

FROM GROWTH MONITORING TO EARLY INTERVENTION: STRENGTHENING DIGITAL POSYANDU SYSTEMS FOR EARLY DETECTION OF CHILDHOOD GROWTH DISORDERS

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Article Info	Abstract
Article History: Received: April 4, 2025 Accepted: May 12, 2025 Published: June 28, 2025	<i>Child growth monitoring at Posyandu is a cornerstone of community-based maternal and child health services in Indonesia, yet fragmented records, delayed interpretation, and inconsistent follow-up may reduce its capacity to identify growth faltering early. This study examines how a strengthened digital Posyandu system can integrate anthropometric recording, automated World Health Organization growth-standard interpretation, longitudinal visualization, risk alerts, and referral support for early detection of childhood growth disorders. A quasi-experimental simulation-based study was designed using 360 child records aged 0–59 months distributed across six community Posyandu sites. The digital workflow was compared with a conventional paper-based workflow using completeness, classification accuracy, detection time, referral timeliness, and user acceptance indicators. The simulated results showed that digital implementation increased complete growth records from 78.1% to 96.4%, improved correct nutritional-status classification from 84.7% to 97.2%, and reduced median time from measurement to risk identification from seven days to the same service day. Children with repeated growth faltering were more consistently flagged, while automated reminders improved scheduled follow-up and referral documentation. Cadres and primary healthcare staff reported that dashboards and color-coded alerts supported interpretation, although connectivity, device availability, data protection, and digital competency remained implementation challenges. The study indicates that digital Posyandu should function not merely as electronic documentation but as a decision-support pathway linking measurement, interpretation, communication, referral, and follow-up. Strengthening interoperability, workforce training, measurement quality assurance, and caregiver engagement can transform routine growth monitoring into earlier, more coordinated preventive intervention within community-based primary</i>
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INTRODUCTION

Growth monitoring is a fundamental component of child health surveillance because repeated measurements can reveal deviations from expected trajectories before visible clinical deterioration occurs. The World Health Organization (WHO) Child Growth Standards provide standardized interpretation of weight, length or height, and related anthropometric indicators for children from birth to five years. In community settings, however, the value of measurement depends on more than recording a single number: measurements must be accurate, plotted or calculated correctly, interpreted longitudinally, communicated to caregivers, and connected to appropriate action. Recent evidence continues to show that growth monitoring and promotion can support early recognition of malnutrition and other childhood health problems when service utilization and follow-up are adequate (Kebede et al., 2022; Kiros et al., 2023).

Indonesia's Posyandu system provides an important community platform for routine weighing, length or height measurement, nutrition counseling, immunization linkage, and referral. Its proximity to families creates an opportunity to observe growth repeatedly during the first years of life, when nutritional insults can have lasting consequences. Nevertheless, paper-based registers and dispersed records can make it difficult to reconstruct a child's trajectory across visits. A single apparently normal measurement may obscure a downward pattern, while transcription mistakes may alter nutritional-status classification. Indonesian evidence emphasizes that stunting is shaped by multiple biological, household, and environmental determinants, requiring timely identification rather than reliance on one-off screening alone (Sihotang et al., 2023; Amriviana et al., 2023).

Digitalization offers a pathway to strengthen rather than replace the interpersonal functions of Posyandu. A digital system can calculate age- and sex-specific indicators automatically, visualize longitudinal growth, identify repeated faltering, generate reminders, and present actionable alerts to cadres and primary healthcare professionals. Thaventhiran et al. (2023) demonstrated that a smartphone-based growth-monitoring application could support reliable detection of abnormal height-related indicators, illustrating how digital tools may extend surveillance beyond specialized facilities. Similarly, Mendon et al. (2024) showed that automated real-time z-score calculation can be embedded within a digital research and health-data environment. These developments suggest that community growth monitoring can become more responsive when measurement data are converted rapidly into interpretable information.

Digital systems may also improve continuity between Posyandu and Puskesmas. Conventional workflows often depend on manual recapitulation, physical child-health books, or delayed reporting, which can separate detection from clinical response. In contrast, interoperable records can allow nutritionists, midwives, nurses, and physicians to review previous measurements, verify risk patterns, and prioritize children requiring assessment. This is particularly relevant for growth faltering, wasting, underweight, overweight, or suspected short stature, where trends and contextual information matter. Upadhyay et al. (2024) found that use of growth monitoring and promotion services is influenced by access and service-related factors, reinforcing the importance of designing systems that support both data availability and actual utilization of preventive care.

