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DEVELOPMENT AND FEASIBILITY ASSESSMENT OF A DIGITAL STUNTINGMETER FOR CHILD GROWTH MONITORING IN INDONESIA

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Abstract: Child malnutrition, including stunting, wasting, and underweight, remains a major public health challenge in Indonesia, with long-term consequences on cognitive development, productivity, and national economic growth. Accurate and real-time growth monitoring is essential for the early detection and timely nutritional interventions. This study presents the development and feasibility assessment of the Digital Stuntingmeter, an ultrasonic-based anthropometric device designed to improve measurement accuracy and enable real-time integration with national health information systems. A multiparameter feasibility study was conducted covering technical, economic, social, and regulatory aspects. Technical feasibility was evaluated through laboratory-based accuracy testing by comparing Digital Stuntingmeter measurements with a gold-standard FLUKE laser distance meter. Social feasibility and user acceptance were assessed among 120 health cadres, midwives, and nutritionists using a structured survey based on the Diffusion of Innovations theory and qualitative Force Field Analysis. Economic feasibility was analyzed through production cost estimation, return on investment (ROI), and break-even point calculations, while regulatory feasibility was assessed against national medical device and child anthropometric standards. The results demonstrated high measurement accuracy, with an average deviation of ±0.2 cm, and strong user acceptance, with a mean acceptance score of 8.62 on a 10-point scale. The device supports both offline and online operation and enables real-time data integration with national systems such as e-PPGBM and SIGIZI. Economically, the estimated unit cost was 365 USD, with a positive ROI and a short break-even period under institutional procurement scenarios. The Digital Stuntingmeter shows strong potential for widespread application through institutional adoption in primary health care settings, particularly Posyandu and Puskesmas. With regulatory alignment and a clear commercialization pathway, this innovation offers a scalable and sustainable solution to strengthen child growth monitoring and support national stunting reduction strategies.

Keywords: stunting, digital anthropometry, child growth monitoring, early detection, feasibility study, health technology

1. Introduction

Child malnutrition remains a significant public health concern globally, particularly in developing countries such as Indonesia. Three major forms of undernutrition such as stunting, wasting, and underweight have long-lasting effects on cognitive development, learning capacity, productivity, and national economic performance (Al Jawaldeh et al., 2020; De Sanctis V, Soliman A, Alaaraj N, Ahmed S, Alyafei F et al., 2021; Haywood & Pienaar, 2021; Jańczewska et al., 2023; Kinyoki et al., 2020; Mathewson et al., 2021). According to the World Health Organization (WHO), stunting reflects chronic nutritional deficiencies and recurrent infections, with children categorized as stunted if their height-for-age is below minus two standard deviations (WHO, 2015). In 2023, the Indonesian Health Survey reported that 21.5% of children under five were stunted, 8.5% were wasted, and 15.9% were underweight (Ministry of Health of the Republic of Indonesia., 2023). Although stunting was declining,

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it remained above the national target of 14% by 2024(National Development Planning Agency, 2020). This indicates an urgent need for more effective strategies to address child malnutrition through early detection and intervention.

Several contributing factors have perpetuated the high prevalence of malnutrition in Indonesia. These include food insecurity (Patriota et al., 2024), poor maternal nutrition (Saleh et al., 2021), limited access to clean water and sanitation (Mudadu Silva et al., 2023), suboptimal infant feeding practices (Abdullah et al., 2018; Siswati et al., 2022), and a lack of integrated growth monitoring systems (Helmyati et al., 2022). Compounding the issue, the conventional anthropometric tools used in Posyandu and other frontline services is a conventional measurement such as microtoise and infantometers are prone to human error, require skilled handling, and are often not integrated with digital health information systems. This leads to delays in diagnosis, intervention, and reporting, and can erode public trust in the quality of growth monitoring outcomes (Siswati et al., 2023).

