Jurnal Teknokes
Homepage: teknokes.org; Vol. 19, No. 1, pp. 001-013, March 2026;
e-ISSN: 2407-8964
p-ISSN: 1907-7904

RESEARCH PAPER
OPEN ACCES

Child Growth and Development Monitoring in the Digital Era: A Systematic Review of Mobile and Digital Health Applications in Indonesia

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ABSTRACT

Monitoring child growth and development is essential for improving early childhood health outcomes and preventing stunting; however, monitoring systems in Indonesia remain fragmented and largely focused on anthropometric data. This study synthesizes evidence on digital applications developed between 2020 and 2025 to support child growth and developmental monitoring in Indonesia. Following PRISMA guidelines, 18 studies were identified from national and international databases and appraised using the JBI checklist. The review examined application characteristics, monitoring functions, design quality, user experience, and their contributions to parenting and developmental stimulation. Findings show that most applications prioritize physical growth tracking, while only a minority integrate assessments of cognitive, motor, and socio-emotional development. Thematic synthesis identifies three major gaps: limited incorporation of holistic developmental frameworks, suboptimal interface and interaction quality, and insufficient evidence-based educational content to support sustained caregiver engagement. Although most systems demonstrate high functional performance and methodological quality, interoperability with regional health information networks remains weak, and long-term user engagement is inconsistently documented. Contextual factors influencing these patterns include variability in digital literacy, infrastructural disparities across regions, and the technical challenges of digitizing developmental screening tools. The increasing use of Agile and RAD development approaches indicates potential to improve adaptability, usability, and iterative system refinement. This review underscores the need for integrated, family-centered digital platforms supported by national policy, capacity-building initiatives, and standardized developmental assessment protocols. The synthesized insights provide a foundation for guiding future system development, with interoperability, user-centered design, and equitable access as core principles for strengthening Indonesia's digital child-health monitoring ecosystem.

PAPER HISTORY

Received January 02, 2026
Revised January 16, 2026
Accepted January 30, 2026
Published March 17, 2026

KEYWORDS

Child growth monitoring;
Child development assessment;
Digital health app;
Mobile health;
Stunting prevention

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I. INTRODUCTION

Monitoring child growth and development plays a central role in preventing early childhood health risks, including stunting, during the first 1,000 days of life [1], [2], [3]. Child monitoring encompasses two complementary dimensions: physical growth, commonly assessed through anthropometric indicators [4], [5], [6], and developmental progress involving cognitive, motor, socio-emotional, and adaptive behaviors [7], [8], [9]. Despite their importance, community-level monitoring in Indonesia remains highly fragmented and largely reliant on manual documentation in child health books (KIA), which are vulnerable to loss, incomplete recording, and limited interoperability with national health information systems [10], [11]. This mismatch between policy expectations and on-the-ground implementation creates structural limitations in achieving comprehensive early childhood surveillance [12], [13]. Global digital health frameworks, such as the WHO Digital Health Intervention (DHI) classification, emphasize that digital tools should not only support data recording but also enable decision support, tailored education, interoperability, and caregiver empowerment [14], [15] [16]. However, compared with these global benchmarks, Indonesian digital applications exhibit a narrow functional focus primarily on physical growth and limited integration of developmental screening or interactive health education components. These gaps reflect deeper systemic constraints, including technical challenges in digitizing developmental assessments, variation in digital literacy among caregivers and health cadres, and infrastructural

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DOI: https://doi.org/10.35882/teknokes.v19i1.128

disparities between urban and rural regions [17], [18], [19], [20].

