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Original Article

Association of Hygienic Drinking Water Provision with Growth Outcomes among Stunted Children Under Two Years of Age: A Quasi-Experimental Study in Rural Indonesia

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ABSTRACT

Background: Stunting among children under two years of age remains a major public health problem in rural Indonesia, particularly in areas with limited access to safe drinking water. Recurrent enteric infections associated with unsafe water may impair nutrient absorption and contribute to growth faltering. **Objective:** This study aimed to examine the association between a hygienic drinking water intervention and growth outcomes among stunted children under two years of age. **Methods:** A quasi-experimental non-randomized study was conducted in Sukarame District, Tasikmalaya Regency, Indonesia, from October 2024 to March 2025. A total of 108 stunted children were allocated into intervention (n = 54) and control (n = 54) groups. The intervention group received 1.8 liters of hygienic ready-to-drink water daily for five months, while the control group continued using their usual household water sources. Primary outcomes were changes in body weight and body length. Baseline equivalence between groups was assessed using independent t-tests and chi-square tests. Mean changes between groups were compared, and between-group differences in change scores were calculated with 95% confidence intervals (CI). Effect sizes were estimated using Cohen's d. **Results:** Baseline characteristics were broadly comparable between groups. The mean weight change was 3.09 ± 0.97 kg in the intervention group and 1.30 ± 0.96 kg in the control group. The between-group difference in weight change was 1.79 kg (95% CI: 1.40–2.31), with a large effect size (Cohen's d = 1.85). The mean increase in body length was 4.00 ± 1.62 cm in the intervention group and 4.56 ± 1.62 cm in the control group. The between-group difference was −0.56 cm (95% CI: −0.72 to 0.04), corresponding to a small effect size (Cohen's d = −0.34). **Conclusion:** Provision of hygienic drinking water was associated with greater short-term weight gain among stunted children under two years of age, although no differential effect on linear growth was observed during the five-month intervention period. Given the quasi-experimental design and the potential for residual confounding, these findings should be interpreted cautiously.

Keywords: hygienic drinking water, stunting, children under two years, growth, environmental health

INTRODUCTION

A significant public health problem in Indonesia is stunting in children younger than two, especially in rural regions where basic infrastructure is lacking[1-3]. Linear growth, brain development, and immune system maturation all occur within the first two years of life, which is a key window. Impaired physical growth, diminished cognitive ability, and an increased risk of non-communicable illnesses in later life are some of the permanent repercussions that might arise from growth faltering during this age[3-6]. On a global scale, stunting in childhood is regularly linked to less-than-ideal adult height, less academic performance, poorer economic production, and health problems[6,7].

The Indonesian Nutrition Status Survey for 2023 states that stunting remains a problem in our country. The current stunting figure 1 and figure 2 shows a national prevalence of 21.5%, with even higher numbers for children under 2[8]. Within the country's stunting figures, those for Tasikmalaya Regency show a prevalence of 24% to 26%. This is rural Tasikmalaya Regency. Sukarame District is one of the rural areas in Tasikmalaya Regency that continues to face stunting, worsened by environmental health issues. Local health data show that stunting for children under 2 years of age is above the district target[9,10].

The causes of stunting go beyond insufficient nutrition to include indirect determinants, such as environmental health. While national strategies for stunting have dealt with the nutrition-specific strategies of \micronutrient supplementation,supplementary feeding, and maternal and child education nutrition, the environment to which the strategies are applied is likely to have a strong moderating effect. The absence of drinking water and poor sanitation and hygiene facilities mean children have greater exposure to enteric pathogens, which increases the likelihood of infection and stunted growth[11,12].

