children who may have developmental challenges due to their birth history.

We found no significant improvement in cognitive function after the *Brain Gym®* intervention, as indicated by the results of the pre-test and post-test comparisons. The lack of improvement in cognitive function is in contrast to the findings of several studies that have shown positive effects of physical activity, including structured exercises like *Brain Gym®*, on cognitive development.[18,19] A possible explanation for this discrepancy is that cognitive function in very young children, particularly those in the 12 to 23-month-age group, might be less influenced by short-term interventions. Cognitive development at this stage is highly individual and influenced by various factors, including genetics, home environment, and early exposure to learning opportunities. It is also possible that the duration of the *Brain Gym®* intervention, or the specific exercises employed, were not sufficient to evoke noticeable cognitive changes.[18]

Fine motor skills showed a more promising trend. Although the statistical analysis did not reach significance, there was a noticeable increase in fine motor performance post-intervention. This aligned with a previous study that suggested that structured physical activities, such as those involved in *Brain Gym®*, can lead to improvements in fine motor coordination and control in young children.[20] These skills are vital for daily activities such as grasping objects, feeding, and later in life, writing and other tasks that require dexterity. The trend observed here may suggest that the intervention's benefits for fine motor development are more gradual and may require a longer or more intensive intervention to yield significant results.

Gross motor skills presented an interesting pattern in this study. We observed a statistically significant difference (P=0.014) in the experimental group when comparing pre- and post-test scores, indicating that the intervention contributed to measurable gains in gross motor skills. However, when comparing post-test results between the experimental and control groups, no significant difference was found. Interestingly, the control group actually demonstrated slightly better gross motor scores than the intervention group at the post-test stage. Gross motor skills, which involve large body movements such as walking, running, or standing, typically develop rapidly in children between the ages of 12-23 months. This rapid and naturally occurring development may partially explain the improvements observed in both groups, while also leading to a plateau effect in measurable differences between them. In other words, once children in both groups reached a certain developmental milestone, further changes became less distinguishable within the timeframe of the study.

Our findings regarding cognitive function are consistent with some studies that have shown limited immediate effects of physical interventions on cognitive outcomes in young children.[10] Physical activity programs did not significantly improve cognitive performance in children under three years old, suggesting that cognitive development in this age group might be influenced by factors beyond physical activity.[21] However, our results diverged from other research that has demonstrated the efficacy of structured physical activities like *Brain Gym®* in improving motor skills. Children who participated in physical interventions showed significant improvements in both fine and gross motor skills, particularly in children with developmental delay.[22] This contrast highlights the variability in the impact of *Brain Gym®* across different populations and suggests that factors such as the duration of the intervention and the individual characteristics of participants (e.g., age, baseline developmental status) may influence outcomes.

Regarding cortisol levels, the reduction observed in the experimental group is supported by existing literature on the benefits of physical activity in reducing stress and cortisol levels in children.[23] Physical activity can lower cortisol levels in children with developmental challenges, which is consistent with our findings.[24] Our study extends these findings by specifically focusing on children with LBW, a group known to be at higher risk for stress-related developmental issues.

This study features the potential of *Brain Gym®* exercises to enhance gross and fine motor development and reduce stress levels in toddlers with low birth weight (LBW). *Brain Gym®* can be incorporated into regular motor-stimulation activities conducted at posyandu sessions under the SDIDTK (Early Detection and Intervention for Child Development) program. Movements such as cross crawl, lazy 8s, and hook-ups are simple, equipment-free, and easily implemented by parents at home. This makes *Brain Gym®* a feasible and accessible method to be scaled in community health settings. To support effective implementation, short training modules should be developed for posyandu cadres or community physiotherapists. These trainings would include fundamental principles of neurodevelopment, the purpose of each *Brain Gym®* movement, and techniques for instructing caregivers. Training can be integrated into existing *Stimulasi, Deteksi, dan Intervensi Dini Tumbuh Kembang*/SDIDTK (*Stimulation, Detection, and Early Intervention on Growth and Development*) capacity-building initiatives coordinated by local health authorities.

While this study provides valuable insights into the effects of *Brain Gym®* on early childhood development, several limitations should be acknowledged. First, the sample size was relatively small, which may limit the generalizability of our findings. A larger sample size would have increased the statistical power of the study and provided more reliable estimates of the intervention's effects. Additionally, the study was conducted over a short period, and the outcomes might differ with longer-term interventions. Previous studies have shown that sustained physical activity over extended periods is necessary to observe significant developmental changes.[25] Another limitation is the lack of a more comprehensive control group. In our study, the control group did not receive any intervention, but it would have been beneficial to compare *Brain Gym®* with other types of physical interventions to assess its relative effectiveness. Furthermore, our study relied solely on pre- and post-test measurements, which do not account for any changes that may have occurred during the follow-up period. Longitudinal studies that measure outcomes at multiple time points would provide a more complete picture of the long-term effects of *Brain Gym®* on child development. Lastly, we used non-parametric tests due to the non-normal distribution of data. While this is a valid approach, it can be less powerful than parametric tests, which may have affected our ability to detect subtle changes in the variables measured. Participants were recruited through posyandu in Sragen; hence, families who attend these services may differ from non-attendees, introducing possible selection bias.

Future research should aim to address these limitations by employing a larger, more diverse sample and implementing longitudinal designs to track the effects of *Brain Gym®* over time. This would help establish whether the observed effects are sustained and to determine the optimal duration of the intervention. Moreover, comparing *Brain Gym®* with other well-established physical intervention programs, such as those focusing on motor skill development or stress management, would provide a clearer understanding of its relative effectiveness.

Additionally, research could explore the underlying mechanisms that explain how *Brain Gym®* influences stress and developmental outcomes in children with LBW. Understanding these mechanisms could inform the design of more targeted interventions and contribute to the development of evidence-based practices for promoting early childhood development in at-risk populations.

This research is particularly significant for several reasons. First, it contributes to the limited body of literature exploring the use of *Brain Gym®* among infants and toddlers with developmental vulnerabilities. Second, it addresses a critical health disparity by focusing on a high-risk population in a rural setting where conventional therapies may not be readily available. Third, it incorporates a holistic view of child development, recognizing that cognition, motor function, and stress regulation are interconnected domains that must be addressed together for optimal outcomes. Lastly, the study has the potential to inform policy recommendations for integrating simple, movement-based interventions into existing maternal and child health programs in Indonesia.

This study demonstrated significant improvements in gross motor skills and reductions in cortisol levels in the experimental group of children aged 12-23 months with a history of low birth weight, indicating the potential benefits of *Brain Gym®* in supporting motor development and stress regulation at an early age. However, no significant differences were observed in fine motor skills or cognitive function when compared to the control group. These findings should be interpreted cautiously, as the sample size was small and the intervention duration was limited. Further research with larger and more diverse samples is necessary to validate these results and to better understand the potential role of *Brain Gym®* in early childhood development.

## Conflicts of interest

None declared.

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