Several digital anthropometry innovations have been developed globally to improve child growth monitoring, including digital stadiometers, image-assisted measurement systems, and mobile-based anthropometric applications (Heymsfield et al., 2018) (Rodríguez et al., 2021a). Although these technologies demonstrate potential to reduce manual recording errors, many remain limited in public health practice due to high costs, dependence on stable internet connectivity, suboptimal accuracy in field conditions, and limited usability by community health workers (Mocini et al., 2023). In many countries, such tools are implemented primarily as standalone devices or pilot interventions, restricting their contribution to routine surveillance and programmatic decision-making (Heymsfield et al., 2018). These limitations highlight the need for a system-integrated, field-adapted digital growth monitoring device suitable for decentralized primary health care settings.

The Government of Indonesia has made stunting reduction a national priority, as reflected in the RPJMN 2020–2024(National Development Planning Agency, 2020) and Perpres No. 72/2021 on the Acceleration of Stunting Reduction (Presiden RI, 2021). Despite the introduction of digital health tools and integrated service platforms, challenges persist in achieving accurate and real-time anthropometric assessments at scale. Most existing digital devices on the market fail to fully address the need for real-time data transmission, accuracy in diverse field conditions, and compatibility with national information systems like e-PPGBM or SIGIZI. Therefore, a novel technological intervention is required to bridge these gaps and align with the broader agenda of health technology transformation (Transformation Pillar 3: Digital Health Resilience).

Despite the increasing availability of growth monitoring tools, most existing anthropometric devices used in primary health care settings remain manual, prone to measurement error, and poorly integrated with digital health information systems. Conventional tools such as infantometers/stadiometers require skilled handling and are highly dependent on operator technique, which can compromise data accuracy and consistency, particularly in community-based settings. While several digital anthropometric solutions have been introduced, many lack real-time data integration, are costly, or are not designed for use in low-resource and decentralized health systems. These limitations create critical gaps between the need for accurate, timely child growth data and the capacity of existing technologies to support early

detection and programmatic decision-making. In the context of Indonesia's high stunting burden and ongoing digital health transformation, there is a clear need for a growth monitoring device that combines measurement accuracy, ease of use, and real-time system integration. This gap provided the foundation for the development of the Digital Stuntingmeter.

This research introduces the Digital Stuntingmeter, a breakthrough innovation in growth monitoring, which utilizes ultrasonic technology to measure children's height with higher precision and integrates measurement results in real time into the national reporting systems. Uniquely, the device also offers a composite growth analysis (CIAF), enabling the simultaneous detection of stunting, wasting, and underweight. The tool is designed for ease of use by both trained health workers and community health cadres and is operable in areas with limited internet connectivity. Its portable, ergonomic, and intelligent design ensures suitability for use across various health service settings, from Posyandu to hospitals (Siswati et al., 2024). This research contributes to improving accuracy of anthropometric measurement with ultrasonic technology, enables real-time integration with national health information systems, provides (CIAF) beyond stunting only as well as enhances usability for cadres in low-resource settings, portable, and can be use both offline and online mode.

This study aims to evaluate the feasibility of the Digital Stuntingmeter from four key aspects: technical, economic, social, and regulatory. This study aims to assess the feasibility of the Digital Stuntingmeter across technical, economic, social, and regulatory domains. Technical feasibility was defined by measurement accuracy against a gold-standard device, economic feasibility by production cost, ROI, and break-even point, social feasibility by user acceptance scores among health workers, and regulatory feasibility by compliance with national anthropometric and medical device standards.

2. Materials and Methods

2.1 Research Design

This research uses a multiparameter feasibility study approach. The four main aspects analyzed include: technical, economic, social, and regulatory feasibility. This research is a research with a multi-methodological approach, a combination of early-stage product development and a mixed-methods approach. There are quantitative studies for accuracy test & survey, and a qualitative study for Force Field Analysis (FFA) & observation design. A mixed-methods approach was used to capture both measurable feasibility outcomes and contextual factors influencing technology adoption in primary health care settings. Comparative analysis with other stunting detection technologies was beyond the scope of this study, as the focus was on early-stage feasibility and implementation readiness

2.2 Setting and Time

The research was carried out in January-October 2024 in several locations, including the manufacture of tools at PT Entry Jaya Makmur, testing the accuracy of tools at the National Calibration Laboratory Official, as well as social feasibility and acceptance of respondents in several Posyandu and Puskesmas

in Sleman Regency (Yogyakarta), Kulon Progo (Yogyakarta), Pekalongan (Central Java), and South Kalimantan.

