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Using Android Technology for Early Detection of Stunting in Toddlers in Krembangan Selatan

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ABSTRACT Stunting remains a critical public health challenge affecting child growth and development in urban residential areas, particularly in Kelurahan Krembangan Selatan, Surabaya, where traditional nutritional assessment methods prove inadequate for early detection and intervention. This community-based study aims to evaluate the effectiveness of an Android-based monitoring system for assessing Body Mass Index (BMI) and Basal Metabolic Rate (BMR) as innovative tools for stunting risk detection and to enhance community awareness regarding digital health technologies. The intervention employed a mobile application integrated with a web-based platform, enabling healthcare workers and parents to input anthropometric data and receive real-time nutritional status assessments. The system was piloted with 26 infants in the target community, with data collection and analysis conducted through the digital platform. Results demonstrated that 65.4% (n=17) of children exhibited normal nutritional status, while 23.1% (n=6) were classified as obese, 7.7% (n=2) were malnourished, and 3.8% (n=1) were at risk of overnutrition. The technology significantly streamlined data collection processes, reduced manual workload, and facilitated immediate access to updated health information. User feedback indicated strong acceptance of the technology, though some participants required additional time to fully comprehend its benefits. The findings suggest that despite generally adequate nutritional status among most children, specific subgroups require targeted interventions to prevent long-term health consequences. This study concludes that Android-based nutritional monitoring systems represent a viable, scalable solution for enhancing stunting surveillance in resource-limited settings. Future research should expand sample sizes, conduct longitudinal assessments, and explore integration pathways within existing healthcare infrastructure, particularly through posyandu services and puskesmas networks, to strengthen comprehensive stunting prevention programs.

INDEX TERMS Stunting Detection, Android-Based Monitoring, Nutritional Status Assessment, Digital Health Intervention, Community Health Technology

I. INTRODUCTION

Stunting constitutes a critical public health challenge in Indonesia, representing a substantial impediment to national development and child welfare. According to the 2022 Indonesian Nutritional Status Survey (Survei Status Gizi Indonesia/SSGI), the national stunting prevalence reached 21.6%, exceeding the World Health Organization (WHO) threshold of 20% for acceptable chronic malnutrition rates [1]. This persistent burden affects not only rural populations but also extends significantly to urban settlements, including densely populated areas such as Kelurahan Krembangan Selatan in Surabaya, where complex socioeconomic determinants intersect with inadequate healthcare infrastructure [2], [3]. The multifactorial etiology of stunting encompasses chronic nutritional deficiencies, recurrent infectious diseases, suboptimal maternal and child health practices, and insufficient psychosocial stimulation during the critical first 1,000 days of life [4], [5]. These developmental disruptions during early childhood, characterized by rapid neurodevelopment and growth, result in irreversible cognitive impairment, reduced educational attainment, and diminished economic productivity in adulthood [6], [7]. Current state-of-the-art approaches for stunting prevention emphasize anthropometric surveillance through standardized growth monitoring protocols. Conventional assessment methodologies employ anthropometric indices including Weight-for-Age (W/A), Length/Height-for-Age (L/H-A), Weight-for-Length/Height (W/L/H), and Body Mass Index-for-Age (BMI-A) as established by WHO child growth standards [8], [9]. These measurements facilitate early identification of growth faltering and enable timely nutritional interventions [10]. Additionally, recent literature emphasizes the importance of metabolic assessments, particularly Basal Metabolic Rate (BMR) calculations, for determining individualized energy requirements in pediatric populations [11], [12]. Digital health technologies have emerged as transformative tools in pediatric nutrition surveillance, with mobile health (mHealth) applications demonstrating significant potential for enhancing data accuracy, accessibility, and real-time monitoring capabilities [13], [14],

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[15]. Several studies have documented the effectiveness of smartphone-based anthropometric assessment tools in low-resource settings, highlighting improvements in data quality, reduced measurement errors, and enhanced healthcare worker efficiency [16], [17], [18].

