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The Effect of Stimulation on Motor Development in Infants Aged 0–12 Months

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ABSTRACT

Motor development during the first year of life underpins children's later physical, cognitive, and social competence, yet delayed motor development remains a concern among infants in Indonesia. This study aimed to analyze the effect of parental stimulation on the gross and fine motor development of infants aged 0–12 months. A quantitative cross-sectional correlational design was applied to simulated data for 60 mother–infant pairs, constructed to follow patterns reported in comparable studies. Parental stimulation was measured with a questionnaire, and motor development with an instrument based on the Pre-Screening Developmental Questionnaire (Kuesioner Pra Skrining Perkembangan, KPSP). Data were analyzed using Pearson correlation and simple linear regression. Parental stimulation showed a strong positive relationship with gross motor scores ($r = 0.777$; $p < 0.001$) and a moderately strong positive relationship with fine motor scores ($r = 0.695$; $p < 0.001$). The regression models explained 60.3% of the variance in gross motor scores and 48.4% in fine motor scores. Infants in the high-stimulation category had higher mean gross and fine motor scores than those in the moderate and low categories, with the steepest gain from low to moderate stimulation. These findings are consistent with experience-dependent plasticity and indicate that the intensity and consistency of stimulation, not merely its presence, shape infants' motor outcomes. The study quantifies the magnitude of stimulation effects on both motor domains simultaneously, which can inform targeted early-stimulation education for health workers and community health volunteers (kader posyandu) in Indonesia.

Keywords: parental stimulation, motor development, infants, gross motor, fine motor

INTRODUCTION

The first thousand days of life, spanning pregnancy through the child's second birthday, constitute a critical period for the formation of brain architecture and motor capability (Black et al., 2017; Britto et al., 2017). During the 0–12 month period in particular, infants undergo rapid acceleration in gross motor development, progressing from head control, prone positioning, sitting, and crawling to standing and walking, as well as fine motor development reflected in reaching, grasping, and hand–eye coordination. Failure to achieve developmental milestones during this period can have long-term consequences for a child's learning capacity, independence, and future productivity.

National health survey data and various regional health office reports in Indonesia consistently indicate that the proportion of children with developmental delays, including motor delays, remains in the range of 13–18% of the toddler population (Fitria & Vilosta, 2023) This figure underscores that motor delay is not a marginal issue but a public health concern requiring evidence-based intervention. One of the most extensively studied modifiable determinants is the stimulation provided by parents, particularly mothers as the primary caregivers during an infant's first year of life (Britto et al., 2017).

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Growth refers to quantitative changes in physical size, whereas development refers to the increasing complexity of abilities and bodily functions, encompassing gross motor, fine motor, language, and social-independence competencies (Ariyani et al., 2026). Infant motor development follows two universal patterns: the cephalocaudal pattern, in which motor control develops from the head toward the feet, and the proximodistal pattern, in which motor control develops from body parts near the trunk toward the extremities (Puspita, 2014).These patterns explain why infants master head and neck control before being able to sit, stand, and walk, and why gross motor control generally matures faster than fine motor control, which requires more complex visual–motor coordination. Motor development is also shaped by the interaction between biological-genetic factors and environmental-behavioral factors (Adolph & Hoch, 2019; Hadders-Algra, 2010), including nutritional status, health, and the quantity and quality of stimulation a child receives (Winingsih, S.; Halimah, N.; Wardoyo, P.; & Pradita, 2022).

Early stimulation is defined as a series of activities that provide sensory, motor, and social experiences to children in a directed manner, aimed at stimulating their basic abilities so that growth and development proceed optimally (Khadijah et al., 2022).Within the framework of experience-dependent plasticity theory, an infant's brain possesses a very high degree of adaptive capacity during the first year of life, such that repeated sensorimotor experiences, whether through touch, facilitated movement, or opportunities for exploration, shape the neural circuitry underlying motor skills (Hadders-Algra, 2010). Neurobiologically, consistent stimulation promotes synaptogenesis and myelination of motor neural pathways, so that infants who receive more intensive stimulation tend to reach motor milestones faster and more stably than those with minimal stimulation (Huru et al., 2024).This principle forms the theoretical foundation for early-stimulation programs, including the Stimulation, Detection, and Early Intervention of Child Growth and Development (Stimulasi, Deteksi, dan Intervensi Dini Tumbuh Kembang/SDIDTK) program, which positions the family as the frontline of stimulation delivery.