The environment in the Sukarame district remains far from ideal. The Central Statistics Agency of Tasikmalaya Regency estimates that in 2024, 12.6% of households will still not have access to clean drinking water, and 22.3% will not have access to serviceable latrines. The absence of these facilities increases the risk of transmission of pathogens, and the end result will always be death from diarrhoeal disease, especially in the case of young children. The mortality rate from diarrhea is highest among Indonesian children younger than five years old. The rate of mortality from these causes is substantially higher in rural regions compared to metropolitan

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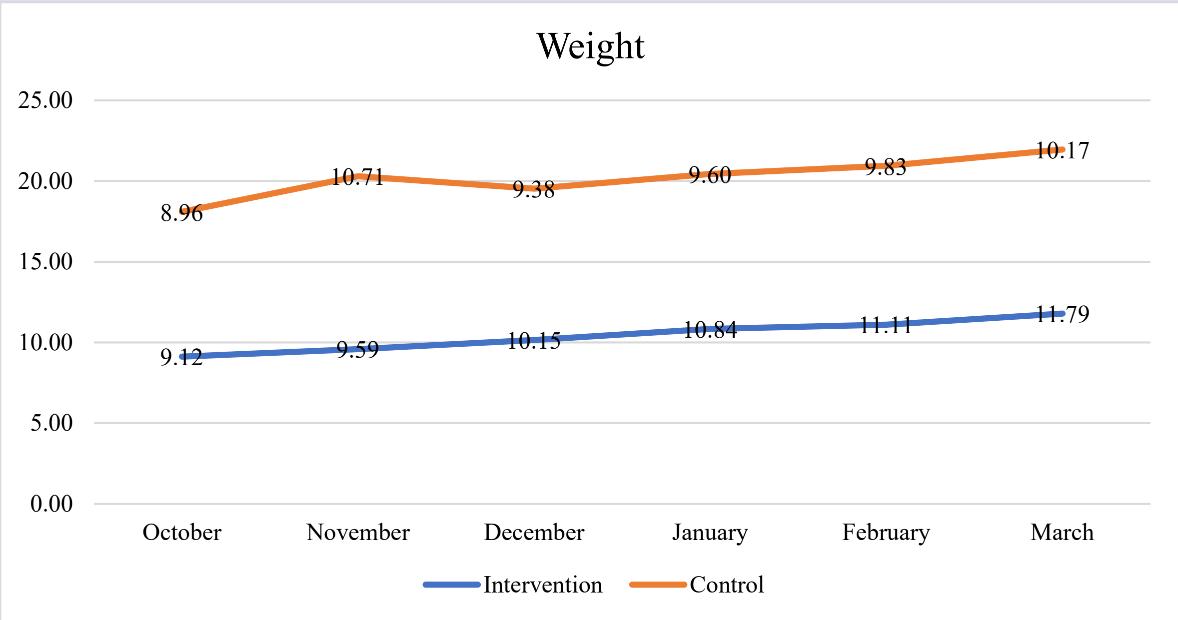

Figure 1. Monthly weight progression of stunted children in the intervention and control groups

