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Development and Validation of a Mobile Application for Early Childhood Nutrition Monitoring: A Multisensor-Based Non-Contact Anthropometric System

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Abstract

Proper early childhood nutrition or a lack thereof is paramount in Indonesia because stunting—their most common outcome—can become both physically and mentally irreversible. Parents all too often find difficulty in the accurate and consistent monitoring of their children's nutritional status, which can prevent early identification of deficiencies. This study presents the Multisensor-Based Non-Contact Anthropometric System, a mobile application designed to monitor nutritional status of under-five children using multisensory images. The research had five phases, which are based on a modified ADDIE model (Analysis, Design, Development, Implementation and Evaluation). Parent questionnaires highlighted key nutritional concerns, as well barriers to growth due stunting during the Analysis phase. Design- to lay down the objectives and create educational content inside of the app. In Phase 3, Production; the app was developed and then reviewed by experts in content accuracy as well as media design and instructional strategies. During the implementation phase, in Malang City were given Pretest and Postest to 15 parents as a tester of this APP about testing practically and effectively. Results showed that there were significant improvements in parental knowledge and skills to monitor child nutrition status for stunting, with average expert validation scores of 92.6% (range:75 –100) on media design, 86.25% (67–97) on material content as well as instructional design 87.28%(70 -96). The MB-NCAS app is a valid, reliable and feasible dietary assessment instrument for nutritional monitoring among preschool children. Nonetheless, the lack of tech capabilities in some geographically and/or financially constrained regions is a barrier to wider utilisation. Future research should investigate the generalizability of this app in various settings and work toward increasing technological access to maximize migrant health.

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Introduction

Stunting in Indonesia is associated with poverty and economic growth, but may also have long-term implications for cognitive development, productivity and the overall public health of society which emphasizes a need more early interventions before there important functions are fully established (Dewey & Begum, 2011; Kustanto, 2021; Rizal & van Doorslaer, 2019). Second, one needs to unpack these environmental elements as poor water and sanitation causes undernourishment and cognitive development in children

(Cameron et al., 2019). Moreover, to design successful public health programs in Indonesia addressing the root causes of stunting (low socioeconomic status and non-exclusive breastfeeding: Alam et al., (2020) and Beal et al., (2018) has a paramount importance. Meeting these problems with a combined solution will be the only way to fix health and economic futures for our children.

Severals of research also suggested that the first thousand days were crucial to preventing stunting and obtaining optimal growth (Permatasari et al., 2021). Several studies have shown that nutritional interventions can improve child health and reduce stunting frequency (Deshpande & Ramachandran, 2022; Islam et al., 2020; Sánchez et al., 2024). Promotion of breastfeeding, appropriate maternal nutrition and nutrient-dense complementary feeding for infants are examples (Badham, 2013; Vossenaar & Solomons, 2012). Despite this, in low- and middle-income countries such as Tanzania -financial constraints, cultural challenges or insufficient access to healthcare act like major barriers for several of these initiatives (Urgell-Lahuerta et al., 2021; Yafie et al., 2023). It highlights the urgency of developing novel methods to address these challenges in addition to conventional tools.

In turn, mHealth (mobile health technologies) has emerged as an area of increasing promise in relation to nutritional monitoring and stunting detection. The app Nutrimo uses real-time data to track the nutritional consumption of children that allows recommendation for a personalised diet (Permana et al., 2021). Wicaksono and Satiti (2020) found that mobile apps could help stunted children to grow faster, so the benefits can be obtained even though regular medical personnel are unable to operate during the pandemic. The rise of these successes have inspired the creation of more convenient and inclusive tools which helpparents track their kid's nutrition. While results of above apps would be promising, but they are still in developement phase and lacking core feature to detect stunting early on making them not so effective for management.

The advent of multisensor systems, in particular, has estconvinced new opportunities for growth monitoring among children. The combination of non-contact sensors with mobile applications could allow for an accurate measurement of critical anthropometric measurements, such as weight, head circumference and height (Burini et al., 2020; Conkle et al., 2018). It enables more convenient and accurate monitoring of children's growth, at home. However, this approach if particularly important when few conventional medical alternatives are available in regions under-resource for healthcare (Andrews et al., 2019). The application in multisensor technology embedded within mobile applications is an important step forward in the development of a repeatable, as well large scale solution for early stunting detection.

