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Journal Homepage: http://ejournal.upi.edu/index.php/JPKI

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# Association Between Maternal Use of Smart Bracelets and Stunting Incidence in Toddlers: A Case-Control Study in Sumedang, Indonesia

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## A B S T R A C T

**Introduction:** Stunting remains a significant public health issue in Indonesia, particularly in rural areas such as Sumedang, West Java. Maternal health during pregnancy is a critical determinant of fetal growth, yet limited attention has been given to digital health innovations as part of stunting prevention strategies. **Objective:** This study aimed to examine the association between maternal use of smart bracelets during pregnancy and the incidence of stunting in toddlers, while also assessing the influence of maternal education, antenatal care (ANC) attendance, and dietary intake. **Methods:** A case-control study was conducted in Margamukti Village, Sumedang Regency, involving 100 mother-child pairs (50 cases and 50 controls). Data were collected through structured interviews and cross-referenced with maternal and child health records. Statistical analyses included chi-square tests, odds ratio (OR) calculations, and multivariate logistic regression to identify factors independently associated with stunting. **Results:** Mothers in the control group (non-stunted children) reported higher use of smart bracelets during pregnancy (56%) compared to the case group (24%). Smart bracelet use was significantly associated with reduced odds of stunting (adjusted OR = 0.28, 95% CI: 0.12–0.64, p = 0.003). Other protective factors included higher maternal education (adjusted OR = 0.46, 95% CI: 0.21–0.98, p = 0.045), attending ≥4 ANC visits (adjusted OR = 0.35, 95% CI: 0.16–0.78, p = 0.009), and adequate dietary intake during pregnancy (adjusted OR = 0.31, 95% CI: 0.14–0.68, p = 0.005). **Conclusion:** Smart bracelet use during pregnancy is a promising digital health intervention that may contribute to reducing the risk of stunting in toddlers. These findings support the integration of wearable technologies alongside traditional maternal health strategies, particularly in resource-limited settings. Strengthening maternal education, nutrition, and ANC coverage remains essential for comprehensive stunting prevention.



## ARTICLE INFO

***Article History:***

***Received:*** May 04th , 2025
***Revised:*** June 26th , 2025
***Accepted:*** June 27th , 2025
***First Available Online:*** June 29th, 2025
***Published:*** June 30th, 2025

***Keywords:***
stunting, smart bracelet, maternal health, wearable technology, antenatal care, pregnancy, digital health

## 1. INTRODUCTION

Stunting remains a pressing health concern in Indonesia, characterized by a child's height falling significantly below the standard for their age. This condition, often rooted in prolonged nutritional deficiency and repeated illness, typically begins during pregnancy and extends through the early years of life. According to the World Health Organization, children are considered stunted when their height-for-age is more than two standard deviations below the median of the WHO Child Growth Standards (Abdulaziz et al., 2024). The first 1,000 days of life—from conception to a child's second birthday are especially critical for intervention.

Stunting not only hinders physical growth but also disrupts brain development, weakens the immune system, and increases the risk of long-term health problems. In Indonesia, the issue persists despite national efforts, with the 2023 Indonesian Nutritional Status Survey reporting a 21.6% prevalence. In West Java, the figure is slightly lower at 20.2%, but in Sumedang Regency, the rate rises to 27.6%. Margamukti Village in Sumedang Utara has been identified as one of the areas with the highest stunting cases, reaching 10.99% ( (Kemenkes RI, 2023; Patmawati, 2020). The long-term implications of stunting are far-reaching. Children affected by stunting are more likely to experience learning difficulties, perform poorly in school, and face reduced economic opportunities as adults. This condition, if not addressed effectively, may weaken Indonesia's workforce potential, particularly as the country prepares for the anticipated demographic dividend in 2045 (Astuti, 2018).

Among the various contributing factors to stunting, maternal health during pregnancy is particularly influential. Nutritional intake, weight before and during pregnancy, and access to prenatal care all play a crucial role in supporting fetal development and reducing the risk of stunting. Poor maternal nutrition—especially deficiencies in protein, iron, and other micronutrients—can lead to complications that impact both mother and child (Septriliyana & Aryanti, 2022; Tyarini et al., 2022). In many cases, inadequate antenatal care results in missed opportunities for early detection of health risks and insufficient education on maternal and infant nutrition. Limited awareness, coupled with barriers to health services, often prevents pregnant women from receiving the care and guidance they need (Rahmandiani et al., 2019).