Although several digital applications have been developed in Indonesia, most studies examining them employ heterogeneous designs, inconsistent evaluation metrics, and limited theoretical grounding [21], [22], [23]. Many applications embed features aligned with family-centered monitoring principles, yet the conceptual basis of "family-centered care" remains implicit and insufficiently defined in existing literature. Similarly, while digital innovations are aligned with Indonesia's ongoing Health System Transformation, particularly the drive to strengthen primary care and achieve Satu Sehat interoperability, current applications rarely demonstrate strong policy alignment or systematic integration with the national e-health architecture. Existing reviews tend to focus on technical aspects of individual applications or describe usability testing without synthesizing broader patterns, theoretical implications, or systemic challenges [24], [25], [26]. Furthermore, few reviews explicitly address methodological gaps, such as inconsistencies in developmental domains assessed, the absence of standardized UI/UX evaluation frameworks, or the lack of evidence-based educational content. This highlights the need for a rigorous synthesis that integrates technological, behavioral, and policy perspectives to better understand the current landscape of digital child-monitoring tools [27], [28], [29], [30], [31]. Accordingly, this study conducts a PRISMA-guided Systematic Literature Review (SLR) to: (1) identify characteristics of digital child growth and development monitoring applications in Indonesia; (2) examine the features and functions supporting stunting prevention; (3) evaluate system design and user experience quality; and (4) explore the role of digital tools in supporting family-centered monitoring and developmental stimulation. The novelty of this review lies in its integration of multidisciplinary perspectives on digital health, developmental science, behavioral theory, and health policy to provide a holistic understanding of Indonesia's digital child-health ecosystem. This synthesis aims to inform future development of integrated, user-centered, and contextually grounded platforms that strengthen early childhood monitoring across diverse communities.

The remainder of this article is structured as follows. Section II describes the methodology of the systematic literature review, including the search strategy, eligibility criteria, and quality appraisal process. Section III presents the review results, covering application characteristics, functional features, design quality, and thematic findings. Section IV discusses the results in relation to existing digital health frameworks, family-centered care principles, and policy implications. Finally, Section V concludes the article by summarizing key insights and outlining directions for future research and system development.

II. MATERIALS AND METHOD

This study employed a Systematic Literature Review (SLR) guided by the PRISMA 2020 statement to ensure methodological transparency, rigor, and standardization. The review protocol consisted of predefined eligibility criteria, structured search strategies, screening procedures, quality appraisal stages, and a clearly articulated synthesis approach. Although the protocol was not registered in PROSPERO, this decision aligns with PROSPERO's prioritization of clinical intervention reviews, whereas the present study focuses on national-level digital health applications. A complete PRISMA checklist and supporting materials are provided in the appendices.

A comprehensive literature search was conducted across international databases (Scopus, PubMed, ScienceDirect), broad-index repositories (Google Scholar), and national databases (Garuda and DOAJ Indonesia) to capture diverse sources of evidence. Boolean search strings were developed systematically, combining keywords related to child growth, developmental monitoring, digital health applications, and the Indonesian context. These search strings were adapted for each database to ensure sensitivity and specificity, and the complete set of strings is presented in Appendix A. The search was conducted between February and December 2025. Eligibility criteria were determined a priori. Studies were included if they focused on digital applications for child growth and/or development monitoring in Indonesia, were published between 2020 and 2025, were written in Indonesian or English, and were available in full-text form. Eligible study designs included quantitative, qualitative, mixed-method research, prototype testing, and program evaluations. Exclusion criteria encompassed non-empirical works (e.g., commentaries, conceptual papers), studies unrelated to growth or developmental monitoring, research conducted outside Indonesia, and articles without complete full-text access. Detailed inclusion and exclusion criteria are listed in Appendix B.