One of the most important factors in detecting and preventing stunting at an earlier stage is parents. Parents are more likely to prevent and treat stunting in their children, if they have necessary information and resources (Kalinda et al., 2023; Shapu et al., 2022). De Arriba Munõz et al., (2022) and Rufaindah & Patemah, (2021) posited that providing the resource for education in companion with monitoring tools via mobile apps was potential approach to increase parental awareness and involvement. It is indeed sad that parents still do not have easy tools to prevent stunting. Mobile solutions will estimate morphometric growth, in connection with state-of-the-art multisensor technology and dissemination capacity of your textbook, real-time monitoring systems, as well as field back up.

Although some improvements have been made, there are still shortcomings in the methods used for stunting detection and prevention. These capabilities demand the integration of advanced multisensor technology for precise and real-time detection to be incorporated into many existing mobile applications. Several studies call for further investigation into the proper customization of these technologies to be used in (limited-resource) settings (Prasiska et al., 2020). Additionally, many of the applications currently available are narrow in their focus and intended more for general monitoring or nutrition education than an all-encompassing user-friendly solution that parents can trust to use daily (Stania et al., 2023). These gaps must be addressed in order to create tools more commonly used and of greater impact to lower after-birth stunting (Mukodri et al., 2023).

In this direction, we developed and validated the multi-sensor-based non-contact anthropometric system (MB-NCAS) for early childhood stunting detection and nutritional monitoring. The app, called MB-NCAS combines cutting-edge multisensor technology with a user-friendly interface to help parents track the growth of their kids in real-time, measure them accurately and get personalized nutritional recommendations. While the app will monitor, it also has a roll of teaching tidbits to help them so their child wont be stunted. This innovative approach is also a great tool to revolutionize child health monitoring and involve parents in more efficient management of their children's well-being through globally implemented process aimed at reducing stunting and improving overall results of child care.

Methods

2.1. Research Design

The study is conducted through a development research framework in Ghirardini (2011). ADDIE model, with adaptations. As we can see in figure 1, the five-stage ADDIE model used in this research.

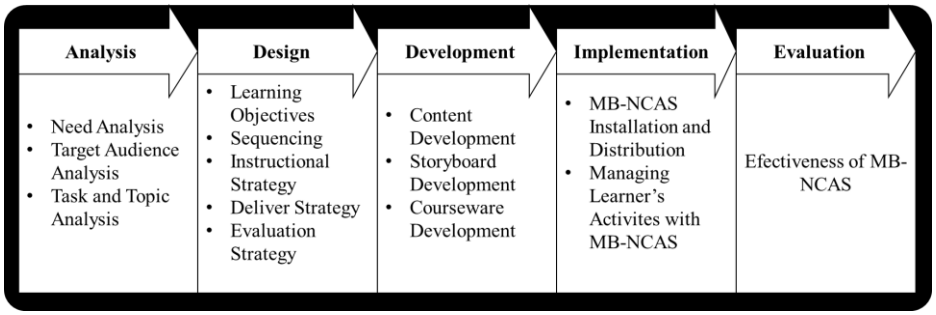

Figure 1. Research flow

Analysis was likewise divided into three main sub-phases. The first step in our **Needs Analysis** was for parents to fill out surveys. This was done with a view to understanding the issues concerning stunting and improper nutrition amongst children. Afterward, a **Target Audience Analysis** was conducted to determine the potential users of the MB-NCAS app. This process also centered around parents' qualitative insights into providing children with appropriate nutritional care, awareness of what stunting is and how to manage it, smartphone literacy and the relevance for an app on their demographics as well as internet availability and smartphone ownership. Finally, **the tasks and topic analisys** entailed in the MB-NCAS application were defined via task & topic analysis. This work concerned the generation of educational materials, quizzes, algorithms for screening

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stunting and components in any assessment that are needed to determine what a child eats.