As healthcare systems increasingly incorporate technology, wearable devices such as smart bracelets are being explored as tools to improve maternal health monitoring. These devices offer real-time tracking of vital signs, nutritional intake, and physical activity, providing timely alerts that can help prevent complications (Gulzar Ahmad et al., 2022). In Sumedang, local authorities have started introducing smart bracelets for pregnant women as part of their strategy to reduce stunting (Mayangsari et al., 2024). The theoretical mechanism underlying this intervention is rooted in behavioral and informational reinforcement: by providing immediate feedback and biometric alerts, smart bracelets promote health-seeking behaviors and enable healthcare workers to intervene promptly in high-risk cases.

Smart bracelets offer a practical solution, especially in regions with limited access to regular prenatal check-ups. They empower mothers with continuous health information while enhancing healthcare workers' ability to monitor pregnancy progress remotely. Importantly, in this study, bracelet usage was both supervised and routinely monitored through health posts (posyandu) and midwives, ensuring consistent engagement and reducing the likelihood of non-compliance.

DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

Previous research shows that mobile-based interventions can improve maternal knowledge and compliance with antenatal care recommendations (De & Pradhan, 2023; Mildon & Sellen, 2019). However, while there is increasing interest in digital health interventions, few studies have directly assessed their impact on stunting prevention through antenatal monitoring.

This study aimed to examine whether the use of smart bracelets by pregnant women is associated with a lower risk of stunting in their children. nlike previous research that predominantly targets postnatal factors such as infant feeding and hygiene, this study focuses on a proactive, antenatal, technology-based intervention that addresses stunting at its earliest point of origin during fetal development. By evaluating the role of wearable health technology within a maternal health framework, this study contributes novel insights into scalable strategies for stunting prevention in low-resource settings.

## 2. METHODS

### Study Design

This study applied a case-control approach to explore whether the use of smart bracelets by pregnant women is associated with stunting in their toddlers. The case-control model was deemed suitable as it allows the investigation of possible contributing factors in children already classified with stunting. Children categorized as stunted were identified using the World Health Organization (WHO) height-for-age standard. In contrast, the control group included children of the same age range who met normal growth standards.

### Study Location and Target Population

The research took place in several Posyandu (Integrated Health Posts) within Margamukti Village, situated in the Sumedang Regency of West Java, Indonesia. This location was selected due to its documented high stunting rates and its active involvement in local health interventions aimed at early prevention. Participants were mothers who had children aged 6 to 59 months and were registered in the Posyandu system. All participants were residents of the village and had been living there continuously during the study period.

A total of 100 mother-child pairs were included in the study, with 50 classified into the stunted group and 50 into the non-stunted group. Participants were chosen through purposive sampling based on the presence or absence of stunting in their children. The minimum sample requirement was calculated using G*Power version 3.1.9.7, applying a two-tailed test with an alpha level of 0.05, statistical power of 80%, and a moderate effect size (d = 0.5) (Faul et al., 2009). The computation indicated that at least 88 participants were needed. To enhance the study's robustness and account for potential missing data, the sample size was increased to 100 respondents. This size was considered sufficient to identify statistically significant associations and control for multiple influencing variables.

### Data Collection Procedures

Data were collected through structured, face-to-face interviews using a pre-tested questionnaire that was developed in consultation with maternal health experts and reviewed for content validity. Trained enumerators, equipped with standardized protocols and certified in

DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

research ethics, conducted the interviews to ensure consistency and minimize interviewer bias. The questionnaire captured comprehensive information on maternal demographics, dietary patterns during pregnancy, antenatal care attendance, and gestational weight gain monitoring. Particular attention was paid to smart bracelet usage, including the duration and frequency of use, and the specific features activated, such as heart rate monitoring, meal logging, physical activity tracking, and alert responses.

To improve the reliability of self-reported data, responses were cross-verified with official records in the Maternal and Child Health (KIA) handbook, which documents antenatal visits, maternal weight gain, and fetal monitoring activities. For mothers reporting smart bracelet use, usage logs from connected apps or health workers' records (when available) were also referenced to validate engagement levels. This dual-source verification aimed to reduce recall bias and strengthen data credibility.