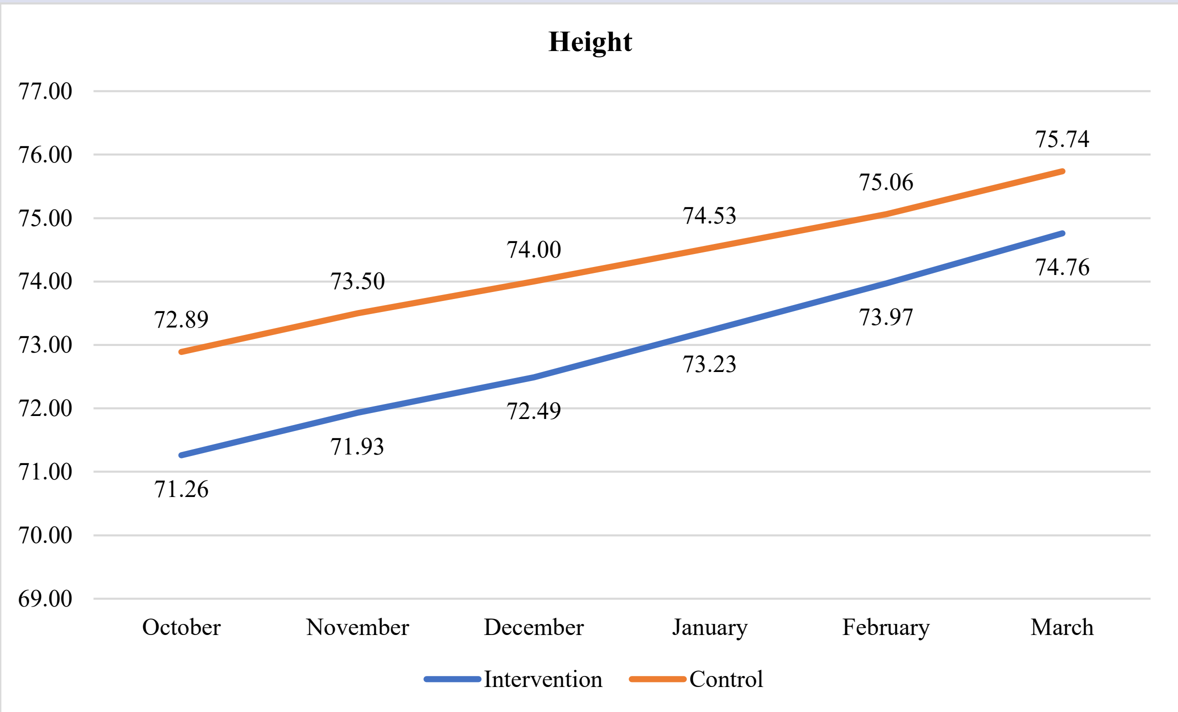

Figure 2. Monthly height progression of stunted children in the intervention and control groups

centers[13]. In Indonesia, children younger than five still have a significant risk of contracting diarrhea, with rural regions reporting greater rates than urban ones[14,15].

Enteric infections, especially repeated episodes of diarrhea, are fundamental in articulating the relationship between the environment and the pathways of growth Failure in children. Intestinal infections result in repeated loss of intestinal mucosa and secondary infection, increasing the body's metabolic demand due to inflammation. Repeated infection by certain pathogens in children can cause a form of subclinical EED, which stands for Environmental Enteric Dysfunction, and is considered a form of intestinal inflammation. EED has been widely accepted to help explain the poor results that nutrition interventions yield in areas lacking adequate WASH (water, sanitation, and hygiene) interventions[16-19].

The interconnected conditions of limited access to safe drinking water, heightened exposure to enteric pathogens, recurrent infections, and stunting illustrate an infection-malnutrition cycle in rural areas such as the Sukarame District[9]. This cycle demonstrates the necessity of combined approaches that address environmental factors alongside nutrition.

In this context, the present study implemented a hygienic drinking water intervention using ready-to-drink packaged water, provided at 1.8 liters per child per day for 5 months. This volume was based on recommended daily fluid requirements for children under two years of age, taking into account age, body weight, and fluid intake from food sources. By replacing potentially contaminated household drinking water, this intervention aimed to reduce exposure to enteric pathogens and support improved growth outcomes[20-23].

Despite the acknowledged significance of environmental health in children's growth, there is a lack of information about the direct effect of interventions to improve water hygiene on the growth outcomes of stunted children under the age of two, especially in rural areas of Indonesia. Unlike previous studies that have largely focused on nutrition-specific interventions or observational associations, this study directly assesses the effect of a hygienic drinking water intervention on changes in body weight and body length among stunted children in a high-risk rural context.

This study begins to tackle the hypothesis that the regular provision of hygienic drinking water will improve the growth of stunted children under 2 years of age. This specifically hypothesizes that the greater improvement in growth (measured by increases in weight and length) is in contrast to the absence of that improvement among children who access household drinking water. The purpose of this research is to find out how much of an effect clean water has on the height and weight of stunted children in the Sukarame District of Tasikmalaya Regency who are less than two years old.