2.3 Population and Sample

The sample size for the acceptance test was calculated by the sample calculation formula ($Z=1.96$; $\sigma=2$; $d=0.35$). Based on the calculation results, the number of samples under five was set at 120 people using the purposive sampling technique. They were measured in height/length. Meanwhile, the social population is health workers (midwives, nutritionists, health programs), Posyandu cadres, PAUD teachers, and potential users of 40 tools. The inclusion criteria are 21–60 years old, active as a health worker/cadre ≥1 year, have taken measurements of toddlers, and are willing to sign informed consent, while the exclusion criteria are respondents who cannot take part in training/testing of tools, refuse informed consent, or have cognitive/communication impairments during interviews.

2.4 Research Variables

The free variables in this study include tool innovation (features, accuracy, complexity, observability, compatibility, *trialability*), with acceptance score (scale 1–10), ROI value (%), break-even point (month), accuracy (mm).

2.5 Data Collection and Instruments

The accuracy testing technique of the tool was carried out technically based on the laboratory test of the Digital Stuntingmeter compared to the standard FLUKE 414D Laser Distance Meter. Meanwhile, to assess the acceptability of the tool, a test of the acceptance of the tool was carried out with the theory of Diffusion of Innovation Theory (Rogers) using the Likert scale(Rogers, 2003). The value of the range is 0-10, the bigger the score, the more accepted it is. Meanwhile, qualitative data on tool evaluation was carried out with Force Field Analysis format interviews to map driving and inhibiting factors as well as in-depth interviews. User acceptance was assessed using a structured questionnaire based on key attributes of the Diffusion of Innovations Theory, including perceived usefulness, ease of use, compatibility with routine practice, and intention to adopt. Responses were measured using a Likert-scale format, and descriptive statistical analysis was applied to summarize acceptance levels among health workers. Qualitative feedback from open-ended responses was used to complement the quantitative findings by identifying perceived barriers and facilitators of device adoption.

2.6 Data Analysis

The results of respondents' acceptance scores were measured using SPSS, financial analysis was conducted by calculating ROI and Break-Even Point, while qualitative data from FFA were grouped by quadrant identified by factors driving and inhibiting innovation adoption.

2.7 Research Ethics

This research has received ethical approval from the Universitas Gadjah Mada Health Research Ethics Committee No: KE/ FK/0671/EC/2023 on 27 April 2023

3. Results and Discussion

3.1 Technical Feasibility

The developed Digital Stuntingmeter has reached the fourth version (V4) and uses HC-SR04, a low-cost and high-accuracy ultrasonic sensor(Theodoro et al., 2023)(Komarizadehasl et al., 2022) (Fig 1).

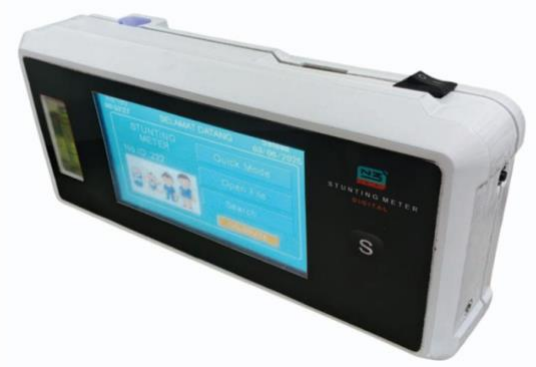


Fig 1. Digital Stuntingmeter Version-4

The accuracy test was carried out by comparing the measurement results of Digital Stuntingmeter to the gold standard FLUKE 414D Laser Distance Meter(Jans et al., 2020) (Fig 2).