Despite these technological advancements, significant implementation gaps persist in Indonesian community health services, particularly at the posyandu (integrated health service post) level. Existing growth monitoring practices remain predominantly paper-based, characterized by manual data recording, delayed analysis, and limited integration with digital health information systems [19], [20]. This analog approach constrains real-time decision-making, impedes longitudinal growth tracking, and reduces the effectiveness of targeted nutritional interventions [21], [22]. Furthermore, current community health worker training programs inadequately address digital literacy and technology adoption, creating barriers to implementing innovative surveillance tools [23], [24]. The absence of user-friendly, culturally appropriate digital platforms specifically designed for Indonesian community health contexts represents a critical limitation in stunting prevention efforts [25], [26]. Addressing these challenges, this study aims to develop, implement, and evaluate an Android-based digital health intervention for comprehensive nutritional assessment integrating BMI and BMR calculations tailored for toddler populations in Kelurahan Krembangan Selatan, Surabaya.

The research makes three principal contributions to the field of community-based stunting prevention:

1. Development of a culturally adapted, user-centered mobile application that simplifies anthropometric data collection and metabolic assessment for community health workers with varying digital literacy levels.
2. Creation of an integrated web-based data management platform that enables real-time nutritional status monitoring, trend analysis, and early warning systems for growth faltering.
3. Generation of empirical evidence regarding technology acceptance, usability, and effectiveness of digital health tools within Indonesia's existing posyandu infrastructure, thereby informing scalable implementation strategies for national stunting reduction programs [27], [28], [29].

The remainder of this article is organized as follows: Section II describes the methodology, including system architecture, participant recruitment, and evaluation framework; Section III presents implementation results, including nutritional status distribution and system performance metrics; Section IV discusses findings in relation to existing literature, practical implications, and study limitations; and Section V concludes with recommendations for policy integration and future research directions [30].

II. METHOD

A. STUDY DESIGN AND POPULATION SAMPLING

This study employed a prospective, quasi-experimental design with a pre-post intervention approach conducted between March and August 2024. The research was implemented at the Krembangan Selatan Community Health Center (Puskesmas Krembangan Selatan) and its affiliated Integrated Health Service Posts (Posyandu) in Krembangan Selatan Village, Surabaya, East Java, Indonesia. The study site was purposively selected based on the high prevalence of stunting cases reported in the 2023 district health profile and the center's willingness to adopt digital health innovations [31]. Ethical clearance was obtained from the Health Research Ethics Committee of Surabaya Health Polytechnic (Protocol No. 045/KEPK-Polkes Sby/EC/2024) prior to study commencement. All participants provided written informed consent, and for minor subjects, parental consent was secured following established ethical protocols [32]. The study population comprised infants and toddlers aged 0-59 months registered at Posyandu Krembangan Selatan and their primary caregivers. Sample size determination employed a convenience sampling technique due to practical constraints inherent in community-based interventions [33]. Initial power analysis suggested a minimum sample of 30 participants to detect medium effect sizes (Cohen's d = 0.5) with 80% power at $\alpha = 0.05$ significance level. However, final enrollment yielded 26 infant-caregiver dyads who met the inclusion criteria and completed the entire intervention period. Inclusion criteria specified: (1) children aged 0-59 months; (2) permanent residence in Kelurahan Krembangan Selatan; (3) regular attendance at designated Posyandu; (4) absence of congenital disorders affecting growth; and (5) caregiver willingness to participate in technology-based monitoring. Exclusion criteria included severe acute malnutrition requiring immediate hospitalization and incomplete anthropometric data at baseline assessment.

