

ANALYSIS OF THE BRAIN SPARING EFFECT PHENOMENON: A COMPARISON OF HEAD CIRCUMFERENCE GROWTH RATE BETWEEN WEIGH-FALTERING AND WELL-NOURISHED TODDLERS AT MEKARSARI POSYANDU

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ABSTRACT

Weight faltering or failure to grow in toddlers is often feared to have a bad impact on brain development, but the human body has a physiological adaptation mechanism known as the Brain Sparing Effect. This mechanism prioritizes the distribution of nutrients to the brain when an acute energy deficit occurs, so that the growth of the head circumference is expected to be maintained. This study uses analytical observational design with a longitudinal approach (time series) for three months (October–December) in Posyandu Mekarsari and Mekarsari A. Purposive sampling technique is used to select 99 toddlers (86 good nutrition, 13 weight faltering) who meet the inclusion criteria. Data analysis using the Mann-Whitney test to compare the difference in growth (delta) of the head circumference. This study aims to analyze the Brain Sparing Effect phenomenon by comparing the growth rate of head circumference between toddlers with weight faltering status and good nutrition. The average growth of the head circumference in the weight faltering group was recorded at 0.51 cm, slightly higher than the well-nourished group of 0.53 cm, with a stable growth trend in both groups. Statistical test results show that there is no significant difference in the growth rate of head circumference between the two groups ($p=0.845$). The findings showed no significant difference in head circumference growth between toddlers with weight faltering and those with good nutritional status.

Keywords : Brain Sparing Effect, Head Circumference, Weight Faltering, Toddlers, Integrated Health Post.

INTRODUCTION

Childhood malnutrition remains a serious global health challenge because of its long-term impact on the quality of human resources. The latest Global Nutrition Report indicates that the world is still falling short of global nutrition targets, with millions of children continuing to suffer from the double burden of malnutrition (Cesare et al., 2022). Growth faltering is often an early indicator of nutritional disorders that, if left untreated, may progress to stunting (Sari & Hipni, 2025). Failure to gain weight is a warning sign indicating inadequate nutritional intake to support the physiological needs of the rapidly growing body (Kemenkes RI, 2020). Delayed management at this stage affects not only physical development but also has the potential to disrupt the development of other vital organs and increase the risk of morbidity in the future. Head circumference is a crucial anthropometric parameter that reflects intracranial volume and brain growth during the golden period of life. Optimal brain growth is highly dependent on adequate nutrient availability, given that the brain is the most energy-demanding organ (Sun et al., 2025). Nutritional problems such as underweight are often associated with impaired linear growth and neurological development, but their effects may vary depending on the duration of malnutrition (Sithamparapillai et al., 2022). Body weight is generally more sensitive to short-term changes in nutritional intake than indicators of bone growth or head circumference. A fundamental question is the extent to which weight loss or stagnation during the acute phase directly inhibits the rate of head circumference growth. Concerns regarding the impact of growth faltering on reduced brain volume need to be addressed through careful analysis of growth trajectories to understand the actual neurodevelopmental risk (Cho et al., 2025).

The human body has remarkable biological adaptation mechanisms to protect vital organs when faced with energy deficiency or hypoxia. This phenomenon is known as the Brain Sparing Effect, in which the metabolic system prioritizes the distribution of blood flow and nutrients to the brain at the expense of the growth of other somatic tissues (Benítez-Marín et al., 2021). This hemodynamic redistribution mechanism aims to ensure that neurological development continues despite growth restriction in body weight or other organs (Shin et al., 2023). Rich (2024) also highlights that nutritional influences are intergenerational and that the body's adaptation to nutritional deficiencies can be highly complex in maintaining vital functions (Rich, 2024). This theory implies that in cases of non-chronic weight faltering, the rate of head circumference growth may still be maintained within normal limits. The existence of this mechanism provides an important opportunity for nutritional intervention before permanent brain damage occurs.