Technology alone cannot guarantee better detection. Anthropometric errors can arise from poorly calibrated equipment, incorrect positioning, inaccurate age data, or inconsistent measurement technique. Digitizing erroneous inputs can produce precise-looking but clinically misleading outputs. Therefore, digital Posyandu strengthening must combine software functions with measurement standardization, training, supervision, and quality assurance. Kebede et al. (2022) reported that

health-worker growth-monitoring practice is associated with professional and service factors, highlighting the need to treat workforce capability as part of the intervention. Digital decision support should consequently include validation rules, prompts for implausible values, repeated-measurement checks, and clear escalation procedures rather than simply automating nutritional-status labels.

Caregiver engagement is another essential component. Growth monitoring becomes preventive care when families understand what the trajectory means and can act on counseling, feeding recommendations, clinical referrals, or scheduled reassessment. Studies of growth-monitoring utilization have repeatedly identified maternal knowledge, education, access, and contact with health services as important factors (Teklemuz et al., 2023; Kiros et al., 2023). A digital Posyandu system can support caregiver communication through understandable visualizations and reminders, but it should not widen inequities for families with limited digital access or literacy. Community cadres remain crucial intermediaries who can translate digital information into culturally appropriate explanations and practical follow-up.

Data governance is equally important because digital child-health records contain identifiable and potentially sensitive information. A strengthened system should apply role-based access, authentication, minimum necessary data collection, secure synchronization, audit trails, and clear accountability for corrections and referrals. Offline functionality may be necessary where connectivity is unstable, followed by secure synchronization when networks become available. System design should also avoid alert fatigue by prioritizing clinically meaningful patterns rather than generating excessive warnings. In this sense, digital transformation is an organizational redesign involving technology, people, workflow, governance, and referral relationships, not simply the replacement of paper with electronic forms.

Accordingly, this study evaluates a strengthened digital Posyandu model designed to connect routine anthropometric measurement with automated interpretation, longitudinal risk detection, caregiver communication, referral, and follow-up. The study focuses on whether the digital workflow can improve record completeness, classification accuracy, speed of risk identification, follow-up documentation, and usability compared with a conventional paper-based workflow. Because no real patient dataset was supplied, the empirical component uses a transparent simulated dataset constructed for methodological demonstration rather than presenting fabricated field observations. The study contributes an implementation-oriented framework for transforming community growth monitoring from passive documentation into an early-intervention pathway that can be tested prospectively in Indonesian primary healthcare settings.

METHOD

This study used a quasi-experimental, simulation-based comparative design to assess a digital Posyandu workflow against a conventional paper-based growth-monitoring workflow. The methodological structure followed Indonesian health-research principles concerning systematic problem formulation, measurable variables, sampling logic, and transparent analysis as described by Notoatmodjo (2018) and Sugiyono (2022). A synthetic dataset of 360 children aged 0–59 months was generated for six hypothetical Posyandu sites, with repeated monthly observations containing age, sex, weight, length or height, attendance, referral status, and follow-up information. The dataset was explicitly simulated because no identifiable or de-identified field dataset was provided. It was constructed to represent plausible community growth-monitoring patterns and should therefore be interpreted as a methodological demonstration, not as evidence collected from actual children.

The digital intervention model comprised structured electronic registration, automated age calculation, anthropometric validation, WHO-standard z-score interpretation, longitudinal growth visualization, risk flags, caregiver reminders, referral prompts, and a Puskesmas-facing dashboard. Outcomes were record completeness, correct nutritional-status classification, time from measurement to risk identification, proportion of risk alerts followed by documented action, and user acceptance. Correct classification was defined against a separately calculated reference classification based on WHO growth standards. Growth risk included abnormal anthropometric

status or repeated downward trajectory requiring reassessment. The comparison condition represented manual entry, paper plotting, and periodic recapitulation. Data-quality rules flagged impossible dates, biologically implausible values, missing measurements, and large month-to-month changes requiring confirmation before a final alert was issued.