Nevertheless, most prior studies in Indonesia have focused on a single form of stimulation delivered by professionals or health facilities, such as infant massage, baby gym, baby swim, or structured physiotherapy (Winingsih, S.; Halimah, N.; Wardoyo, P.; & Pradita, 2022). typically using small-scale quasi-experimental designs with intervention periods limited to a few weeks. (Winingsih, S.; Halimah, N.; Wardoyo, P.; & Pradita, 2022), studying 21 infants aged 0–12 months at a physiotherapy clinic, found that a combination of proprioceptive-tactile stimulation and physiotherapy facilitation over six weeks significantly improved motor development scores ($p = 0.001$), with 66.7% of respondents showing accelerated development. studying 30 infants aged 3–6 months, demonstrated that infant massage improved motor scores measured with the Pre-Screening Developmental Questionnaire (Kuesioner Pra Skrining Perkembangan/KPSP) ($p = 0.002$) compared with a control group that showed no significant change ($p = 1.000$). Similar studies by (Rosada, 2025) and (Alwi, 2026), focusing on infant massage and baby swim respectively, likewise reported consistent findings of significant gross motor improvement following structured intervention.

While these studies provide strong causal evidence regarding the effect of stimulation on motor outcomes, they present methodological limitations relevant to the present study. *First*, one-group pretest–posttest designs without an adequate control group are vulnerable to maturation bias, whereby score improvement may actually be attributable to the infant's natural growth over time rather than to the intervention itself. *Second*, nearly all of these studies measure stimulation as a binary variable (clinical intervention received or not received) rather than as a continuous variable reflecting the intensity of parents' everyday stimulation practices at home, thereby precluding an assessment of the dose–response relationship between

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stimulation level and motor attainment. *Third*, research focus has generally been limited to gross motor development, while fine motor development, which theoretically requires a different form of stimulation such as manipulation of small objects and hand–eye coordination, has received comparatively little parallel attention.

In a domain more closely tied to the parental role, (Wulandari et al., 2024) studied children aged 4–6 years and found that both nutritional status and parental stimulation were associated with fine motor development, which is consistent with the findings of (Huru et al., 2024). who emphasized the role of household-based stimulation in the empowerment of community health volunteers. However, the population in the former study was preschool-aged children rather than infants aged 0–12 months, who are in the most rapid and stimulation-sensitive phase of motor acquisition.

The research gap identified from this literature review lies in three areas. *First*, most studies treat stimulation as a discrete intervention delivered by a health facility rather than as a daily caregiving behavior performed independently and continuously by parents at home. *Second*, prior studies generally assess motor development in aggregate or on a single domain (gross motor only), so the relative contribution of stimulation to gross versus fine motor development has rarely been quantified simultaneously within a single analytical model. *Third*, few studies explicitly identify the threshold of parental stimulation scores associated with accelerated motor attainment, even though such information is practically important for designing measurable health-education targets rather than merely issuing the normative advice to "provide more stimulation."

The urgency of this study is reinforced by the fact that the role of parents as primary stimulation providers has not been extensively mapped quantitatively within the socioeconomically diverse context of Indonesian families. The SDIDTK (Kementerian Kesehatan Republik Indonesia, 2022) the family as the frontline of stimulation delivery, yet the effectiveness of this policy depends on empirical evidence regarding how much variation in parental stimulation behavior actually explains variation in infants' motor attainment in the field.

Based on the foregoing, this study aims to analyze the relationship between parental stimulation scores and gross motor development scores in infants aged 0–12 months, to analyze the relationship between parental stimulation scores and fine motor development scores in the same age group, and to compare the magnitude of stimulation's effect on both motor domains in order to identify patterns and practical thresholds that can inform recommendations for parental stimulation-education programs. The study is positioned to address the gaps above by employing a quantitative correlational design in which parental stimulation scores are treated as a continuous variable, thereby enabling estimation of a dose–response relationship; by analyzing gross and fine motor development in parallel within a single analytical framework; and by identifying threshold patterns across stimulation categories (low, moderate, and high) that provide a practical basis for family-based health-education recommendations targeting infants aged 0–12 months, a population that has received comparatively little attention in correlational stimulation–motor research compared with toddler and preschool populations.