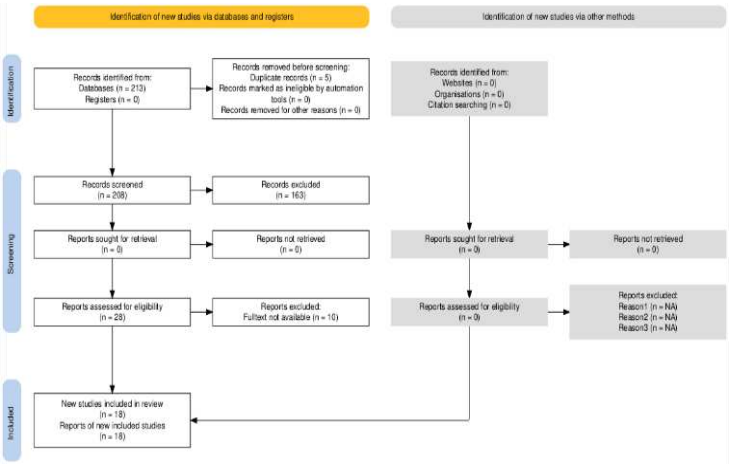

Fig. 1. Flowchart PRISMA

All search results were exported into EndNote for deduplication. Two independent reviewers screened titles and abstracts based on the predefined criteria. Prior to full screening, a calibration exercise using 20 sample articles was conducted, yielding a Cohen's κ coefficient of 0.87, indicating strong agreement between reviewers. A full-text assessment was also conducted independently, with

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p-ISSN: 1907-7904

discrepancies resolved through discussion or adjudication by a third reviewer. **Fig. 1** shows the study selection process, which is illustrated in the PRISMA flow diagram [24], [32], [33], [34], [35].

Data extraction used a standardized form that was developed and piloted prior to application. Extracted data included bibliographic details, study design, population characteristics, application features (growth monitoring, developmental domains, educational content), system design attributes (platform, UI/UX, interaction quality), evaluation approaches, and reported outcomes or implementation challenges. Extraction was conducted independently by two reviewers, and disagreements were resolved through consensus. Quality appraisal was performed using the Joanna Briggs Institute (JBI) Critical Appraisal Tools tailored to the specific study design. Each study was scored according to the JBI criteria, with responses coded as "Yes," "No," or "Unclear," and then converted into percentage scores. Studies scoring ≥75% were categorized as having acceptable methodological quality [36], [37], [38], [39], [40], [41]. In addition to numerical scoring, a narrative appraisal of potential risks of bias was conducted, encompassing selection bias, measurement bias, and reporting bias. Considerable heterogeneity was observed across studies in terms of sample size, developmental domains assessed, evaluation methods, and software development approaches, precluding meta-analysis and supporting the use of narrative synthesis.

Data synthesis employed a thematic approach supported by NVivo 12. The analytical process included open coding of extracted data, grouping codes into thematic clusters (e.g., functional features, developmental assessments, user experience, integration challenges), and iterative refinement to identify cross-study patterns and divergences. Quantitative trends, such as the distribution of growth versus developmental features, were summarized descriptively to complement qualitative synthesis. As this review used secondary data from published literature, ethical approval was not required. However, ethical and equity-related considerations reported in the primary studies, particularly regarding data privacy, informed participation, and digital access disparities, are addressed in the Discussion section. This methodological approach ensures a comprehensive, transparent, and contextually grounded synthesis of digital child monitoring applications in Indonesia.

III. RESULTS

A. General Study Characteristics

Eighteen studies met the inclusion criteria and demonstrated consistently high methodological quality, with JBI Critical Appraisal scores ≥90% (Table 1). These studies included R&D designs (72.2%, n = 13), quantitative evaluations, and qualitative analyses, forming a strong evidence base for synthesizing the current landscape of digital child growth and development applications in Indonesia. Most studies were conducted in Java (61.1%) and Kalimantan (22.2%), primarily in posyandu, daycare centers, and primary healthcare facilities, reflecting the rapid rise of digital health initiatives following the COVID-19 pandemic [3], [16], [42].

Table 1. Article Quality Assessment with JBI Critical Appraisal Checklist

No	Author, Year	Study Type	Score (%)	Quality Category	Key Remarks
1	Febriyanti et al., 2021	R&D	100	High	RAD method and comprehensive user testing. Lacks in-depth analysis of long-term usage sustainability.
2	Abdillah and Sancoko. 2024	R&D	90	High	Mobile web application with 100% functional success test results. Reliable system, but user experience (UX) not thoroughly evaluated.
3	Terttiaavini, 2024	R&D	100	High	Agile method implementation produces an adaptive system with Random Forest-based predictive features. Field effectiveness testing not yet conducted.
4	Kirana et al., 2024	R&D	100	High	Strong expert validation and KPSP integration aligned with IDAI standards, but tested on a small population with no long-term data.
5	Pasha et al, 2023	R&D	90	High	Effective Extreme Programming method implementation with 96.92% functional test results. However, usability aspects remain limited and not tested across various regions.
6	Damayanti et al, 2022	Quantitative	100	High	Satisfaction study (95% very satisfied). Structured survey design with simple statistical analysis. However, sustainability aspects and potential respondent bias need discussion.