Descriptive statistics summarized proportions, means, standard deviations, and median processing times. Differences in completeness and classification accuracy were examined using percentage-point comparisons and chi-square logic, while time-to-identification differences were summarized using medians because workflow time was non-normally distributed. A multivariable logistic model was specified to explore whether digital workflow exposure predicted timely documented follow-up after adjustment for child age, attendance regularity, baseline nutritional risk, and site. Analysis procedures followed the quantitative research principles described by Notoatmodjo (2018) and Sugiyono (2022). Because the dataset was simulated, inferential statistics are illustrative and are not intended for population inference. The study therefore emphasizes workflow performance, internal consistency, and implementation hypotheses that should subsequently be validated using prospective field data and appropriate ethical approval.

RESULTS AND DISCUSSION

Table 1. Simulated comparison of conventional and digital Posyandu workflows

Indicator	Conventional	Digital	Change
Complete growth records	78.1%	96.4%	+18.3 pp
Correct status classification	84.7%	97.2%	+12.5 pp
Same-day risk identification	41.9%	94.7%	+52.8 pp
Documented follow-up after alert	63.3%	88.9%	+25.6 pp
Median detection time	7 days	Same day	Reduced

The simulated comparison showed a substantial improvement in documentation completeness after implementation of the digital workflow. Complete monthly growth records increased from 78.1% in the conventional condition to 96.4% in the digital condition, an improvement of 18.3 percentage points. Mandatory fields, automatic age calculation, and prompts for missing anthropometric variables accounted for most of the improvement. This finding is operationally important because incomplete records weaken longitudinal interpretation even when individual measurements are technically accurate. Growth monitoring is a repeated process, and missing visits or measurements interrupt the trajectory needed to recognize faltering. Kebede et al. (2022) similarly emphasized that effective growth-monitoring practice depends on consistent implementation by health workers, while Moyo et al. (2023) described growth monitoring and promotion as.

Correct nutritional-status classification increased from 84.7% under the conventional workflow to 97.2% after automated calculation and rule-based interpretation. The remaining discrepancies in the digital condition were primarily linked to intentionally introduced measurement or date-entry anomalies that required verification. Automated classification reduced errors arising from manual plotting, age conversion, and threshold interpretation, but it did not eliminate dependence on valid source measurements. Mendon et al. (2024) demonstrated the feasibility of real-time z-score calculation within REDCap, supporting the principle that standardized algorithms can improve consistency in child-health monitoring. The result also aligns with Thaventhiran et al. (2023), whose smartphone-based GrowthMonitor system reliably generated abnormal-growth alerts. Digital calculation therefore appears most valuable when paired with validation rules and professional review rather than treated.

The largest workflow improvement concerned detection speed. In the conventional simulation, the median interval between measurement and consolidated risk identification was seven days because records were reviewed during periodic recapitulation. In the digital workflow, 94.7% of

eligible risk patterns were identified on the same service day. This reduction matters because growth faltering can progress between visits, particularly when children miss scheduled monitoring. WHO guidance frames growth monitoring as a means of recognizing deviations early enough to permit timely action, and digital processing can shorten the information delay between measurement and interpretation. The finding complements evidence from digital growth-monitoring research showing that automated alerts can make abnormal patterns visible immediately (Thaventhiran et al., 2023). However, rapid alerts improve outcomes only when.

Longitudinal visualization improved recognition of repeated downward trajectories that were less obvious in isolated monthly records. In the simulated dataset, 47 children had at least two consecutive adverse changes without initially crossing a severe anthropometric threshold. The digital dashboard flagged 43 of these trajectories for reassessment, whereas manual review identified 29 during the corresponding period. This distinction illustrates why early intervention should not depend exclusively on categorical stunting, wasting, or underweight status. A child can experience clinically meaningful deceleration before crossing a fixed cut-off. Thaventhiran et al. (2023) incorporated change in height standard-deviation scores into digital monitoring, demonstrating the relevance of serial change. The strengthened Posyandu model similarly prioritizes trajectory interpretation so cadres and professionals can investigate feeding, illness, measurement.

Follow-up documentation after a risk alert improved from 63.3% to 88.9%. The digital workflow linked each alert to a required action field covering repeat measurement, caregiver counseling, scheduled return, referral to Puskesmas, or documented clinical review. This design converted alerts into trackable tasks rather than passive notifications. The result is consistent with the broader concept of growth monitoring and promotion, in which measurement must be connected with counseling and action (Moyo et al., 2023). Kiros et al. (2023) also emphasized that utilization of growth-monitoring services creates opportunities for nutrition education and early identification of childhood problems. For Posyandu, the practical implication is that dashboard performance should be judged not by the number of alerts generated but by whether alerts produce.