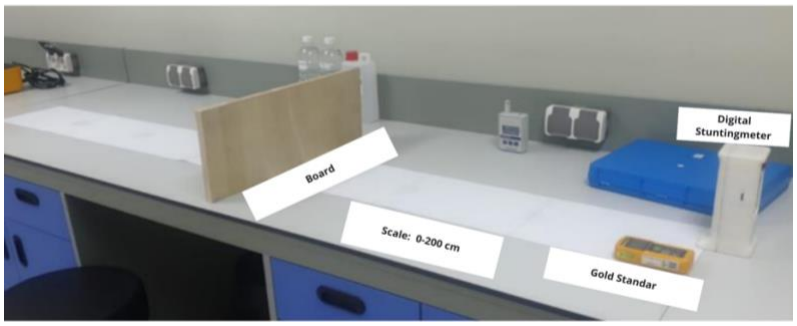


Fig 2. Test of the accuracy of Digital Stuntingmeter and gold standard tools

The results showed that the average deviation in height measurement was ±0.2 cm (Table 1), indicating a high level of precision for the Digital Stuntingmeter. This small difference in measurement can be effectively corrected using the calibration button on the device, which allows users to adjust and standardize the readings before each measurement session. The availability of this calibration feature ensures consistent accuracy across different users and settings, minimizing potential errors due to handling or environmental variations. Consequently, the tool provides reliable anthropometric data that can be confidently used for monitoring child growth in both clinical and field settings, supporting timely and data-driven decision-making in stunting prevention programs. The results of the accuracy test measurement by credible institutions are detailed in Table 1.

Table 1. The results of the accuracy test measurement Digital Stuntingmeter

Parameters	Setting	Output (gold standard)	Output Digital Stuntingmeter (recumbent)	Standard corrections			Outcome **($\bar{x}$)**	Converse **($\bar{x}$)**
				1	2	3		
Distances	30	30.2	29.9	29.9	29.9	30.1	29.9	29.9
	60	60.2	60.5	60.5	60.5	60.1	60.5	60.5
	90	90.2	91.3	91.3	91.3	90.1	91.3	91.3
	120	120.2	120.2	120.2	120.2	120.2	119.5	119.8

Parameters	Setting	Outcome (gold standard)	Outcome (standing)	Standard corrections			Outcome ($\bar{x}$)	Converse ($\bar{x}$)
				1	2	3		
Distance	30	30.2	30	30	30	30.1	30	30
	60	60.2	60.7	60.7	60.7	60.1	60.7	60.7
	90	90.2	90.8	90.8	90.8	90.1	90.8	90.8
	120	120.2	120.1	120.1	120.1	120.1	120.1	120.1

Digital Stuntingmeter can be used offline as well as online and saves data to internal memory. The integration of the tool with systems such as e-PPGBM and SIGIZI also has been successfully tested, so that the data can be directly connected to the national system. The results of this study confirm that the Digital Stuntingmeter has a high level of accuracy, portable design, and real-time data integration that is relevant for use in various locations, including remote areas. This fact proves the advantages of ultrasonic sensor technology in overcoming the limitations of conventional anthropometric devices, such as stadiometers or infantometers, which are prone to manual errors and take longer(Siswati et al., 2023). These findings are in line with modern anthropometric measurement theories that emphasize the role of digital technology in improving precision while accelerating data-driven decision-making(Heymsfield et al., 2018; Mocini et al., 2023; Rodríguez et al., 2021b).

In addition, Digital Stuntingmeter meet the criteria of Technology Readiness Level (TRL)-9(Olechowski et al., 2020) and have a Domestic Component Level (in Bahasa: Tingkat Komponen Dalam Negeri/TKDN) of more than 55%, exceeding the minimum TKDN recommended by the Indonesian government(Peraturan Pemerintah RI Nomor 21, 2021). This feature indicates that the tool is ready for wider testing and can be manufactured with local components. This tool is also easy to use by health workers, thus accelerating the early detection process of stunting(Siswati et al., 2024). Suggested images include photos of the final version of the tool, system integration diagrams, and a comparison graph of measurement results vs FLUKE. These findings confirm that Digital Stuntingmeter have high technical feasibility and can be applied practically in the field. While technical accuracy is a fundamental requirement, its contribution to public health impact depends on whether the Digital Stuntingmeter can be produced and implemented in a financially sustainable manner.