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No	Author, Year	Study Type	Score (%)	Quality Category	Key Remarks
7	Noratama Putri et al., 2021	R&D	90	High	The implementation of the PosyanduQ application successfully improved users' skills. However, requires long-term evaluation of application effectiveness and social impact.
8	Musrifah et al., 2020	R&D	90	High	Innovative Fuzzy Sugeno method improves decision-making accuracy. However, validation testing is limited to one location and does not address user experience.
9	Naufal et al, 2022	R&D	100	High	Flutter-based Healthcare Intelligence System development shows stable technical results and good API integration, but field testing and end-user response analysis not yet conducted.
10	Muttaqin et al., 2022	R&D	100	High	A functional web-based system was successfully implemented with integrated online data, but minimal data security analysis and a user digital literacy assessment
11	Irawan et all, 2025	Evaluative	90	High	Application quality evaluation with the MARS method is methodologically and comparatively strong. However, the application sample representation is limited to popular platforms.
12	Haq et al, 2024	Qualitative	100	High	In-depth visual storytelling analysis with a strong theoretical framework. However, results are conceptual without empirical user testing.
13	Puspaningtyas et al., 2022	R&D	100	High	An innovative, less paper system model in daycare integrated with childcare processes. However, effectiveness testing is not yet available.
14	Tri Rahayu et al., 2024	R&D	90	High	CATWOE and GOMS approaches are appropriate for UI analysis. Efficient UI results, but does not assess subjective user satisfaction aspects.
15	Indrayasa and Suryanti., 2023	Qualitative	100	High	In-depth descriptive study of Chai's Play application and its contribution to learning through play. Limitations in empirical data and the generalization of results.
16	Hayati et al., 2021	Qualitative	90	High	A descriptive study on parenting webinars that improve parents' digital literacy. However, without quantitative measurement and no long-term follow-up.
17	Srirahayu et al., 2024	R&D	100	High	Field testing produces strong validity, but documentation of quantitative user satisfaction results is limited.
18	Novadela et al., 2023	R&D	100	High	Interface refinement and predictive analytics features. However, full integration with regional health service systems not yet implemented.

Quality Category Criteria: High = ≥75%; Moderate=60–74%; Low = <60%.

System development methodologies varied across studies, including Rapid Application Development (RAD) (27.8%), Agile (16.7%), Waterfall (16.7%), and Extreme Programming (11.1%). These approaches were supported by various technical frameworks such as PHP MySQL, Django PostgreSQL, and Flutter [43], [44], [45], [46]. Although functional performance was generally high (90–100%), substantial heterogeneity remained in application purpose, system integration capability, and user experience quality. **Table 2.** shows a summary of methodological quality and key remarks, including strengths (e.g., predictive analytics, expert validation, functional success rates) and limitations (e.g., absence of long-term testing, limited user experience analysis, and lack of multi-regional samples). **Table 2.** shows that across all applications, anthropometric recording was universally implemented (100%), with nutritional status categorization appearing in 88.9% of systems and WHO growth chart visualization in 77.8%. However, comprehensive developmental screening, including

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e-ISSN: 2407-8964
p-ISSN: 1907-7904

KPSP or multidomain assessments, was integrated in only 22.2% of applications [47]. This pattern highlights a strong skew toward growth monitoring, with limited incorporation of cognitive, motor, socio-emotional, or adaptive domains [48], [49], [50], [51], [52], [53], [54].