Attendance regularity remained a major determinant of successful early detection. Children with at least four consecutive simulated monthly visits were more likely to have interpretable growth trajectories and timely follow-up than children with intermittent attendance. Digital reminders increased the modeled proportion of scheduled return visits, but they could not fully compensate for prolonged absence. Studies from different community settings show that growth-monitoring utilization is influenced by maternal knowledge, education, facility access, and contact with maternal and child health services (Teklemuz et al., 2023; Upadhyay et al., 2024). Consequently, a digital Posyandu strategy should combine reminders with community outreach, home follow-up when appropriate, and counseling about why repeated measurement matters. Digitalization strengthens continuity only when families remain connected to the service.

The simulation also demonstrated the importance of measurement quality assurance. Approximately 4.2% of initially entered records triggered plausibility checks because of extreme month-to-month changes, inconsistent dates, or values outside expected ranges. After simulated remeasurement, most were corrected before nutritional-status classification. This safeguard prevented erroneous data from becoming persistent electronic records and generating inappropriate referrals. The lesson is that digital precision must not be confused with measurement validity. WHO growth assessment depends on accurate weight, length, height, age, and sex information. Kebede et al. (2022) found variation in health-worker growth-monitoring practice, indicating that technical training remains essential. A strengthened digital system should therefore incorporate calibration schedules, measurement checklists, competency refreshers, and prompts to repeat implausible values before automated interpretation is accepted.

Caregiver-facing communication was modeled as a core component rather than an optional feature. The digital interface translated complex z-score outputs into simple trajectory graphics and standardized counseling prompts while preserving professional explanation by cadres and health workers. This approach is important because caregivers may not understand the significance of a single anthropometric category or the need for repeat assessment. Teklemuz et al. (2023) reported a strong relationship between maternal knowledge and growth-monitoring utilization, while Kiros et

al. (2023) highlighted the educational role of growth-monitoring services. In practice, digital visualization should be designed for comprehension rather than technical display. Color coding, plain-language explanations, and clear next steps can support shared understanding, but culturally appropriate counseling remains necessary to avoid anxiety, stigma.

The proposed model strengthened coordination between community cadres and Puskesmas personnel by creating a shared referral queue. High-priority alerts were visible to authorized primary-care staff, while cadres could see whether a referral had been received, assessed, or scheduled for further review. This closed-loop design addresses a common weakness of community screening programs: detection may occur without confirmation that the child reached the next level of care. Upadhyay et al. (2024) showed that access and service-related factors influence utilization of growth-monitoring and promotion, suggesting that information continuity should be accompanied by accessible clinical pathways. Digital referral tracking can improve accountability, but it cannot solve shortages of staff, transport barriers, or unavailable nutrition services. System strengthening therefore requires organizational agreements alongside technical.

The simulated usability assessment indicated high acceptance among hypothetical cadre and primary-care users, particularly for automatic calculations, longitudinal graphs, and prioritized worklists. Nevertheless, users identified connectivity, device sharing, login complexity, and fear of incorrect data entry as potential barriers. These concerns are consistent with digital-health implementation principles in which usability, infrastructure, and workforce confidence shape adoption. A Posyandu system should therefore support offline-first data capture, synchronization, simple navigation, and role-specific interfaces. Training should include not only button-level operation but also interpretation of alerts and procedures for correcting errors. Technology that increases documentation burden may be abandoned even when analytically sophisticated. The strongest implementation model is consequently one that reduces duplicate work, aligns with existing service routines, and provides immediate value.

Equity analysis is essential because digital transformation can unintentionally advantage families who already have better connectivity, devices, literacy, and access to services. The strengthened model therefore treats caregiver messaging as supplementary to in-person Posyandu engagement rather than a prerequisite for receiving care. Families without smartphones can receive printed summaries or cadre-mediated reminders, while the health-worker application can operate offline. Evidence on growth-monitoring utilization indicates persistent associations with education, access, and socioeconomic conditions (Teklemuz et al., 2023; Upadhyay et al., 2024). Digital Posyandu should be evaluated not only for average efficiency but also for whether vulnerable children remain visible. Equity-sensitive indicators could include missed-visit recovery, referral completion by geographic area, language accessibility, and differences in detection performance across socioeconomic groups. This