From an implementation perspective, the existence of offline features makes this tool relevant for use in areas with limited internet access. The concept of user-centered design applied supports the literature that states that simplicity and ease of use are key factors in the successful adoption of health technology in the primary care setting. Therefore, these devices not only increase technical efficiency, but also strengthen the capacity of cadres and health workers at the community level(Siswati et al., 2024). Meanwhile, in the context of health transformation, the development of this tool shows domestic innovations that can be fast, accurate, reduce dependence on imported devices, tools for fast and accurate child growth monitoring, but also allow data to be integrated directly with national reporting systems and enhance digital health system(Ministry of Health of the Republic of Indonesia., 2022; PT Dian Daya Dinamika., 2023). This marks a step forward towards a more adaptive and technology-based nutrition surveillance system.

3.2 Economic Feasibility

The production cost of one unit of Digital Stuntingmeter is estimated at 365 USD with the same selling price. The break-even point (BEP) is reached after eight units are sold, so that new profits are obtained starting from the ninth unit. This shows that at the current production scale, profits are not significant if the number of units is limited. Further analysis shows that if production costs are reduced to 331 USD per unit, the margin per unit can increase to 34 USD. With this strategy, the return on investment (ROI) of the tool will increase significantly and make the tool more economical for mass production.

The market potential for this tool is huge. National data shows that there are around 300,000 Posyandu, 10,180 health centers, and more than 2,800 hospitals in Indonesia, including maternal-child hospitals and maternity clinics that have the potential to become users of this tool. If the distribution strategy is directed at health institutions and not just individual cadres, then the chances of market penetration are much higher.

Assuming a conservative scenario, if in the first 2 years 500 units are successfully marketed in the first year and 1,500 units in the second year, plus 20% repeat orders or around 400 units, then total sales will reach 2,400 units.

However, in terms of economic feasibility, this tool still has strong prospects due to the wide market and real needs in the national nutrition program. With a slight adjustment of pricing strategies or production efficiency, profit margins can be created. For example, if the selling price is increased even though it is only 34 USD higher than the production cost, then with the sale of 2,400 units, the potential profit reaches 733,320USD with a positive ROI. In addition, multi-tier pricing strategies for governments, NGOs, and the commercial sector, as well as public-private partnership (PPP) schemes or cross-subsidies, can increase affordability while ensuring product sustainability(Moon et al., 2011)(Chalkidou et al., 2020).

Thus, the economic viability of Digital Stuntingmeter is highly dependent on production cost optimization, pricing strategies, and the ability to utilize the very large institutional market in Indonesia. If this step is taken, the device will not only provide financial benefits for manufacturers, but also contribute significantly to long-term health cost savings through stunting prevention. However, economic viability alone does not guarantee successful implementation, as adoption ultimately relies on acceptance, usability, and perceived benefits among health workers in routine service settings.

3.3 Social Acceptability

The social feasibility assessment was carried out on 120 respondents, consisting of Posyandu cadres, midwives, nutritionists, early childhood education teachers, and health promotion workers. The results of the analysis showed that the average acceptance score of Digital Stuntingmeter was 8.62 ± 1.65 on a Likert scale of 1–10, indicating a high acceptance rate. The detailed information in the previous issues(Siswati et al., 2024). The dimension of innovation according to Rogers' theory, namely relative advantage, compatibility, and complexity, has been shown to have a significant effect on acceptance. Respondents rated the tool as easy to use, relevant to their work, and provides clear benefits in monitoring children's growth(Siswati et al., 2024). These findings indicate that Digital Stuntingmeter have the potential for wide social adoption among health workers.

FFA identified the driving and inhibiting factors of admission. Key driving forces include high levels of accuracy, ease of use, and integration with national data systems. Meanwhile, the inhibiting forces include doubts about the use of new tools, the need for initial training, and the perception of a relatively high initial price. From the perspective of Technology Acceptance Model (TAM) theory, technology acceptance is influenced by the perception of perceived ease of use and perceived usefulness. Digital Stuntingmeter meet both of these aspects, because cadres feel that the tool is superior to the old method and in accordance with their needs and work culture. In addition, the suitability of the tool with the local context and global trends of digital health strengthens the social readiness for adoption. Strategies to increase demand, such as integration with Posyandu, school health programs, and mother-child campaigns, are expected to increase the visibility and utilization of tools.