Most previous studies have focused more on the long-term effects of stunting or chronic malnutrition on children's cognitive development (Pratiwi et al., 2021). Research focusing on the transition or acute phase of growth faltering at the primary healthcare level, such as Integrated Health Posts, remains relatively limited, even though this phase is a critical point for prevention. This study aims to address this gap by analyzing the Brain Sparing Effect directly in the field using real-time growth monitoring data. Observations were conducted over a three-month period at Mekarsari and Mekarsari A Integrated Health Posts to compare the head circumference growth rate between toddlers experiencing weight faltering and toddlers with good nutritional status. The results of this analysis are expected to explore the possibility of a consistent pattern with the Brain Sparing Effect concept among toddlers experiencing impaired weight gain in the area.

Growth Faltering Concept

Growth faltering is defined as a condition in which the rate of growth slows in a manner inconsistent with standard growth curves, often preceding chronic malnutrition or stunting (Sari & Hipni, 2025). This condition is usually characterized by weight loss or the inability to gain weight appropriately for age over a certain period. According to Pratiwi (2021), growth faltering is a growth disorder that has significant effects on immune responses, cognitive development, and long-term morbidity risk (Pratiwi et al., 2021). Sithamparapillai (2022), in a cohort study, found that the onset of growth faltering often occurs at an early age, even before 6 months of age, and is closely related to inadequate feeding practices (Sithamparapillai et al., 2022). Early detection through routine monitoring at basic healthcare services such as Integrated Health Posts is key, considering that growth failure at this stage can have permanent effects if not intervened upon (Kemenkes RI, 2020).

Head Circumference as an Indicator of Neurological Development

Head circumference is not merely a physical anthropometric measurement, but a valid proxy indicator for estimating intracranial volume and children's brain growth (Luciana et al., 2024). Lasman (2025) emphasized that there is a close relationship between head circumference and intellectual intelligence (IQ), in which optimal head circumference growth reflects good neurocognitive development (Lasman et al., 2025). A longitudinal study by Zhu (2022) showed that head circumference growth trajectories during the first two years of life strongly determine children's cognitive, emotional, and behavioral outcomes in adolescence (Zhu et al., 2022). Therefore, stagnation in head circumference growth is considered a more serious warning sign than weight stagnation alone because it is directly

related to brain architecture.

Adaptation Mechanism: Brain Sparing Effect Phenomenon

The Brain Sparing Effect is a physiological adaptation mechanism in which the body redistributes blood flow and nutrients (hemodynamics) to prioritize vital organs, especially the brain, under conditions of energy deficiency or hypoxia (Benítez-Marín et al., 2021). According to Shin's (2023) study using echocardiographic examination, infants experiencing growth restriction (Small for Gestational Age) showed increased blood flow to the upper body (Upper Body Blood Flow) as a compensatory effort to maintain oxygen and glucose supply to the brain (Shin et al., 2023). In the context of malnutrition, this theory explains why head circumference growth is often affected "later" than body weight. A child's body weight may decrease or stagnate (weight faltering) as an initial response to a calorie deficit,

Relationship Between Nutritional Status and Growth Dynamics

Nutritional status has intergenerational and long-term effects on children's linear growth (Rich, 2024). However, during the acute phase of growth faltering, the body's response focuses on the survival of vital organs. Sithamparapillai (2022) found that although growth faltering is associated with a risk of neurodevelopmental delay, children who are able to achieve catch-up growth or have effective protective mechanisms tend to have better developmental outcomes (Sithamparapillai et al., 2022). Imami (2023) also emphasized the importance of protein and zinc nutritional interventions to support this catch-up growth period so that the brain-sparing mechanism does not fail due to prolonged deficiency (Imami, 2023).

RESEARCH OBJECTIVE

This study aims to analyze the Brain Sparing Effect phenomenon by comparing the head circumference growth rate between toddlers experiencing weight faltering and toddlers with good nutritional status. Through this approach, the study aims to compare the head circumference growth rate between toddlers experiencing weight faltering and those with good nutritional status.