Table 2. Integrated Study Characteristics and Application Features (n=18)

Characteristics /Features	Category/Type	n	%
Technology Platform	Android	11	61.1
	Web-based	4	22.2
	Hybrid (Web-Mobile)	3	16.7
Primary Monitoring Focus	Growth only (anthropometric)	10	55.6
	Development only (KPSP/screening)	2	11.1
	Integrated (Growth + Development)	6	33.3
Core Features Implemented	Anthropometric recording	18	100.0
	WHO growth chart visualization	14	77.8
	Nutritional status categorization	16	88.9
	KPSP/developmental screening	4	22.2
	Educational content (nutrition/parenting)	12	66.7
	Automatic notifications/reminders	11	61.1
	Discussion forum/consultation	7	38.9
	Predictive analytics (AI/ML)	3	16.7
System Integration	Cloud database storage	13	72.2
	Regional health system connection	3	16.7
	API integration capability	5	27.8
Geographic Distribution	Java	11	61.1
	Kalimantan	4	22.2
	Other/National	3	16.7
Functional Success Rate	90-100%	16	88.9
	<90% or Not Reported	2	11.1

Android-based monitoring systems developed using RAD showed strong potential to replace manual KIA books, offering improved data accuracy, reporting speed, and communication among midwives, cadres, and parents [44]. Waterfall-based applications also demonstrated high functional success (100%) in early risk detection [43]. Agile-based systems, such as Bunda Care, integrated Random Forest predictive analytics and achieved 100% functionality while offering developmental insights and automated reminders [46]. Digital transformation at the community level was further evidenced by innovations such as e-Posyandu, with functional success of 96.92% and user satisfaction of 82.33% [45], and ePoK, which achieved 95% cadre satisfaction [55]. Training-based implementations like PosyanduQ increased digital literacy and operational ability among cadres [56]. Machine-learning approaches, such as Fuzzy Sugeno, supported early growth-risk detection with an accuracy rate of 72% [57]. Additional systems, such as the Flutter-based HIS, demonstrated stable API connectivity and integrated maternal–child monitoring [58].

User-experience and design quality varied substantially. MARS evaluations revealed high engagement and information quality in applications such as Asianparent and Tentang Anak, whereas PSG Balita and Astuti scored lower due to limited interactivity and weaker content credibility [59]. Visual storytelling analysis of PrimaKu suggested that monotonous narrative flow reduced long-term motivation [60]. A less paper-based daycare system integrated developmental checks, growth assessment, and daily reports, enhancing two-way communication and operational efficiency [61]. Other prototypes, including those evaluated using CATWOE and GOMS, demonstrated strong interface efficiency with task completion times averaging 42 seconds [62]. Developmental screening applications validated by experts [57], [63] further highlighted trends in usability improvement. Experimental comparisons also showed the superiority of digital applications over manual documentation. For example, Rajabalita delivered 80% timely information compared with 64% in conventional KIA books [64]. Digital applications increasingly function as parenting tools supporting family participation. The less paper daycare model provided daily reports and educational features that strengthened collaboration between parents and caregivers [65]. Bunda Care offered curated content, real-time notifications, and nutrition information to improve family involvement in developmental monitoring [46]. Learning-through-play applications such as Chai's Play provided cognitive, sensory, and emotional stimulation resources tailored for digitally adept millennial parents [66]. Social-support features including discussion forums available in Baby

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Care and similar applications facilitated parental interaction, peer learning, and shared problem-solving [62]. Training using Google Family Link improved parents' ability to regulate children's device use and digital exposure [67], [68]. A synthesis of eighteen studies indicates rapid advances in digital monitoring applications in Indonesia, particularly in anthropometric recording accuracy, functional performance, and usability, driven by RAD, Agile, and Waterfall development approaches. However, significant systemic gaps remain:

1. Fragmented integration of developmental domains, with only a minority of applications offering comprehensive screening.
2. Limited interoperability with regional health systems, despite high technical performance [68].
3. Variation in UI/UX and educational design, affecting engagement and sustainability.
4. Persistent digital literacy and connectivity disparities, especially in rural areas.