METHODE

This study employed a quasi-experimental, non-randomized pretest–posttest control group design. Although this design allows evaluation of community-based interventions in real-world settings, it inherently entails a higher risk of selection bias and residual confounding than randomized controlled trials. Because participants were not randomly assigned, baseline differences between the intervention and control groups could potentially influence the observed outcomes. To reduce this risk, baseline comparability between groups was assessed for key characteristics, including child age and sex. Both groups were drawn from the same geographic area and health service catchment population, which helped ensure relatively similar environmental, socioeconomic, and health service contexts. Nonetheless, unmeasured factors—including household sanitation conditions, caregiver practices, dietary intake, and baseline health status—may still have affected the outcomes. Therefore, the findings should be interpreted cautiously, as causal inference cannot be established with the same certainty as in randomized controlled trials. Despite these limitations, quasi-experimental approaches remain valuable for assessing public health interventions in community settings where randomization may be impractical or ethically problematic. The purpose of this research was to evaluate the effect of a water purification program on the development of underweight infants in the Sukarame District of Tasikmalaya Regency who were under two years of age[24,25]. Baseline characteristics were compared using independent t-tests for continuous variables and chi-square tests for categorical variables. Changes in growth outcomes were analyzed by comparing mean differences between groups. Effect sizes (Cohen's d) and 95% confidence intervals were also calculated.

Population and Sample

The study population comprised all children (<2 years of age) who were stunted, as defined by length/height-for-age indices (LAZ/HAZ), in the study area. A total of 108 stunted children were included, who were non-randomly assigned to one of two groups (54 children in the intervention group, 54 in the control group). Participants were allocated non-randomly due to the community-based nature of the intervention, with baseline equivalence accounted for (especially regarding age and sex)[26,27].

Sample Size Estimation

Appropriate for quasi-experimental research with intervention and control groups, the method for comparing two independent means was used to estimate the sample size. The calculation aimed to detect a minimum clinically meaningful difference in mean body weight gain between groups over the intervention period.

The parameters used in the calculation were defined a priori. A standard deviation (SD) of 1.50 kg was adopted based on previous studies evaluating weight change among stunted children under two years of age. The statistical model was tested using a 5% two-sided significance level ($Z\alpha/2 = 1.96$) and an 80% statistical power ($Z\beta = 0.84$).

When comparing the intervention and control groups, the expected effect size (d) was calculated as the predicted difference in mean body weight gain. The estimated change was around 0.65 kg, based on published intervention studies done in similar populations.

Using these assumptions, the minimum required sample size was calculated to be 54 participants per group. This sample size was considered sufficient to detect a statistically meaningful difference in body weight gain between groups, while remaining feasible for implementation in a community-based rural setting[28].

Intervention Description

Children in the intervention cohort drank hygienic drinking water (ready-to-drink packaged water, 1.8 liters total, 3 bottles, 600 mL each). This water was intended as the child's primary drinking water source throughout the five-month intervention. The intervention was introduced gradually and served daily to replace potentially contaminated home drinking water sources. The control group had no exposure and continued to use their usual household drinking water sources[29,30].

Variables

The independent variable in this study was the availability of clean drinking water, while the dependent variable was children's growth, measured as changes in body length/height (cm) and length/height-for-age z-scores (LAZ/HAZ). Anthropometry was performed by trained personnel using standardized equipment in accordance with World Health Organization guidelines, and measurements were taken at baseline and again after 5 months of intervention.

Data Collection Technique

As part of data collection, baseline evaluations of body weight and height were conducted prior to the start of the intervention. The intervention lasted 5 months and provided participants with 1.8 liters of hygienic drinking water daily. To track compliance, trained enumerators completed daily consumption logs and conducted follow-up visits. As for the control group, they were not provided hygienic drinking water and were monitored through observation forms completed by community health volunteers. Participants in both groups underwent monthly anthropometric measurements of weight and height, and final assessments were conducted at the conclusion of the five-month intervention period.