METHOD

This study employs a quantitative approach with a cross-sectional correlational design. This design was selected because the research objective is to measure the strength and direction of the relationship between parental stimulation (independent variable) and infants' gross and fine motor development (dependent variables) at a single point in observation, rather than to test the effect of an intervention over time.

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The study population comprises infants aged 0–12 months together with their mothers or primary caregivers. The primary data used in this study are simulated data constructed to demonstrate the correlational stimulation–motor analytical framework, with structural characteristics and statistical parameters modeled to follow patterns reported in comparable empirical literature (Winingsih, S.; Halimah, N.; Wardoyo, P.; & Pradita, 2022).The simulated analytical unit consists of 60 mother–infant pairs, consistent with the range of sample sizes commonly used in comparable studies conducted at primary health-care facilities (Rosada, 2025), with a relatively even distribution of infant ages from 1 to 12 months.

Two instruments were used in simulated form in this study. *First*, a parental stimulation questionnaire adapted from items in the SDIDTK instrument (Kementerian Kesehatan Republik Indonesia, 2022), covering the frequency and variety of gross motor stimulation (e.g., tummy time, facilitated sitting and standing exercises) (Hewitt et al., 2020) and fine motor stimulation (e.g., provision of graspable toys, reaching activities) performed by parents at home during the preceding week. The total questionnaire score ranges from 10 to 40 and is categorized as low (≤20), moderate (21–30), and high (>30). *Second*, motor-development observation using an instrument based on the KPSP, which is commonly used in Indonesian infant growth-and-development studies (Suryaningtyas et al., 2024), with gross and fine motor scores each scaled from 0 to 100 for continuous quantitative analysis.

Data analysis was conducted in stages. Univariate analysis was used to describe sample characteristics and the distribution of scores for each variable. Bivariate analysis used the Pearson correlation test to examine the strength and direction of the relationship between parental stimulation scores and gross and fine motor scores. Simple linear regression analysis was used to estimate the magnitude of effect (beta coefficient) and the proportion of variance explained (coefficient of determination, R^2) by parental stimulation for each motor domain. Statistical significance was set at $\alpha = 0.05$. All data processing was performed using Python (NumPy, SciPy), following analytical procedures equivalent to correlation and regression testing in conventional statistical software.

RESULTS AND DISCUSSION

The simulated dataset comprised 60 mother–infant pairs with infant ages distributed from 1 to 12 months. The parental stimulation score had a mean of 27.1 (SD = 5.8) out of a theoretical range of 10–40, indicating that most respondents fell within the moderate-to-high stimulation category. The distribution across stimulation categories showed 9 infants (15.0%) in the low category, 37 infants (61.7%) in the moderate category, and 14 infants (23.3%) in the high category.

Motor Scores by Parental Stimulation Category

Table 1 shows a consistent gradient pattern: higher stimulation categories correspond to higher mean scores in both motor domains. The mean difference in gross motor scores between the high and low categories reaches 29.8 points, while the difference in fine motor scores reaches 27.2 points, indicating that stimulation is associated with a large and consistent gain across both domains, with a slight advantage in the gross motor domain.

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Table 1. Mean Gross and Fine Motor Scores by Parental Stimulation Category

Stimulation Category	n	Mean Gross Motor (SD)	Mean Fine Motor (SD)
Low (score ≤20)	9	53.6 (9.4)	46.8 (6.8)
Moderate (score 21–30)	37	71.6 (7.0)	61.7 (9.4)
High (score >30)	14	83.4 (9.1)	74.0 (10.4)

Figure 1 visualizes this pattern as a bar chart, showing that the increase in mean motor scores from the low to moderate category is steeper than the increase from the moderate to high category, particularly for gross motor development. This pattern suggests a possible diminishing marginal return effect, whereby increasing stimulation from a low to a moderate level yields a larger gain in motor attainment than increasing it from a moderate to a high level.