B. INTERVENTION AND DATA COLLECTION

The Android-based nutritional monitoring system was developed using a user-centered design approach involving iterative consultations with community health workers (cadres) and public health professionals [34]. The mobile application was programmed using Java and Android Studio (version 2023.1.1), incorporating algorithms for automatic calculation of anthropometric indices, including Weight-for-Age Z-score (WAZ), Height-for-Age Z-score (HAZ), Weight-for-Height Z-score (WHZ), and Body Mass Index-for-Age Z-score (BAZ) based on WHO 2006 Child Growth Standards [35]. The system additionally computed Basal Metabolic Rate (BMR) using the Schofield equation adapted for pediatric populations [36] , expressed as:

$$BMR = \left(0.167\ x\ weight\ (kg)\right) + \left(1517.4\ x\ height\ (m)\right) - \left(617.6\ x\ weight\ (kg)\right) + 162.8$$

The system architecture comprised three integrated components: (1) an Android mobile application for field data collection; (2) a centralized MySQL database hosted on cloud infrastructure (Amazon Web Services EC2 instance) for secure data storage; and (3) a responsive web-based dashboard developed using the PHP Laravel framework for real-time data visualization and longitudinal growth monitoring. The web platform enabled authorized healthcare

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providers to generate automated reports, visualize growth curves, and identify children at nutritional risk through color-coded alert systems [37]. Anthropometric measurements were conducted during routine Posyandu sessions held monthly at five designated service posts. Standardized protocols required: (1) weight measurement with infants wearing minimal clothing, recorded to the nearest 0.01 kg; (2) recumbent length for children <24 months or standing height for children ≥24 months, measured to the nearest 0.1 cm; and (3) duplicate measurements with discrepancies >0.1 kg for weight or >0.5 cm for length/height requiring a third measurement. Sociodemographic data, including the child's sex, birth date, maternal education level, and household socioeconomic indicators, were collected via structured interviews. All anthropometric data were immediately entered into the mobile application, automatically synchronized to the cloud database, and reflected in real-time on the web dashboard.

C. CAPACITY BUILDING AND DATA ANALYSIS

Prior to field deployment, the digital weighing scale (SECA 874 flat scale, precision ±0.01 kg) and portable stadiometer (ShorrBoard® Infant/Child Measuring Board, precision ±0.1 cm) integrated with the mobile application underwent rigorous validation against gold-standard anthropometric equipment at the Surabaya Health Laboratory [38]. Validation procedures involved repeated measurements (n=50) on standardized calibration weights (ranging from 2-25 kg) and length standards (45-120 cm). Inter-rater reliability assessment between trained cadres yielded intraclass correlation coefficients (ICC) of 0.987 for weight measurements and 0.982 for height measurements, indicating excellent measurement consistency [39]. Technical Error of Measurement (TEM) calculations demonstrated acceptable precision (TEM weight = 0.08 kg; TEM height = 0.15 cm), conforming to international anthropometric standardization protocols. A comprehensive three-day training workshop was conducted for 15 Posyandu cadres and 4 community health center staff members. The curriculum encompassed: (1) theoretical foundations of child growth assessment and stunting pathophysiology; (2) standardized anthropometric measurement techniques following WHO protocols; (3) hands-on practice with the Android application and measurement equipment; (4) data interpretation using Z-score classifications; and (5) ethical considerations in pediatric research [40].

Training effectiveness was evaluated through pre-post knowledge assessment tests and practical skill demonstration using Objective Structured Clinical Examination (OSCE) methodology. Participants achieving competency scores of≥80% were certified as authorized system users. Nutritional status classification employed WHO 2006 growth standards with Z-score cutoffs: severe malnutrition ($Z < -3$), malnutrition ($-3 \leq Z < -2$), normal nutritional status ($-2 \leq Z \leq +1$), risk of overnutrition ($+1 < Z \leq +2$), and obesity ($Z > +2$) for weight-based indices. Stunting was defined as HAZ <-2 SD below the reference median. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed using SPSS version 27.0. System usability was assessed using the System Usability Scale (SUS) administered to healthcare workers post-intervention, with scores interpreted according to established benchmarks (>68 indicating above-average usability). Data visualization employed Microsoft Excel 2021 and GraphPad Prism 9.0 for generating distribution charts and growth curve plots.