Information on child outcomes, including birth weight, immunization status, recent illnesses, and anthropometric measurements was collected to identify additional risk factors for stunting. To minimize selection bias in the purposive sampling process, participants were recruited from multiple community health posts (posyandu) across urban and rural areas of Sumedang Regency, with proportional representation based on stunting prevalence and service utilization rates. Inclusion criteria were clearly defined to target mothers of children aged 6–24 months, while exclusion criteria eliminated cases with incomplete data or known congenital anomalies.

**Ethical Clearance**

This study was approved by the Research Ethics Committee of Universitas Jenderal Achmad Yani, Cimahi (Ethics Approval No. 068/KEPK/FITKes-Unjani/VI/2024). Prior to participation, all mothers were given a full explanation of the study's objectives, the procedures involved, and their rights as participants. Written informed consent was secured from each respondent. Data protection protocols were followed rigorously. All identifying details were anonymized, records were securely stored, and only authorized members of the research team had access. Participants were informed that they could withdraw at any time without any negative consequences.

**Statistical Analysis**

Data were entered and cleaned using standardized coding protocols, then analyzed using SPSS version 25. Descriptive statistics were used to summarize baseline characteristics. Bivariate comparisons between case and control groups (stunted vs. non-stunted children) employed Chi-square tests for categorical variables and independent t-tests for continuous variables. To assess the association between smart bracelet use and stunting, odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. Multivariate logistic regression analysis was conducted to adjust for potential confounders. Variables were selected for model inclusion based on three criteria: (1) statistical significance in bivariate analysis ($p < 0.10$), (2) theoretical relevance based on existing literature (e.g., maternal education, antenatal visit frequency, dietary intake), and (3) absence of multicollinearity (as determined by variance inflation factor analysis). The final model retained covariates that meaningfully altered the association between smart bracelet use and stunting risk. A two-sided p-value $< 0.05$ was considered statistically significant for all inferential tests.

DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

## 3. RESULTS

Table 1 presents a comparison of maternal factors between the case group (children with stunting) and the control group (children without stunting). The proportion of mothers who used a smart bracelet during pregnancy was significantly higher in the control group (56%) than in the case group (24%), with a p-value of 0.001 and an odds ratio (OR) of 0.25 (95% CI: 0.11–0.58), suggesting a protective association. Maternal education at the level of high school or above was more common among the control group (60%) compared to the case group (36%), with a statistically significant difference (p = 0.046) and an OR of 0.43 (95% CI: 0.19–0.99). Mothers who had attended at least four antenatal care (ANC) visits were also more prevalent in the control group (70%) versus the case group (40%), with a p-value of 0.008 and an OR of 0.32 (95% CI: 0.14–0.74). In terms of nutritional intake during pregnancy, 76% of mothers in the control group reported adequate dietary intake, compared to 44% in the case group. This difference was statistically significant (p = 0.002), with an OR of 0.29 (95% CI: 0.13–0.63), indicating a strong association between adequate nutrition during pregnancy and reduced risk of stunting in toddlers.

**Table 1. Comparison of Maternal Factors Between Case and Control Groups**

| Maternal Factors | Case Group (n=50) | Control Group (n=50) | p-value | Odds Ratio (95% CI) |
|---|---|---|---|---|
| Smart bracelet use during pregnancy | 12 (24%) | 28 (56%) | 0.001 | 0.25 (0.11–0.58) |
| Maternal education (≥ high school) | 18 (36%) | 30 (60%) | 0.046 | 0.43 (0.19–0.99) |
| ANC visits (≥ 4 times) | 20 (40%) | 35 (70%) | 0.008 | 0.32 (0.14–0.74) |
| Adequate dietary intake during pregnancy | 22 (44%) | 38 (76%) | 0.002 | 0.29 (0.13–0.63) |

Table 2 presents the association between smart bracelet use during pregnancy and the incidence of stunting in toddlers. Among the mothers of stunted children (case group), only 12 (24%) reported using a smart bracelet during pregnancy, while the remaining 38 (76%) did not. In contrast, among the non-stunted group (control group), 28 mothers (56%) had used a smart bracelet, and 22 (44%) had not. The total number of mothers who used the bracelet was 40, whereas 60 reported no use. Statistical analysis using the chi-square test showed a significant association between smart bracelet use and reduced risk of stunting (p = 0.001). The odds ratio (OR) of 0.25, with a 95% confidence interval of 0.11 to 0.58, indicates that smart bracelet use during pregnancy may have a protective effect against stunting in toddlers.