RESEARCH METHODS

Research Design

This study used a quantitative research method with an analytical observational design using a longitudinal approach (time series). This approach was selected to monitor head circumference growth dynamics periodically (prospective cohort) in order to observe the trends in changes occurring during the monitoring period.

Research Location and Period

The study was conducted in the working areas of Mekarsari Integrated Health Post and Mekarsari A Integrated Health Post. The locations were selected based on the active growth-monitoring activities for toddlers in these areas. Data collection was conducted over three consecutive months, from October to December, according to the schedule of routine Integrated Health Post activities.

Population and Sample

The population in this study consisted of all toddlers aged 0–59 months registered at Mekarsari and Mekarsari A Integrated Health Posts, with a recorded total population of 166 toddlers. The sampling technique used purposive sampling based on inclusion criteria, namely toddlers with complete anthropometric measurement data (body weight and head circumference) for three consecutive months and without congenital abnormalities or chronic diseases. After

data cleaning to exclude incomplete data and extreme outliers, the final sample consisted of 99 respondents included in the analysis.

Research Variables

This study consisted of two main variables. The independent variable was weight growth status, categorized into two groups: Normal (weight increased according to the growth chart) and Weight Faltering (weight remained unchanged or decreased), referring to the growth-monitoring standards of the Indonesian Ministry of Health and WHO. The dependent variable was the head circumference growth rate, measured based on the difference (delta) in growth between October and December and the average monthly trend pattern.

Data Analysis

Data analysis was conducted using statistical software in two stages. First, univariate analysis was performed to describe respondent characteristics and the frequency distribution of the study variables. Second, bivariate analysis was performed to test differences in head circumference growth rates between the two groups. Data normality testing using the Kolmogorov-Smirnov and Shapiro-Wilk tests showed that head circumference growth data were not normally distributed ($p < 0.05$). Therefore, the hypothesis was tested using the non-parametric Mann-Whitney U Test with a significance level of $\alpha = 0.05$.

RESEARCH RESULTS

Respondent Characteristics

The analysis included 99 toddlers who met the inclusion criteria (complete data for 3 months). Table 1 presents the demographic distribution (sex and age) and the prevalence of nutritional status (Weight Faltering) in the study population.

Table 1. Distribution of Respondents' Demographic Characteristics and Nutritional Status (N=99)

Variabel	Category	Frekuensi (n)	Persentase (%)
Gender	Male	43	43,4%
	Female	56	56,6%
Age	0-6 months	7	7,1%
	6-12 months	12	12,1%
	13-24 months	23	23,2%
Age	> 24 months	57	57,6%
Nutritional Status	Normal (Good Nutrition)	86	86,9%
(Weight For Age)	Weight Faltering	13	13,1%
Total		99	100%

(Source: Processed Primary Data, 2026)

Based on Table 1, the majority of respondents in this study were female, totaling 56 children (56.6%). In terms of age, the largest respondent group consisted of toddlers over 24 months old, totaling 57 children (57.6%), followed by the 13–24-month age group at 23.2%. This indicates that the study sample represented a broad range of toddler growth stages. Regarding nutritional status based on the weight-for-age indicator, most respondents had good nutritional status (86.9%), while the prevalence of weight faltering in the study population was 13.1% (13 children).

Comparative Descriptive Analysis of Head Circumference Growth

To examine the Brain Sparing Effect phenomenon, the mean head circumference growth (Head Circumference Delta) over three months was compared between the good-nutrition and weight-faltering groups.

Table 2. Comparison of Head between the Good Nutrition and Weight Faltering Groups

Growth Indicators	Nutritional Status: Normal (n=86)	Nutritional Status: Weight Faltering (n=13)	Difference (Gap)
Delta HC	0,53 cm	0,51 cm	–0,02 cm
Median Delta HC			
Standard Deviation (SD)	0,683	0,646	–0,037
Range (Min - Max)	-1 cm - 2 cm	0 cm - 2 cm	

(Source: Processed Primary Data, 2026)

Table 2 shows that the mean Head Circumference Delta in the normal nutritional status group was 0.53 cm and in the weight faltering group was 0.51 cm, with a gap of –0.02 cm. The median Head Circumference Delta in both groups was 0.00 cm. The standard deviations were 0.683 and 0.646, respectively. The Head Circumference Delta range in the normal group was –1–2 cm, while in the weight faltering group it was 0–2 cm. Descriptively, changes in head circumference in the two groups showed relatively similar values.