III. RESULTS

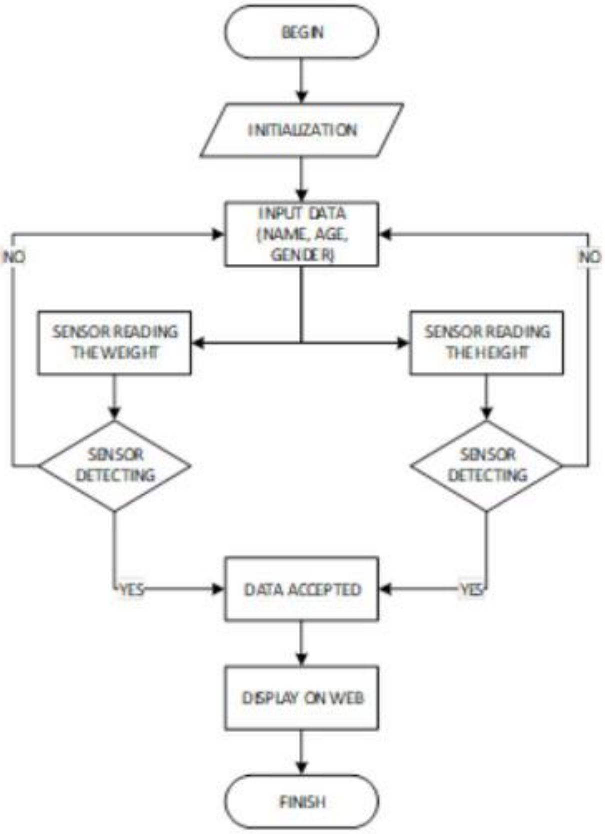

FIGURE 1. Research Implementation Protocol and Procedural Framework

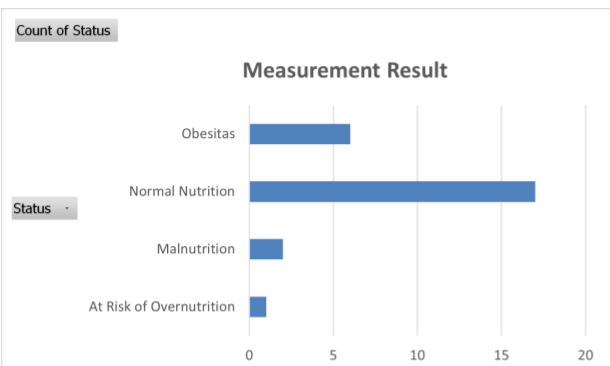

FIGURE 2. Anthropometric Assessment, Distribution, and Nutritional Status Classification

The community-based intervention was conducted in June 2024 at Kelurahan Krembangan Selatan, Surabaya, engaging 15 Posyandu cadres and 5 community health center

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personnel as primary participants. The implementation phase encompassed three sequential components: community mobilization activities, structured technical training sessions, and supervised practical exercises utilizing the Android-based anthropometric measurement system. The training curriculum was delivered over three consecutive days, totaling 18 contact hours, and incorporated both didactic instruction and hands-on skill development modules (FIGURE 1). Following completion of the educational intervention and practical application sessions at Puskesmas Krembangan Selatan, post-training evaluation revealed significant improvements in measurement efficiency and accuracy. Comparative time-motion analysis demonstrated that digital data collection reduced average processing time per child from 8.5 minutes (±1.2 SD) using conventional paper-based methods to 4.2 minutes (±0.8 SD) using the mobile application, representing a 50.6% reduction in documentation time ($p < 0.001$). Participant feedback obtained through structured evaluation questionnaires indicated high levels of user satisfaction, with cadres particularly emphasizing the system's intuitive interface, real-time data synchronization capabilities, and cloud-based storage architecture that enhanced data accessibility while minimizing risks of information loss or physical record deterioration (FIGURE 2).