Data collection consisted of baseline evaluations conducted before the intervention, including assessments of body weight and length/height. The intervention lasted 5 months and involved the group receiving 1.8 liters of hygienic drinking water daily. Daily consumption logs and regular follow-up visits by trained enumerators documented compliance. The control group did not receive hygienic drinking water and was observed using observation forms completed by community health volunteers. Anthropometric measures of weight and length/height for participants were recorded once a month in both groups, with final measurements obtained at the end of the five-month intervention period.

Data Analysis

There was a sequential approach to the statistical analysis. The research participants' baseline characteristics were described using univariate analysis. Then, we used bivariate analysis to look for changes in patterns within each group both before and after the intervention, as well as any variations in growth outcomes across the groups. No statistical tests were performed below a significance level of α = 0.05 and a confidence level of 95%[31].

Research Instrument. The research instruments were designed to collect data from caregivers and stunted children. Participants were recruited after caregivers provided written informed consent. Instruments contained child characteristics (age, sex) and a note on the parents' compliance monitoring card for recording the adherence to the provision of safe drinking water. In-depth physical growth measurements were administered with a standardized infantometer (body length/height) and a calibrated digital scale for young children. All equipment was calibrated prior to data collection to ensure proper measurements.

Statistical procedures (Data analysis

Data editing, cleaning, coding, and data entry into statistical software. We performed statistical analysis in two major stages: univariate and bivariate analyses. Univariate analysis was used to describe variable distributions using frequency tables and to measure central tendency. Bivariate analysis was done to estimate within- and between-group differences. The data distribution dictated the statistical tests used, which might be either parametric or non-parametric. This study used the Shapiro-Wilk test to determine if the continuous variables were normally distributed. When dealing with data that follows a normal distribution, we used paired t-tests to compare within groups and independent t-tests to compare across groups. For data that did not follow a normal distribution, we used suitable non-parametric tests. We used effect sizes and, where applicable, 95% confidence intervals (95% CI) to quantify the intervention's impact. The significance level was set at $p < 0.05$. We used SPSS 24 for all of our analyses.

Research Ethics

Diponegoro University's Health Research Ethics Committee (Protocol No. 309/EA/KEPK-FKM/2024) approved the current study on September 25, 2024. Additionally, the research complied with all applicable ethical standards, including those of the World Health Organization (WHO) and the CIOMS International Ethical Guidelines (2016).

RESULTS

Baseline Characteristics

A total of 108 children participated in the study, with 54 children in the intervention group and 54 in the control group.

Table 1 presents the baseline characteristics of the study participants. The mean age of children in the intervention group was 15.41 ± 3.20 months, while in the control group it was 15.63 ± 4.19 months. The proportion of male children was similar between the intervention group (55.6%) and the control group (57.4%). Baseline body weight and body length were also comparable between the two groups. The mean baseline body weight was 9.12 ± 1.47 kg in the intervention group and 9.06 ± 2.37 kg in the control group (p = 0.876). Similarly, baseline body length was 74.88 ± 3.96 cm in the intervention group and 74.98 ± 4.65 cm in the control group (p = 0.906). The proportion of children with diarrhoea at baseline was also not significantly different between groups (p = 0.334). These findings indicate that the two groups were broadly comparable at baseline.

Changes in Body Weight

Table 2 presents the changes in body weight during the study period. The mean baseline body weight did not differ significantly between groups. After the intervention period, children in the intervention group had a mean body weight of 12.21 ± 1.83 kg, compared with 10.36 ± 2.35 kg in the control group.