Data protection emerged as an important governance requirement because longitudinal child-health records contain identifiers, anthropometric histories, referral information, and potentially sensitive family data. The proposed architecture limits access according to role, records user activity, encrypts synchronized data, and separates operational identifiers from analytic datasets. These controls are necessary because greater interoperability increases both clinical utility and the consequences of unauthorized access. Digital Posyandu governance should specify who may view, edit, correct, export, and retain records, as well as procedures for device loss and account termination. The principle of data minimization is particularly relevant: only information necessary for growth monitoring, referral, and continuity should be collected. Trust is a functional requirement, because caregivers and community workers are less likely to support.

From a prevention perspective, the digital model reframes Posyandu data as a trigger for graduated intervention. A mild but persistent downward trajectory may prompt remeasurement and feeding assessment; a confirmed abnormal indicator may require counseling and shorter follow-up; severe or clinically concerning findings may trigger immediate referral. This tiered approach reduces the risk that every alert is treated identically and helps prevent alert fatigue. Growth-monitoring literature emphasizes that the purpose of surveillance is action, not merely classification (Moyo et al., 2023). Sihotang et al. (2023) further showed that childhood stunting has multiple determinants,

meaning that digital detection should open a pathway to contextual assessment rather than imply a single nutritional cause. Decision support should therefore guide professional reasoning without replacing.

The simulated multivariable analysis suggested that exposure to the digital workflow was associated with higher odds of timely documented follow-up after adjustment for age, attendance, baseline risk, and site. Because these data are synthetic, the association must not be interpreted as a real-world causal effect. Its value is methodological: it demonstrates measurable outcomes for a future prospective evaluation. A field trial could compare Posyandu clusters using standardized equipment and training, evaluate detection sensitivity and referral completion, and assess caregiver and workforce experience over several months. Real-world research should also examine unintended consequences, including over-referral, false reassurance, duplicate data entry, and unequal adoption. Such evaluation would move the discussion from technological feasibility toward evidence about clinical usefulness, implementation effectiveness, cost, and.

Overall, the results support a systems interpretation of digital Posyandu strengthening. Improvements were greatest when electronic recording, automated interpretation, trajectory analysis, reminders, referral tracking, and professional review operated as one connected workflow. A standalone application that merely digitizes a register would capture only a fraction of this value. The evidence from digital growth monitoring (Thaventhiran et al., 2023), real-time z-score computation (Mendon et al., 2024), and contemporary growth-monitoring utilization studies (Kiros et al., 2023; Upadhyay et al., 2024) collectively supports integration of data quality, interpretation, and action. For Indonesia, the next step is rigorous field validation with interoperable national systems, explicit governance, cadre-centered design, and equity safeguards. The goal should remain earlier recognition and coordinated intervention, not digitalization for its.

CONCLUSION

This study demonstrates, through a transparent simulated comparison, how a strengthened digital Posyandu system could transform routine growth monitoring into an early-intervention workflow. Automated anthropometric interpretation, longitudinal visualization, data-quality checks, reminders, and referral tracking improved modeled record completeness, classification consistency, detection speed, and documented follow-up. The central implication is that digitalization should connect measurement with action. Electronic recording alone is insufficient if abnormal trajectories remain unreviewed or referrals are not completed.

Implementation should prioritize measurement competency, interoperability with Puskesmas and national health-information systems, offline functionality, role-based data access, privacy protection, and interfaces that cadres can use efficiently. Caregiver communication should remain inclusive for families with limited devices or digital literacy. Digital alerts must support, rather than replace, clinical and nutritional judgment because growth disorders can reflect multiple biological, nutritional, infectious, social, and measurement-related causes. Equity and trust should therefore be treated as core performance dimensions alongside technical accuracy.

Future research should validate this model using prospective field data from diverse Posyandu settings, standardized anthropometric procedures, appropriate ethical approval, and sufficiently long follow-up to measure referral completion and child outcomes. Cluster-based implementation studies could examine effectiveness, cost, workload, usability, false-alert rates, and disparities in access. Such evidence is needed before causal or population-level conclusions can be made. If carefully governed and integrated into primary healthcare, digital Posyandu systems have strong potential to shift child growth surveillance from delayed documentation toward earlier recognition, coordinated assessment, and timely preventive care.

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