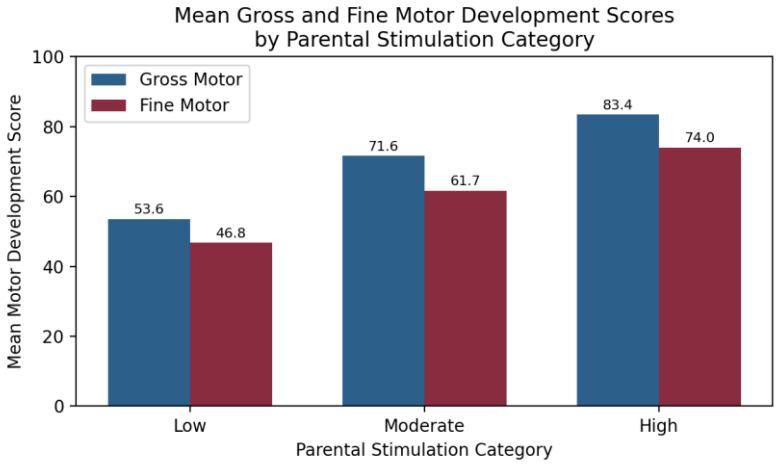


Figure 1. Mean Gross and Fine Motor Development Scores by Parental Stimulation Category

The diminishing marginal return pattern carries an important practical implication for family-based public health policy. It suggests that stimulation-education interventions are most efficiently directed toward the group of parents with low stimulation scores (≤20 category), since this is the group for which increased stimulation is expected to yield the largest marginal gain in infant motor attainment. This approach aligns with the principle of proportionate universalism in public health, whereby universal interventions are delivered with intensity calibrated to the level of risk or need within the target group, and it complements the normative recommendations of prior studies (Huru et al., 2024)
that emphasize community health-volunteer empowerment in general without explicitly targeting at-risk subgroups.

Relationship between Parental Stimulation and Motor Development

Pearson correlation analysis revealed a strong, highly significant positive relationship between parental stimulation scores and gross motor scores ($r = 0.777$; $p < 0.001$), and a moderately strong positive relationship with fine motor scores ($r = 0.695$; $p < 0.001$). Both correlation coefficients exceed 0.60, although the correlation with gross motor scores was consistently higher than with fine motor scores.

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Table 2. Correlation and Simple Linear Regression Results for Parental Stimulation and Motor Development

Motor Domain	r	β	R^2	p value
Gross Motor	0.777	1.703	0.603	<0.001
Fine Motor	0.695	1.582	0.484	<0.001

The simple linear regression results in Table 2 show that each one-point increase in the parental stimulation score is associated with a 1.70-point increase in the gross motor score and a 1.58-point increase in the fine motor score. The gross motor model explains 60.3% of the variance in gross motor scores ($R^2 = 0.603$), whereas the fine motor model explains 48.4% of the variance in fine motor scores ($R^2 = 0.484$). This 11.9-percentage-point difference in R^2 is an important finding: parental stimulation explains a larger proportion of variance in gross motor development than in fine motor development, suggesting that factors beyond stimulation, such as fine neuromuscular maturation or individual variation in visual–motor coordination, contribute more substantially to fine motor attainment than to gross motor attainment.

Figure 2 presents scatter plots with regression lines for both domains, visually confirming that data points for gross motor scores cluster more tightly around the regression line than those for fine motor scores, consistent with the higher R^2 observed for gross motor development.

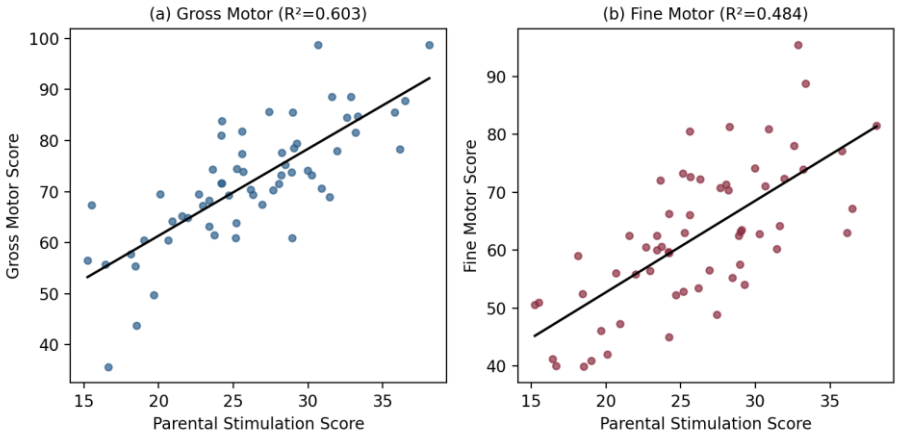


Figure 2. Scatter Plots and Regression Lines for the Relationship between Parental Stimulation Scores and (a) Gross Motor Scores and (b) Fine Motor Scores