The mean weight gain in the intervention group was 3.09 ± 0.90 kg, whereas children in the control group experienced a mean weight gain of 1.30 ± 1.03 kg. The between-group difference in weight change was

Table 1. Subject Characteristics Of The Research In Sukarame, Tasikmalaya Regency

Variable	Intervention (n=54)	Control (n=54)	p-value
Age (months), mean ± SD	15.41 ± 3.20	15.63 ± 4.19	0.757
Male, n (%)	30 (55.6%)	31 (57.4%)	1.000
Baseline weight (kg), mean ± SD	9.12 ± 1.47	9.06 ± 2.37	0.876
Baseline length (cm), mean ± SD	74.88 ± 3.96	74.98 ± 4.65	0.906
Diarrhea incidence, n (%)	43 (79.6%)	39 (72.2%)	0.334

Table 2. Effect of the Intervention on Body Weight

Outcome	Intervention (n=54) Mean ± SD	Control (n=54) Mean ± SD	Between-group difference (Δ)	95% CI	p-value	Cohen's d
Baseline weight (kg)	9.12 ± 1.47	9.06 ± 2.37	–	–	0.876	–
Endline weight (kg)	12.21 ± 1.83	10.36 ± 2.35	–	–	<0.001	–
Weight change (kg)	3.09 ± 0.90	1.30 ± 1.03	1.79	1.43 – 2.15	<0.001	1.85 (large)

Table 3. Effect of the Intervention on Body Length

Outcome	Intervention (n=54) Mean ± SD	Control (n=54) Mean ± SD	Between-group difference (Δ)	95% CI	p-value	Cohen's d
Baseline length (cm)	74.88 ± 3.96	74.98 ± 4.65	–	–	0.906	–
Endline length (cm)	70.88 ± 3.61	70.42 ± 5.35	–	–	0.603	–
Length change (cm)	−4.00 ± 1.55	−4.56 ± 1.68	0.56	−0.05 – 1.17	0.077	0.34 (small)

1.79 kg (95% CI: 1.43–2.15), which was statistically significant ($p < 0.001$). The calculated effect size was Cohen's d = 1.85, indicating a large effect. These findings suggest an association between the intervention and greater short-term weight gain among children.

Changes in Body Length

Changes in body length are presented in Table 3. At baseline, the mean body length was similar between groups. At the end of the intervention, the mean body length was 74.88 ± 3.96 cm in the intervention group and 74.98 ± 4.65 cm in the control group.

The mean change in body length during the study period was 4.00 ± 1.55 cm in the intervention group and 4.56 ± 1.68 cm in the control group. The between-group difference in length change was 0.56 cm (95% CI: −0.05–1.17) and was not statistically significant ($p = 0.077$). The effect size was small (Cohen's d = 0.34**.** These findings indicate that although children in both groups experienced increases in body length, the difference between groups was not statistically significant.

DISCUSSION

This study examined the effect of the intervention on growth among children under two years of age. The results showed that children in the intervention group experienced significantly greater weight gain compared with those in the control group. The mean weight gain was 3.09 kg in the intervention group compared with 1.30 kg in the control group, with a large effect size (Cohen's d = 1.85). These findings suggest an association between the intervention and improved short-term weight gain among children. In contrast, although body length increased in both groups during the study period, the difference in length gain between groups was not statistically significant. The mean increase in body length was slightly higher in the control group, but the between-group difference was small and not statistically significant. This result may reflect the relatively short duration of the intervention, as linear growth generally requires a longer period to show measurable differences.

Interpretation of Findings

Weight gain is often more responsive to short-term nutritional or environmental interventions than linear growth. Improvements in water quality and hygiene may reduce the risk of enteric infections and improve nutrient absorption, which in turn can contribute to better weight gain among children. Therefore, the observed increase in body weight in the intervention group supports the potential role of improved drinking water access in promoting child growth.

However, the lack of a statistically significant difference in body length suggests that the intervention may have limited impact on linear growth within the relatively short observation period of this study. Linear growth is influenced by multiple long-term factors, including nutritional intake, recurrent infections, environmental sanitation, and socioeconomic conditions. As such, longer follow-up periods may be necessary to observe measurable changes in height or length.