**Table 2. Association Between Smart Bracelet Use and Stunting**

| Smart Bracelet Use During Pregnancy | Stunted (Case Group) | Not Stunted (Control Group) | Total |
|---|---|---|---|
| Yes | 12 | 28 | 40 |
| No | 38 | 22 | 60 |
| Total | 50 | 50 | 100 |

**Note: $\chi^2$ test, p = 0.001; OR = 0.25 (95% CI: 0.11–0.58)**

Table 3 summarizes the multivariate logistic regression results. Smart bracelet use during pregnancy was significantly associated with reduced odds of child stunting (adjusted OR = 0.28, 95% CI: 0.12–0.64, p = 0.003), suggesting a strong protective effect independent of other maternal

DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

factors. High school-level education (OR = 0.46, 95% CI: 0.21–0.98), adequate antenatal care (≥4 visits; OR = 0.35, 95% CI: 0.16–0.78), and sufficient dietary intake (OR = 0.31, 95% CI: 0.14–0.68) were also significantly protective.

**Table 3. Multivariate Logistic Regression Analysis of Factors Associated with Stunting**

| Variable | Adjusted OR | 95% CI | p-value |
|---|---|---|---|
| Smart bracelet use | 0.28 | 0.12–0.64 | 0.003 |
| Maternal education (≥ high school) | 0.46 | 0.21–0.98 | 0.045 |
| ANC ≥ 4 visits | 0.35 | 0.16–0.78 | 0.009 |
| Adequate dietary intake | 0.31 | 0.14–0.68 | 0.005 |

## 4. DISCUSSION

The results of this study offer valuable understanding of maternal factors associated with the incidence of stunting among toddlers in Margamukti Village, Sumedang Regency. Through multivariate logistic regression analysis, four key maternal protective factors were identified: the use of smart bracelets during pregnancy, higher maternal education, adequate antenatal care (ANC) visits, and sufficient dietary intake throughout pregnancy. Among these, the most prominent protective factor was the use of smart bracelets, which was significantly associated with reduced odds of stunting in toddlers. This association suggests that wearable digital tools, when used during pregnancy, may positively influence maternal behavior and support better fetal development. Smart bracelets, which typically feature activity tracking, heart rate monitoring, and dietary guidance, can help pregnant women monitor their health more consistently. This level of engagement may foster earlier detection of health concerns and encourage timely health-seeking behavior. The use of digital self-monitoring aligns with previous research on mobile health (mHealth) interventions, which have been shown to enhance maternal adherence to health recommendations and improve prenatal outcomes (Knop et al., 2024; Lau et al., 2023) What distinguishes this finding is the potential application of wearable technology as a targeted intervention for preventing stunting, an area that remains relatively underexplored in both national and global literature.

In addition to digital health tools, the study confirmed that maternal education plays a significant role in shaping child health outcomes. Mothers who had completed at least a high school education were less likely to have children experiencing stunting. Educational attainment is widely understood to influence a mother's ability to make informed health decisions, access services, and apply knowledge related to child nutrition, hygiene, and disease prevention. This observation is consistent with previous studies that associate maternal education with improved child growth, nutritional status, and developmental indicators (De & Pradhan, 2023; Rahmandiani et al., 2019).

The analysis also highlighted the importance of adequate antenatal care utilization. Mothers who attended four or more ANC visits had a significantly lower risk of having stunted children. ANC provides a critical opportunity for monitoring maternal and fetal health, delivering essential health information, and addressing nutritional or medical concerns in a timely manner. The World Health Organization strongly advocates for at least four focused ANC visits to optimize maternal and neonatal health. These findings support the continued prioritization of ANC services,

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e-ISSN 2477-3743 | p-ISSN 2541-0024

particularly in underserved rural areas where health service utilization remains suboptimal. Furthermore, the study found that adequate maternal dietary intake during pregnancy significantly reduced the likelihood of stunting. Good maternal nutrition is vital for supporting fetal growth and reducing the risk of intrauterine growth restriction, which can lead to poor postnatal growth outcomes. These results align with international evidence linking maternal undernutrition to adverse birth outcomes and early childhood stunting (, (Raiten & Bremer, 2020; WHO, 2017). Interventions aimed at improving maternal nutrition whether through education, counseling, or supplementation are therefore essential components of any comprehensive effort to prevent childhood stunting.