Growth Trend Visualization (Time Series)



Figure 1. Trend of Mean Head Circumference in the Good Nutrition and Weight Faltering Groups over 3 Months of Monitoring

The visualization in Figure 1 shows growth dynamics that support the data in the previous table. The head circumference growth line in the Weight Faltering group showed a stable trend during the monitoring period from October to December. This stability differed from the fluctuations observed in the normal group, but both remained on a positive growth trajectory. The trend visualization shows that head circumference growth in both groups during the monitoring period had a relatively stable pattern. However, this visual representation only shows the growth pattern within the study groups and cannot be used directly to prove the existence of a specific physiological mechanism.

Bivariate Analysis (Hypothesis Testing)

Statistical analysis using the Mann-Whitney U Test was conducted to determine whether the slight difference in the descriptive data above was statistically significant.

Table 3. Mann-Whitney Test Results for Differences in Head Circumference Growth Rate by Nutritional Status

Nutritional Status Category	N	Mean Rank	Sum of Ranks	Z-Score	P-Value
Normal (Good Nutrition)	86	49,80	4283,00		
Weight Faltering	13	51,31	667,00	-0,197	0,845
Total	99				

(Source: Processed Primary Data,2026)

The statistical test results in Table 3 show nearly equal Mean Rank values between the normal group (49.80) and the weight faltering group (51.31). The significance value obtained was $p = 0.845$ ($p > 0.05$). This demonstrates that statistically there was no significant difference in the head circumference growth rate between normal toddlers and toddlers experiencing weight faltering. The Mann-Whitney test showed no significant difference in head circumference growth rate between the good-nutrition and weight-faltering groups ($p = 0.845$). These findings cannot be used to prove the existence of the Brain Sparing Effect because the physiological mechanism was not directly measured.

DISCUSSION

Interpretation of Results and the Brain Sparing Effect Phenomenon

The statistical analysis conducted in this study produced a significance value of $p=0.845$, clearly indicating no significant difference in head

circumference growth rate between toddlers with good nutritional status and those with weight faltering. Descriptively, the average change in head circumference in the weight faltering group was 0.53 cm, whereas in the good-nutrition group it was 0.51 cm. However, the mean difference of 0.2 cm was not sufficient to indicate a statistically significant difference in growth. These findings indicate that during the study monitoring period, head circumference growth in the weight-faltering group did not differ significantly from that of toddlers with good nutritional status. The relatively similar head circumference growth patterns in both groups indicate that head circumference growth continued during the observation period, including among toddlers experiencing weight faltering. Thus, these findings highlight the importance of continuous growth monitoring to understand changes in children's growth comprehensively.

Biological Mechanism of Brain Protection

Theoretically, the body has various physiological responses to maintain vital organ function when facing energy or nutritional deficits, as described in the literature on the Brain Sparing Effect. This concept includes possible changes in energy utilization and redistribution of blood flow that prioritize vital organs, particularly the brain (Rich, 2024; Benítez-Marín et al., 2021). Studies in infants with intrauterine growth restriction have also reported changes in blood flow consistent with a brain-sparing response (Shin et al., 2023). However, these mechanisms are explanations based on the literature and were not directly measured in this study. This study only measured changes in head circumference during the monitoring period and did not measure hemodynamic

redistribution, cerebral blood flow, tissue energy utilization, oxygen levels, or other physiological brain parameters.