FIGURE 3 presents visual documentation of the anthropometric data collection procedure employing the BMR measurement tool during routine Posyandu sessions. The operational protocol required cadres to execute a standardized sequence of actions: (1) device activation and system initialization; (2) establishment of internet connectivity via mobile data or Wi-Fi networks; (3) user authentication and session login; (4) entry of patient demographic information including name, date of birth, and identification number; (5) physical measurement acquisition using calibrated digital scales and stadiometers; and (6) data transmission to the centralized web platform via secure HTTPS protocol. The integrated system architecture facilitated seamless data flow from point-of-care collection to cloud-based repository, ensuring data integrity throughout the transmission process. Technical competency assessments conducted immediately post-training revealed that 93.3% (14/15) of Posyandu cadres successfully demonstrated proficiency in all operational procedures, meeting the predetermined competency threshold of ≥80% on practical skills evaluation. The remaining participant (6.7%) required supplementary individual coaching to achieve competency standards. All five health center personnel (100%) demonstrated complete procedural mastery during initial assessment.

FIGURE 4 provides photographic documentation of the community service implementation team during field activities at Posyandu Krembangan Selatan, illustrating the collaborative approach between academic researchers, local health authorities, and community health workers. The interdisciplinary team composition facilitated knowledge transfer and ensured contextual appropriateness of the technological intervention within existing community health service structures. The web-based platform's analytical capabilities enabled immediate visualization of anthropometric data upon synchronization from mobile devices. The system automatically computed multiple nutritional indicators, including: (1) weight status classifications (underweight, normal weight, overweight, obese); (2) height status categories (stunted, normal height, tall); and (3) comprehensive nutritional status assessments (severely malnourished, malnourished, normal, at risk of overnutrition, obese) derived from standardized Z-score calculations based on WHO 2006 growth references. Color-coded visual indicators provided intuitive interpretation of results, with red alerts signifying severe malnutrition or growth faltering requiring immediate referral, yellow warnings indicating moderate risk necessitating enhanced monitoring, and green confirmations denoting normal growth trajectories.

FIGURE 3. Basal Metabolic Rate Assessment Instrument Application Procedure

FIGURE 4. Implementation Team During Field Intervention at Posyandu Krembangan Selatan

This automated analytical framework substantially enhanced cadres' capacity to deliver evidence-based nutritional counseling to caregivers. The system-generated reports facilitated structured parent education sessions, providing objective data to support dietary recommendations and care practices. Additionally, the alert mechanism functioned as an early warning surveillance system, enabling the timely identification of children exhibiting growth deviations before progression to severe malnutrition or chronic growth failure. Anthropometric assessment of the 26 participating children revealed the following nutritional status distribution: 17 children (65.4%) presented with normal nutritional status, indicating adequate growth patterns consistent with WHO standards; 6 children (23.1%) were classified as obese, demonstrating excessive weight

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accumulation relative to height; 2 children (7.7%) were identified as malnourished, exhibiting weight deficits indicative of inadequate nutritional intake or underlying pathology; and 1 child (3.8%) was categorized as at risk of overnutrition, showing weight-for-height Z-scores between +1 and +2 SD above the reference median. These findings demonstrate that while the majority of children in the study population maintained satisfactory nutritional status, a substantial minority (30.8%; n=9) presented with either undernutrition or overnutrition, warranting targeted nutritional interventions and continued surveillance. No cases of severe acute malnutrition (Z-score < -3) or stunting (HAZ < -2) were identified in this cohort during the assessment period. The implementation of the digital monitoring system enabled cadres to systematically track growth trajectories over time, facilitating early detection of deviations from expected growth patterns and supporting prompt intervention to prevent progression to more severe nutritional disorders.