Collectively, these findings indicate that digital applications have contributed meaningfully to improved growth monitoring and parental involvement. However, the ecosystem remains constrained by technical, infrastructural, and educational limitations that require coordinated national strategies, enhanced interoperability, and standardized frameworks for developmental monitoring.

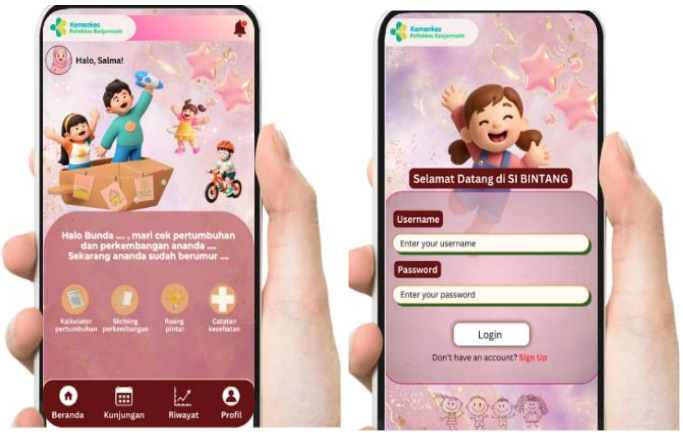

Fig. 2. Initial Display (Login Page) and SI BINTANG Homepage

Fig. 2. Initial login interface and homepage layout of the SI BINTANG prototype. These displays illustrate the conceptual design of an integrated digital platform for monitoring child growth and development, including menu navigation, interactive features, and access pathways for caregivers and health workers.

IV. DISCUSSION

A. Integration Challenges Between Growth and Developmental Monitoring

This systematic review highlights key structural patterns and persistent gaps in the development of digital applications for monitoring child growth and development in Indonesia. Although previous sections summarized specific features and performance indicators, this discussion interprets the broader conceptual implications, methodological characteristics, and systemic challenges influencing the effectiveness and sustainability of these digital solutions.A consistent finding across the reviewed studies is the strong emphasis on anthropometric monitoring, contrasted with the limited integration of developmental screening tools such as KPSP [47]. This disparity may reflect several underlying factors. First, anthropometric data are simpler to capture, standardized, and widely supported by WHO growth charts, whereas developmental assessments require multidimensional items, observational evaluation, and normative reference data [69], [70], [71]. [4], [72] [44], [45]. Third, cultural norms and limited awareness regarding socio-emotional development may contribute to lower demand for comprehensive digital developmental assessments, especially in community-based settings such as posyandu [73], [74], [75], [76], [77] [78], [79]. These patterns indicate that fragmentation in monitoring is not merely a technical problem; it reflects broader systemic limitations, including resource availability, digital literacy, and uneven understanding among caregivers and health workers [80], [81], [82], [83], [84].

B. Digital Divide and Contextual Barriers in Indonesia

The regional distribution of studies, heavily concentrated in Java, reveals an uneven digital landscape. Areas with limited internet stability, lower digital literacy, or fewer trained cadres encounter challenges in adopting interactive applications [85], [86], [87] . The reliance on Android-based platforms (61.1%) further underscores dependence on personal mobile devices rather than integrated national systems. These findings align with global evidence suggesting that digital health innovations often exacerbate existing social inequities unless accompanied by supportive infrastructure and capacity-building programs [88], [89], [90]. The limited interoperability with district health systems [68] reinforces the structural fragmentation of Indonesia's health information architecture. Without standardized APIs, shared data dictionaries, or unified maternal-child digital ecosystems, applications remain siloed prototypes rather than scalable national tools [91], [92], [93]

C. User Engagement, Digital Literacy, and Technology Acceptance

Although short-term usability scores were generally positive, sustained user engagement was rarely assessed [19], [94]. This gap is critical: the global digital health literature emphasizes that user retention depends on iterative feedback loops, personalization, and perceived usefulness elements consistent with models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT). Applications that incorporated interactive

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features, storytelling, or tailored educational content, such as PrimaKu [60] or family-support tools [66] demonstrated a stronger potential for engagement. However, the predominance of static educational materials and linear navigation flows may limit intrinsic motivation for long-term use. This observation implies that digital literacy interventions should accompany application deployment. Training, mentoring, and community support as shown in PosyanduQ [56] and webinar programs [67] improve competence but require sustained reinforcement.