Clinical Implications and Urgency of Intervention

The finding that head circumference continues to grow normally in children with weight faltering should not be misinterpreted as justification for delaying intensive nutritional intervention. The brain-sparing mechanism is essentially only a short-term emergency response that the body possesses for survival and is not an ideal physiological condition for optimal long-term growth and development (Kemenkes RI, 2020). Health cadres and parents may become complacent because the child still appears active and intelligent, even though the child's body is working hard to redirect very limited energy. Early detection of weight stagnation should be considered a critical warning sign or "yellow light" before this brain-protection mechanism fails due to prolonged calorie deficiency (Sari & Hipni, 2025). Failure to respond to this early sign of weight loss may cause children to lose a critical window of growth that cannot be regained later (Sithamparapillai et al., 2022).

Untreated or inadequately managed growth failure is a major gateway to chronic and irreversible stunting. Persistent slowing of weight gain will gradually force the body to compromise linear growth or height after fat stores have been depleted (Rich, 2024). If this nutritional deficit continues without significant improvement in intake, the brain's protective mechanism will eventually fail and lead to permanent structural and cognitive functional impairment (Aneja et al., 2020). Long-term risks of this failure include reduced learning ability, poor school performance, and a drastic decline in economic productivity as the child reaches adulthood (Imami, 2023). The period when a toddler's weight begins to plateau is a critical point for intervention to prevent broader and potentially fatal systemic damage.

Clinical management should focus on improving the quality and quantity of nutrition. Growth showing a non-increasing or plateauing trend on the Kartu Menuju Sehat (KMS) should receive attention. Providing supplementary food (PMT) rich in animal protein and education on appropriate infant and young child feeding (IYCF) practices are key strategies to break this cycle of malnutrition (Hapsari et al., 2024). Routine growth monitoring at Integrated Health Posts should not stop at weighing and recording alone, but should be accompanied by concrete follow-up in the form of nutritional counseling and referral to health facilities when necessary (Kemenkes RI, 2020). Strong synergy among Integrated Health Post cadres, health workers, and families is needed to ensure that every toddler identified with weight faltering receives comprehensive and continuous management. The success of nutritional intervention during this early phase will strongly determine the quality of brain integrity and human resources in the future (Sun et al., 2025).

Study Limitations

This study has several methodological limitations that need to be carefully considered when interpreting the generalizability of the findings. The study's limited monitoring duration of only three months means that the analysis could capture only the body's adaptive response or brain sparing during the acute phase of weight faltering. A comprehensive evaluation of the long-term impact on children's neurocognitive development could not be conducted because of the narrow observation window (Sun et al., 2025). Other confounding factors, such as specific micronutrient intake, including zinc and iron, were not measured in detail in this study, although these nutrients play a vital role in supporting brain tissue growth (Imami, 2023). The study sample came from only one Integrated Health Post area, which may limit the generalizability of the findings to populations with

substantially different sociodemographic characteristics (Hapsari et al., 2024). In addition, the number of respondents in the weight-faltering group was relatively small, with only 13 respondents compared with 86 respondents in the good-nutrition group. The imbalance in sample sizes between groups may affect statistical power in detecting differences. Therefore, future studies are recommended to use larger sample sizes, longer monitoring periods, and more comprehensive measurements of physiological variables.

CONCLUSION

This study shows that there was no statistically significant difference in head circumference growth rate between toddlers with good nutritional status and toddlers experiencing weight faltering during the three-month monitoring period ($p = 0.845$). Descriptively, the average change in head circumference (Head Circumference Delta) in the weight-faltering group was 0.51 cm, while that in the good-nutrition group was 0.53 cm, with a difference of -0.02 cm.

RECOMMENDATIONS

The finding that head circumference was maintained should not reduce the vigilance of Integrated Health Post cadres and health workers regarding weight stagnation in toddlers. Nutritional improvement through supplementary food (PMT) made from local foods and high in protein should remain the main priority to promptly restore the weight-gain trend to the normal trajectory. Early intervention is crucial at this stage because the brain-protection or brain-sparing mechanism is only temporary and has a limited tolerance period before progressing to a chronic condition. Health cadres are expected to

provide more intensive counseling to parents so that growth monitoring is not viewed merely as a routine monthly weighing activity. Close monitoring of body weight combined with rapid nutritional intervention is essential to prevent permanent growth disorders in the future.

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