From the summary of the findings, the high social acceptance of this Digital Stuntingmeter is a strategic opportunity. Support through positive narratives on social media, partnerships with community leaders, and subsidies, can make the Digital Stuntingmeter not only a measurement tool, but also encourage the empowerment of Posyandu cadres in providing health services to the community and potentially strengthen stunting prevention efforts in Indonesia, while making a significant contribution to long-term health cost savings. For this detailed explanation available in other article. In addition to user

acceptance, regulatory compliance is essential to ensure that the device can be legally adopted and integrated into the national health system.

3.4 Regulatory Feasibility

Digital Stuntingmeter has complied with the provisions of applicable regulations, including Permenkes No. 2 of 2020 concerning children's anthropometric standards (Indonesia, 2010)and KMK No. 1919 of 2022 concerning child growth and development tools(Kemenkes RI, 2022). In addition, this tool complies with Law No. 3 of 2014 and Presidential Regulation No. 12 of 2021 regarding the obligation to use domestic medical devices, which require government agencies to give preference to domestic goods with a minimum of 40% of both corporate contribution value (in Bahasa: Bobot Manfaat Perusahaan/BMP) and TKDN(Saragih, 2025).

Compliance with these regulations ensures that the device can be used legally and safely in Indonesia. The regulatory evaluation also ensures the tools are ready for the testing, commercialization, and integration process with the national system. This supports the readiness of Digital Stuntingmeter for large-scale implementations.

In terms of regulations, Digital Stuntingmeter are in accordance with Indonesia's Health Transformation Agenda (Pillar 3: Health Technology Resilience) which encourages the use of local health technology. The fact that these devices meet the main requirements of domestic medical devices strengthens its position to enter official procurement mechanisms such as the LKPP e-catalog and the Health Technology Assessment (HTA). This is important because regulation is the main entry point for technology to be widely adopted in the health system(Indonesia Ministry of Health, 2024).

The theory of diffusion of innovation (Rogers) states that regulatory support accelerates adoption by creating institutional legitimacy(Rogers, 2003). According to the TKDN policy, this device has a greater chance of being recognized and used nationally. In addition, regulations can also be a market protection mechanism that supports the sustainability of domestic production.

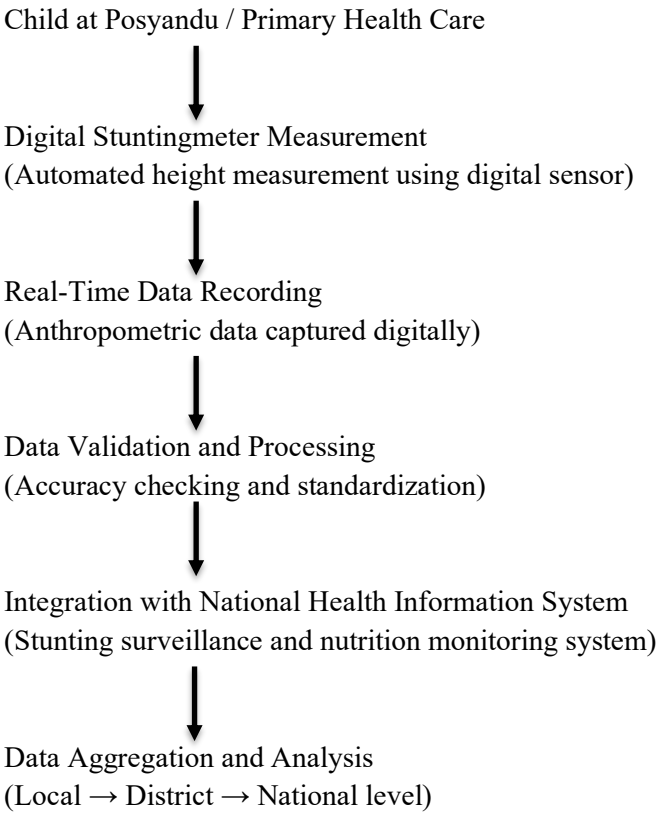
We analized that regulation is a strong determining factor for the success of commercialization and adoption of Digital Stuntingmeter. If the government officially included this device in the procurement list, then its adoption would not only be faster but also more even. This is in line with the national target to reduce the prevalence of stunting below 14% by 2024(National Development Planning Agency, 2020), as well as support the independence of domestic medical devices.