D. Cross-Disciplinary Implications for Public Health, Education, and Informatics

The findings demonstrate that digital growth monitoring is no longer a purely clinical process: it intersects with behavioral science, parenting psychology, early childhood education, and human-computer interaction. For example: predictive analytics using machine learning [46], [57] expand the role of informatics in early detection; parenting education modules enhance family engagement, aligning with early childhood pedagogy; UI/UX methodologies such as GOMS and CATWOE [62] connect computational efficiency with human-centered design. This multidisciplinary nature requires a coordinated framework aligning technical, educational, and behavioral components to ensure equitable adoption and sustainable use.

E. Policy Alignment and National Health System Readiness

Despite Indonesia's ongoing health digitalization agenda, the reviewed applications showed minimal integration with national health platforms [95]. Given the Ministry of Health's commitment to SATUSEHAT and strengthened primary care digital services, standardized data structures, interoperability guidelines, and certification processes will be crucial for scaling these applications [96], [97], [98]. The absence of explicit policy alignment within most applications suggests an opportunity for greater collaboration between developers, policymakers, and public health practitioners [99], [100], [101], [102]. Such alignment would clarify governance models, data protection requirements, and standards for integrating growth and developmental indicators into national dashboards.

F. Study Quality, Bias, and Limitations in the Reviewed Literature

Even though all included studies met high JBI quality thresholds, heterogeneity across study designs, such as limited sample sizes [47], single-site testing [65], or absence of long-term evaluation [56] reduces comparability. Risk of bias arises from: self-reported satisfaction measures, selective reporting of technical success, lack of regional representativeness, and insufficient measurement of behavioral outcomes.

These methodological patterns highlight the need for more rigorous mixed-method evaluations, triangulated data sources, and longitudinal designs.

G. Conceptual Implications for Future System Development

The evidence indicates that digital monitoring systems require more than technological robustness: they must embed developmental frameworks, family-centered design principles, and population-level equity considerations. While SI BINTANG is referenced as an illustrative conceptual model, it should be understood as an ongoing prototype rather than a validated intervention.

V. CONCLUSION

A systematic review of eighteen articles reveals that while digital technology has significantly improved efficiency, accuracy, and accessibility of child growth monitoring in Indonesia, most applications focus on physical growth and nutritional status with limited comprehensive developmental integration (cognitive, motor, social-emotional, adaptive behavior), suboptimal interface design, low user engagement, and insufficient contextual educational content. Success depends on interactive, educational, and visually appealing user-centered design, with applications that provide positive user experiences, adaptive notifications, and evidence-based content, which are more effective at increasing participation and strengthening early detection. The synthesis of eighteen studies reviewed indicates a consistent pattern in which most digital child-monitoring applications emphasize anthropometric indicators, whereas fewer studies incorporate multidimensional developmental assessments. Across the literature, applications with interactive features, adaptive feedback, and evidence-based educational content demonstrate higher usability scores and greater reported acceptance among caregivers and health cadres. However, long-term engagement outcomes, interoperability performance, and population-level effectiveness remain insufficiently reported, limiting cross-study comparability and generalizability. These findings provided the conceptual foundation for SI BINTANG, a web platform comprehensively integrating growth and development monitoring connected directly to regional health systems, aiming to strengthen family-cadre-health worker collaboration in supporting optimal child development and contributing to Indonesia's national stunting prevention program, with future research recommended to evaluate its field effectiveness, acceptability, sustainability, scalability, and impact on community-level child health service quality.

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Jurnal Keperawatan Padjadjaran, vol. 9, no. 3, pp. 190–198, 2021, doi: 10.24198/jkp.v9i3.1722.

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DOI: https://doi.org/10.35882/teknokes.v19i1.128