The finding that parental stimulation is positively and significantly related to both motor domains reinforces the theory of experience-dependent plasticity, which holds that repeated sensorimotor experience shapes the neural circuitry underlying motor skills during the critical period of brain development (Ariyani et al., 2026; Black et al., 2017; Hadders-Algra, 2010). This finding is also consistent with prior experimental research demonstrating significant motor-score improvement following structured stimulation, whether through physiotherapy (Winingsih, S.; Halimah, N.; Wardoyo, P.; & Pradita, 2022), infant massage (Suryaningtyas et al., 2024) or baby swim (Alwi, 2026). However, the present study contributes information not extensively addressed by these prior works, namely a quantification of the dose–response relationship: rather than simply stating that "stimulation has an effect," the finding specifies that "each one-point increase in the stimulation score is associated with an

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approximately 1.6–1.7-point increase in the motor score," which is more operationally useful for designing targeted health-education interventions.

The difference in R^2 between gross motor (60.3%) and fine motor (48.4%) development offers a relevant theoretical insight. Developmentally, gross motor skills involve large muscle groups and movement patterns that are more directly shaped by repeated experience and opportunities for free movement (e.g., tummy time, facilitated sitting and standing practice) (Hewitt et al., 2020), so that variation in the frequency of parental stimulation is more directly reflected in gross motor attainment. Fine motor skills, in contrast, require visual–motor coordination and small-muscle control that depend more heavily on individual neurological maturation (Adolph & Hoch, 2019; Hadders-Algra, 2010) and on the variety of object-manipulation opportunities available, such that the proportion of variance explained by an aggregate stimulation score is comparatively smaller. The practical implication is that parental stimulation-education programs should not apply a uniform approach to both domains; instead, guidance for fine motor stimulation should be more specific and varied, for example by diversifying the types and textures of objects safe for infants to grasp, rather than simply increasing the frequency of gross motor stimulation.

Implications and Contribution of the Findings

Compared with prior studies that focused on the effectiveness of a single clinical form of stimulation (infant massage, baby gym, baby swim, physiotherapy) through quasi-experimental designs, this study demonstrates that parents' daily stimulation behavior at home, which is far less costly and accessible without specialized facilities, shows an association with motor attainment of comparable strength. This provides an argumentative basis for positioning family-based stimulation education as a priority within the SDIDTK program (Black et al., 2017; Britto et al., 2017) , given its broader reach and substantially lower implementation cost compared with structured clinical interventions such as physiotherapy or baby spa services.

The main contribution of this study lies in three aspects. *First*, it quantifies the dose–response relationship between parental stimulation and both motor domains simultaneously within a single analytical framework, complementing prior studies that were generally partial experimental assessments of a single stimulation form and a single motor domain. *Second*, the difference in R^2 between gross and fine motor development provides empirical evidence that the two domains require distinct stimulation strategies, a nuance rarely made explicit in prior literature, which tends to treat "motor development" as a single construct. *Third*, the diminishing marginal return pattern in Table 1 offers a quantitative basis for targeting stimulation-education programs toward parents with low stimulation scores, representing a more resource-efficient strategy than a uniform educational approach applied to the entire population.

CONCLUSION

This study aimed to analyze the effect of parental stimulation on the gross and fine motor development of infants aged 0–12 months. The analysis shows that parental stimulation scores have a strong, significant positive relationship with gross motor scores ($r = 0.777$; $R^2 = 0.603$; $p < 0.001$) and with fine motor scores ($r = 0.695$; $R^2 = 0.484$; $p < 0.001$), with the magnitude of effect and the proportion of variance explained consistently larger for gross motor development than for fine motor development. The gradient pattern across the three stimulation categories (low, moderate, and high) shows that the largest surge in motor attainment occurs with the increase from the low to the moderate category, indicating a potentially greater

marginal impact when stimulation education is prioritized for parents with low stimulation levels.

These findings confirm that parental stimulation at home is an important and modifiable determinant of motor attainment in infants aged 0–12 months, and they provide a quantitative basis for designing early-stimulation education programs that are more targeted, differentiated across motor domains, and appropriately prioritized within Indonesia's SDIDTK framework. Further research using actual primary data, a longitudinal design, and a larger, regionally representative sample is needed to confirm the generalizability of these findings.

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