Despite strong regulatory readiness, large-scale implementation of the Digital Stuntingmeter faces several real-world challenges. Scaling up across Indonesia requires alignment with institutional procurement mechanisms, consistent training for health cadres, and standardized maintenance systems. Given the diversity of infrastructure across regions, adoption is more feasible through institutional deployment in Posyandu and Puskesmas rather than individual ownership. Regulatory alignment with TKDN and national medical device policies provides a strategic entry point for nationwide diffusion and supports system-level adoption.

Although the device can operate offline, sustainable implementation at scale depends on minimum supporting infrastructure, including stable electricity, periodic calibration, and interoperability with regional and national health information systems. Addressing these factors is essential to ensure that the demonstrated feasibility of the Digital Stuntingmeter translates into effective and sustainable public health impact.

The implications of the study show that Digital Stuntingmeter have great potential to strengthen the capacity of cadres and health workers in early detection of stunting, which can contribute to long-term health cost savings. The high local component supports the independence of domestic medical devices and is in line with Indonesia's health transformation agenda. In order for the tool to be widely adopted, appropriate implementation strategies are needed, including cadre training, institutional distribution, and formal regulatory support through e-catalog procurement mechanisms and Health Technology Assessment (HTA).

Beyond technical performance, the high accuracy of the Digital Stuntingmeter has important implications for public health systems. More reliable anthropometric data may improve targeting of nutrition interventions, optimize resource allocation, and strengthen evidence-based planning at primary care and district levels. At the national level, integration of accurate real-time data could support policy decisions related to stunting surveillance, program prioritization, and monitoring of national nutrition targets. **Figure 1** showed detailed Workflow of the Digital Stuntingmeter integration into the national health system, illustrating the process from child anthropometric measurement at the primary health care level to data integration, analysis, and evidence-based policy and program decision-making.



Evidence-Based Decision Making
(Targeting interventions, resource allocation)

Policy Planning and Program Improvement
(Monitoring, evaluation, and national stunting reduction strategy)

Figure 1. Workflow of the Digital Stuntingmeter

Despite the high accuracy and positive user acceptance, several potential barriers to implementation should be considered. Infrastructure constraints in rural and remote areas, such as limited electricity, internet connectivity, and maintenance capacity, may affect routine use of the device. In addition, resistance from health workers accustomed to conventional anthropometric tools may require targeted training and change management strategies to support successful adoption.

These limitations may influence the generalizability of the findings to broader real-world settings. The study was conducted with a limited sample size and under relatively controlled conditions, which may not fully represent the variability of infrastructure, workforce capacity, and service delivery in rural and remote areas. Therefore, caution is needed when extrapolating these results, and further field-based studies in diverse settings are required to confirm applicability at scale.

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Further research is needed to evaluate the long-term impact of the Digital Stuntingmeter on stunting detection and prevention outcomes. Future studies should include pilot implementation in diverse geographic and socio-economic settings across Indonesia to assess scalability, usability, and system integration. Longitudinal evaluation of routine use may also help determine the device's contribution to improved stunting surveillance and program effectiveness at regional and national levels.

4. Conclusion

This research shows that Digital Stuntingmeter is technically feasible, economically, socially, and regulatory. This tool has high accuracy, is easy to use, can work offline and online, and is integrated with national data systems; socially well received by cadres and health workers; economically it has large market potential even though it requires a price strategy and production efficiency; and meet the requirements of national regulations and ethics. The implementation of Digital Stuntingmeter is needed through the stages of cadre training, integration with public health programs, and institutional distribution strategies, as well as utilizing regulatory support for commercialization. The implication is that these devices can accelerate the early detection of stunting, increase the capacity of health workers, support long-term health cost savings, and encourage the independence of domestic medical device innovation.

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Declaration of Interest Statement

We have no conflict of interest

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