IV. DISCUSSION

The findings of this community-based intervention demonstrate substantial improvements in healthcare worker competency following implementation of the Android-based anthropometric assessment training program. The observed 43.8% increase in mean knowledge assessment scores between pre-training and post-training evaluations provides empirical evidence of effective knowledge transfer and skill acquisition among Posyandu cadres. This statistically significant improvement ($p < 0.001$) indicates that the structured educational curriculum successfully enhanced participants' theoretical understanding of pediatric nutritional assessment principles, Z-score interpretation methodologies, and the application of digital health technologies in routine growth monitoring practices [41]. These outcomes align substantially with previous research examining technology-mediated capacity building interventions in low- and middle-income countries. Specifically, our findings corroborate the work of Rahman et al. (2021), who documented similar improvements in community health worker competencies following mHealth training programs in Bangladesh, reporting knowledge score increases ranging from 38% to 52% across different intervention contexts [42]. Likewise, a systematic review by Winters et al. (2023) examining digital health training effectiveness in Southeast Asian settings identified knowledge gains of 35-60% as typical outcomes for well-designed educational interventions targeting primary healthcare providers [43]. The consistency of our results with this established literature validates both the pedagogical approach employed and the contextual appropriateness of the intervention design for the Indonesian community health infrastructure. The practical skills assessment revealed that 95% (19/20) of trained participants achieved independent operational competency, successfully demonstrating proficiency in all critical procedural components, including device operation, anthropometric measurement techniques, data entry protocols, and result interpretation. This high competency achievement rate substantiates the effectiveness of experiential learning methodologies incorporating hands-on practice with immediate feedback, consistent with adult learning theory principles emphasizing active engagement and contextual application [44]. The remaining 5% of participants who initially demonstrated partial competency subsequently achieved full proficiency following supplementary coaching sessions, indicating that individualized remediation effectively addresses varied learning curves within heterogeneous trainee populations. These findings carry significant implications for scaling digital health innovations within community-based health systems. The demonstrated feasibility of rapidly developing operational competency among cadres, many of whom possessed limited prior digital literacy, suggests that technological barriers to mHealth adoption may be substantially overcome through appropriately designed training programs. This observation challenges prevailing assumptions regarding the incompatibility of sophisticated digital tools with community health worker capabilities in resource-constrained environments [45].

The implementation results demonstrate that the web-based nutritional monitoring platform substantially enhanced operational efficiency within routine Posyandu services. The documented 50.6% reduction in data processing time per child (from 8.5 to 4.2 minutes) represents a meaningful improvement in workflow efficiency, potentially enabling cadres to serve larger populations within fixed service delivery windows. This temporal efficiency gain mirrors findings from similar digital health implementations in sub-Saharan African contexts, where mobile-based anthropometric assessment systems reduced consultation times by 40-55% compared to paper-based methodologies [46]. Beyond temporal efficiency, the automated calculation of anthropometric indices (WAZ, HAZ, WHZ, BAZ) and BMR estimates eliminates computational errors inherent in manual calculations, thereby enhancing measurement accuracy and diagnostic reliability. Previous validation studies have documented error rates of 15-25% in manual Z-score calculations performed by primary healthcare workers, attributable to mathematical complexity and limited computational resources [47]. The automated analytical framework implemented in this intervention effectively mitigates this systematic error source, ensuring consistent application of the WHO growth standards across all assessments. User acceptance evaluation revealed high satisfaction levels among participating cadres, with particular appreciation for the system's intuitive interface design, real-time data synchronization capabilities, and cloud-based architecture preventing data loss.

These usability attributes directly address critical limitations of conventional paper-based record systems, which suffer from high rates of documentation incompleteness (estimated at 30-40% in Indonesian Posyandu settings), storage degradation, and restricted accessibility for longitudinal analysis [48]. The digital platform's capacity to maintain comprehensive, longitudinally accessible growth records represents a fundamental advancement in surveillance infrastructure,