This research examines the effects of providing rural children with safe drinking water on their development before the age of two. Clean water was associated with a higher rate of temporary weight gain compared to the control group, according to the research[32]. Both groups showed improved linear growth, and the two groups did not differ significantly in this regard. The different responses of body weight and body length show an important biological difference in child development. Because weight gain is sensitive to brief changes in energy balance, illness, and nutrient intake, and therefore to changes in health or the environment, weight gain will occur faster than improvements in health or the environment[33-35]. On the other hand, weight in inches or centimeters is a long-term effect of long-term environmental nutrition. The lack of a large difference in height gain suggests that the five-month intervention may not have been sufficient to reverse the growth faltering of children with chronic low nutritional growth[36-38].

The intervention group showed a decrease in diarrhea incidence, which helps to explain the increased weight gain in this group. A reduction in drinking water quality could lower levels of enteric pathogens that cause infections, in turn reducing infections that lead to weight loss. The study did not directly measure environmental enteric dysfunction, but the absence of diarrhea during the study supported the theory that reduced exposure to enteric pathogens could improve short-term growth[39,40]. This theory aligns with evidence showing that infection control measures rapidly alter weight gain patterns, regardless of their impact on height. Implementing interventions related to water, sanitation, and hygiene outside of the 'critical window' of the first thousand days of life has a minimal or delayed impact on all types of growth, according to previous studies. While water, sanitation, and hygiene (WASH) treatments can lessen diarrhea and aid in weight maintenance or increase, prolonged exposure is necessary to see benefits in height. Results from large-scale studies in low- and middle-income nations have shown that people's height can improve when they receive both WASH programs and nutrition-specific treatments[41,42]. This study aligns with prior studies and reconfirms that recovery from stunted growth is influenced by several of the aforementioned 'interventions' across multiple factors[43].

The importance of clean drinking water as part of stunting reduction strategies is clear, even if it is not the sole factor. Among the many potential components of interventions to improve short- and medium-term child health and weight gain, water quality may be one of the most significant contributors, especially in high-risk rural areas. Nevertheless, continued improvements in linear growth will likely require more extensive, long-term interventions that address nutrition, infection control, and other environmental factors. A few limitations are worth mentioning. The study design is a quasi-experiment, which means it cannot make causal statements and may be subject to residual confounding. Outcomes related to linear growth could not be measured because the intervention was too short, and the study did not include measures of biological markers of enteric dysfunction. Several limitations should be considered when interpreting the findings of this study. First, the quasi-experimental non-randomized design may introduce selection bias because participants were not randomly allocated to intervention and control groups. Although baseline characteristics between groups were relatively comparable and participants were recruited from the same geographic setting, unmeasured factors such as household sanitation practices, dietary intake, caregiving behaviors, and socioeconomic conditions may have influenced the observed outcomes. Consequently, residual confounding cannot be entirely excluded. Second, the intervention was relatively short (five months), which may explain why significant improvements were observed in body weight but not in linear growth. Linear growth generally reflects long-term nutritional and environmental conditions, and therefore may require longer interventions to demonstrate measurable changes.

Despite these limitations, the study provides important real-world evidence that improving access to safe drinking water may contribute to short-term improvements in growth among stunted children in rural settings[44].. Because this study employed a quasi-experimental non-randomized design, the possibility of selection bias and residual confounding cannot be fully excluded. Although baseline characteristics were broadly comparable between groups, unmeasured factors such as dietary intake, household sanitation conditions, and caregiving practices may still have influenced the observed outcomes

The findings suggest an association between the intervention and improved weight gain among children during the study period. While the results support the potential role of improved drinking water access in child growth, the quasi-experimental design limits causal inference. Nevertheless, the observed changes indicate short-term growth benefits, particularly in terms of body weight.

CONCLUSION

The results of this study suggest an association between the intervention and improved short-term weight gain among children. While the findings support the potential role of improved drinking water access in promoting child growth, the evidence primarily indicates short-term growth benefits in body weight rather than body length. Further studies with longer follow-up periods and randomized designs are recommended to better understand the long-term impact of such interventions on child growth.

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