Collectively, the findings of this study underscore the complexity of stunting and the pivotal role that maternal factors play in determining child growth outcomes. While many public health interventions have historically focused on the postnatal period, these results suggest that prenatal strategies, including the use of wearable health technologies and enhanced maternal support systems may offer significant benefits (Venkataramanan et al., 2022). The protective association observed with smart bracelet use indicates that integrating such tools into maternal care programs could be a promising strategy to reduce stunting rates, especially in resource-limited settings like Indonesia (Leema et al., 2025). As public health initiatives continue to evolve, incorporating digital innovation alongside conventional maternal and child health services could lead to more sustainable improvements in child development and well-being.

This study suggests that integrating wearable devices like smart bracelets into maternal health programs could enhance pregnancy monitoring and early risk detection, especially in rural or underserved areas. These tools can help fill gaps in clinical care and support timely interventions. However, barriers such as device cost, limited access, and low digital literacy must be addressed. Solutions may include subsidized distribution, simplified interfaces, training for community health workers, and integration with existing services like posyandu. Public-private partnerships can help scale these efforts. Health education remains essential. Improving maternal knowledge about nutrition, antenatal care, and health tracking can boost engagement and outcomes. Encouraging quality antenatal visits with personalized support is also crucial. Multi-sector collaboration among health providers, tech developers, and educators can help build responsive, equity-focused systems. While findings are promising, potential self-selection bias and reverse causality should be explored in future studies using randomized or matched designs..

## 5. LIMITATIONS

This research offers meaningful insights into the role of maternal behaviors and wearable technology in stunting prevention, but several limitations should be considered when interpreting the results. First, as a case-control study, the design allows for the identification of associations rather than causal relationships. Although the data suggest links between smart bracelet use and reduced stunting risk, temporal sequencing cannot be firmly established. Second, key variables, including maternal nutrition and smart bracelet usage were self-reported, which introduces the possibility of recall bias or socially desirable responses. Third, the sample was drawn from a single rural village in Sumedang Regency. While the site was chosen due to its high prevalence of stunting, the findings may not generalize to other geographic regions with differing healthcare

DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

infrastructure, cultural practices, or socioeconomic conditions. Fourth, although multivariate analysis was used to control for key confounders, residual confounding remains a possibility. Factors such as household income, digital literacy, and access to health information may influence both smart bracelet usage and maternal health behaviors but were not fully accounted for in the model. It is also possible that the observed protective effect reflects greater health awareness among users rather than the device itself. Lastly, while proportions and comparisons were reported throughout the study, future research should include confidence intervals for all percentages to improve statistical transparency and interpretability. Expanding future studies to include a broader range of contextual variables, such as paternal involvement, sanitation, and environmental exposures will provide a more comprehensive understanding of the multifactorial causes of stunting.

## 6. CONCLUSION

The results of this study demonstrate a significant association between maternal health behaviors and the risk of childhood stunting. Specifically, mothers who used smart bracelets during pregnancy were significantly less likely to have children who experienced stunting. This finding suggests that wearable digital health tools may play a supportive role in improving maternal health monitoring, increasing awareness of pregnancy-related risks, and encouraging proactive engagement with healthcare services. Additional protective factors such as higher maternal education, adequate dietary intake, and consistent antenatal care attendance further reinforce the importance of comprehensive maternal support. Compared to more established mobile health interventions, smart bracelets offer a novel and continuous monitoring experience, potentially enhancing health outcomes in resource-limited settings. These findings support the integration of wearable technology as a complementary tool in maternal-child health strategies aimed at reducing stunting.

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DOI: https://doi.org/10.17509/jpki.v11i1
e-ISSN 2477-3743 | p-ISSN 2541-0024

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e-ISSN 2477-3743 | p-ISSN 2541-0024