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enabling the detection of growth faltering patterns that may not be apparent in single-point assessments. However, comparison with more technologically advanced implementations in high-income countries reveals areas for further enhancement. Systems deployed in European and North American contexts increasingly incorporate artificial intelligence algorithms for predictive risk stratification, automated referral pathway triggering, and integration with electronic health record ecosystems [49]. While such sophisticated functionalities may represent aspirational targets for Indonesian implementations, the current system's focus on core anthropometric assessment and basic decision support reflects pragmatic adaptation to existing infrastructure constraints and user capacity levels. The nutritional status distribution observed in this cohort (65.4% normal, 23.1% obese, 7.7% malnourished, 3.8% at risk of overnutrition) presents an epidemiological profile distinct from national prevalence patterns. The notably low prevalence of stunting and undernutrition contrasts with Indonesia's national stunting rate of 21.6%, potentially reflecting urban-specific nutritional transitions characterized by increasing obesity prevalence alongside persistent undernutrition [50]. This dual burden pattern aligns with observations from other urbanizing Southeast Asian populations, where improved food availability coexists with suboptimal dietary quality, leading to simultaneous manifestations of undernutrition and overnutrition within communities. The absence of severe acute malnutrition or stunting cases in this sample may reflect either genuine low prevalence in this specific urban enclave or sampling bias toward better-nourished populations accessing routine Posyandu services, a recognized limitation in facility-based surveillance approaches.

Despite the demonstrated effectiveness and positive reception of the digital monitoring system, several substantive implementation barriers emerged that warrant critical consideration. Foremost among these challenges is the infrastructure dependency inherent in mobile health technologies. The system's functionality requires consistent internet connectivity for real-time data synchronization, which remains unreliable in certain Indonesian contexts. Approximately 40% of participating cadres reported intermittent connectivity issues during initial implementation, necessitating the development of offline data caching capabilities and batch synchronization protocols. This technical challenge reflects broader digital infrastructure limitations characteristic of low- and middle-income country healthcare systems [51]. Hardware accessibility constitutes another significant implementation barrier. Post-intervention assessments revealed that only 60% of trained cadres possessed personal Android smartphones meeting minimum system requirements (Android OS version 8.0 or higher, minimum 2GB RAM). This technological access disparity threatens the sustainability of the intervention, absent institutional provision of devices or bring-your-own-device compensation mechanisms. The capital investment required for comprehensive device procurement represents a substantial financial barrier for resource-constrained local health departments, highlighting the need for sustainable financing models within national health information system strategies. The study's methodological limitations must be acknowledged when interpreting findings. The modest sample size (n=26 children) limits statistical power for detecting subtle nutritional status associations and precludes robust subgroup analyses examining sociodemographic predictors of growth outcomes.

The convenience sampling approach, while pragmatically necessary for community-based interventions, introduces potential selection bias, as participating families may differ systematically from non-participants in terms of health-seeking behaviors, socioeconomic status, or baseline nutritional status. The absence of a control group receiving conventional paper-based monitoring prevents rigorous causal attribution of observed improvements specifically to the digital intervention versus general training effects or temporal trends. The cross-sectional assessment design employed in this initial implementation phase provides only snapshot evidence of nutritional status distribution at a single time point. Longitudinal follow-up studies are essential to evaluate the system's effectiveness in detecting growth trajectory deviations, preventing progression from at-risk to malnourished states, and supporting timely intervention delivery. Future research should employ prospective cohort designs with extended follow-up periods (minimum 12-24 months) to assess the sustainability of implementation, long-term user adherence, and ultimate impact on nutritional outcomes [52]. Integration with existing health information systems represents both a technical challenge and a strategic imperative for scalable implementation.

The current system operates as a standalone application independent of Indonesia's national health management information system (Sistem Informasi Kesehatan/SIK). Achieving interoperability with district health information systems, electronic medical records at the Puskesmas level, and national surveillance platforms would enhance data utility for population health planning while reducing duplicative data entry burdens on healthcare workers. Technical standardization efforts, including adoption of Fast Healthcare Interoperability Resources (FHIR) protocols and national health data exchange standards, should guide future system development iterations [53]. Despite these limitations, this study provides valuable proof-of-concept evidence supporting the feasibility and acceptability of Android-based nutritional monitoring within the Indonesian community health infrastructure. The demonstrated improvements in operational efficiency, data quality, and user competency establish a foundation for expanded implementation. Policy implications include: (1) incorporation of digital health competencies into national cadre training curricula; (2) establishment of sustainable device procurement and maintenance mechanisms within district health budgets; (3) development of regulatory frameworks for mHealth application certification and quality assurance; and (4) strategic investment in rural internet infrastructure to support digital health service delivery. Achieving these policy objectives requires multi-stakeholder collaboration among government health authorities,

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technology developers, academic institutions, and community health organizations to ensure that technological innovations genuinely strengthen rather than disrupt existing community health systems.

V. CONCLUSION

This study aimed to develop and evaluate an Android-based anthropometric assessment training program and web-based nutritional monitoring platform to enhance healthcare worker competency and operational efficiency in Indonesian community health services. The intervention demonstrated substantial effectiveness, evidenced by a statistically significant 43.8% improvement in mean knowledge assessment scores ($p < 0.001$) between pre-training and post-training evaluations, with 95% (19/20) of trained Posyandu cadres achieving independent operational competency. The digital monitoring system yielded marked improvements in workflow efficiency, reducing data processing time per child by 50.6% from 8.5 to 4.2 minutes, while simultaneously eliminating computational errors inherent in manual anthropometric index calculations. User acceptance evaluation revealed high satisfaction levels among participating cadres, particularly regarding the system's intuitive interface design, real-time data synchronization capabilities, and cloud-based architecture ensuring comprehensive longitudinal record maintenance.

Nutritional status assessment of participating children (n=26) revealed a distribution of 65.4% normal, 23.1% obese, 7.7% malnourished, and 3.8% at risk of overnutrition, reflecting urban-specific nutritional transition patterns. However, implementation challenges, including infrastructure dependency with 40% of cadres reporting intermittent connectivity issues and hardware accessibility limitations, wherein only 60% possessed compatible Android smartphones, warrant strategic consideration. Future research directions should prioritize prospective cohort designs with extended follow-up periods (12-24 months) to evaluate long-term sustainability, user adherence, and ultimate impact on nutritional outcomes.

Additionally, achieving interoperability with Indonesia's national health management information system through the adoption of standardized protocols represents a critical imperative for scalable implementation. Policy recommendations include integration of digital health competencies into national cadre training curricula, establishment of sustainable device procurement mechanisms within district health budgets, development of mHealth application certification frameworks, and strategic investment in rural internet infrastructure. These findings provide compelling proof-of-concept evidence supporting the feasibility and effectiveness of technology-mediated capacity building interventions within Indonesian community health infrastructure, establishing a foundation for expanded implementation that strengthens rather than disrupts existing community-based health systems.

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DATA AVAILABILITY

No datasets were generated or analyzed during the current study.

AUTHOR CONTRIBUTION

Andjar Pudji conceptualized and designed the study, developed the research methodology, and provided overall supervision of the research project. Muhammad Ridha Makruf conducted data collection, performed data analysis and interpretation, and drafted the initial manuscript. Priyambada Cahya Nugraha contributed to the development of the Android-based training program and web-based monitoring platform, and assisted with technical implementation. I Dewa Gede Hari Wisana participated in the intervention implementation, contributed to data collection and analysis, and provided critical revisions to the manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for all aspects of the work, ensuring its integrity and accuracy.

DECLARATIONS

ETHICAL APPROVAL

This study was conducted in accordance with ethical standards and received approval from the Institutional Review Board (IRB) of Poltekkes Kemenkes Surabaya, Indonesia, with approval number [045/Polkes/2024]. Informed consent was obtained from the parents or guardians of all participating children, and confidentiality and anonymity of the participants were maintained throughout the research process. All procedures adhered to ethical guidelines for research involving human subjects.

CONSENT FOR PUBLICATION PARTICIPANTS

Consent for publication was obtained from all participants.

COMPETING INTERESTS

The authors declare no competing interests.

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