Evaluation methods during the **design** phase to determine whether users were able to use it as intended, specification of targets for MB-NCAS application and designed materials within the program. A strategy for implementation was also established. The next phase was drafting the instruction content, story boarded and built application in apk format on MB-NCAS. After the **development** cycle ended, an expert validation testing was performed for on-confirmation of all content, media and IDs at the course level using defined checklist.

Implementation — parents installed and used the MB-NCAS app to track dietary intake of their children, and screening test for early sign on stunting. Parents also engaged in pre-posttest assessments to evaluate the effectiveness of the app, and conducted user trials during this phase. The final **evaluation** gate assessed the readiness of that application for broader dissemination. After detailed technical evaluations to check usability, reliability and functionality, the application was reworked with expert feedback as well as user's comments. We also learned from previous implementations, improving and sharpening the application.

2.2. Research Subject

This study sample and population comes from parents who reside in Malang City. In total, 30 parents from five separate districts were selected at random. The inclusion criteria were having a child aged 0 to 6 and possession of smartphones on which parents could use the app. Additionally, the study involved two content experts, two media experts, and two instructional design experts, each with relevant qualifications, such as early childhood education lecturers, educational technology experts, and nutritionists or pediatricians.

2.3. Data Collection Technique

The data collection instruments are needs analysis framework, media expert validation questionnaire, content expert validation questionnaire, Instructional design questionnaires and user questionnaire. These instruments were designed to assess various aspects of the application, such as nutritional needs, stunting detection, application design, content accuracy, ease of use, instructional strategies, user assessment, and overall user satisfaction. The details of the research instrument are explained in Table 1 below.

Table 1. Research instruments

	Aspects to be assessed	Item	Instrument Item	Scale
Material Expert Instrument	Nutrition Needs	1-5	Questionnaire	Ordinal (1-4)
	Stunting Detection	6-10	Questionnaire	Ordinal (1-4)
Media Expert Instrument	Design	1-5	Questionnaire	Ordinal (1-4)
	Content Accuracy	6-10	Questionnaire	Ordinal (1-4)
	Clarity and Ease of Use	11-15	Questionnaire	Ordinal (1-4)
	Technology requirement	16-20	Questionnaire	Ordinal (1-4)
Instructional Design Expert Instrument	Learning Objectives	1-5	Questionnaire	Ordinal (1-4)
	Instructional Strategies	6-10	Questionnaire	Ordinal (1-4)
	Learner Assessment	11-15	Questionnaire	Ordinal (1-4)

	Aspects to be assessed	Item	Instrument Item	Scale
User Instrument	Usability	1-5	Questionnaire	Ordinal (1-4)
	Reliability	6-10	Questionnaire	Ordinal (1-4)
	Functionality	11-15	Questionnaire	Ordinal (1-4)
	User Satisfaction	15-20	Questionnaire	Ordinal (1-4)

2.4. Data Analyse

For the expert validation result, descriptive analysis was applied as a data analyzing technique. Paired sample t-tests were used to compare the pretest and posttest means of data for accuracy and consistency. These are the supplementary questions and responses from the user trials of application with Parents as respondents for those. The method provided a highly detailed insight into the performance of an app-based system in tracking child nutritional status, ensuring complete data credibility and reliability.

Result

3.1. Analysis

3.1.1 Analysing Respondents

Research subjects were carefully selected for these studies and grouped by gender, parent age of diagnosis and child sex. This will assist us in comprehending the full range of demographic characteristics that may influence the efficacy of the MB-NCAS program. Further information on the respondents can be found in Table 2 below.

Table 2. Respondent Description

No	Respondent characteristics	Amount	%
1	***Gender of Parents***		
	Man	7	23,33
	Women	13	43,33
2	***Parents Age***		
	25 Years -30 Years	5	16,67
	30 Years -35 Years	11	36,67
	35 Years-40 Years	11	36,67
	>40 Years	3	10,00
3	***Child Gender***		
	Boy	11	36,67
	Girl	13	43,33

This is summarized in Table 2 where the attributes of such respondents are presented. Of the parents surveyed, 43.33% are mothers with most being between the ages of 30-40 years old. In this case, since the ratio is a stable 3:7 but $p>0.5$ (Female), there might not be any statistically significant gender difference among children ($p = 0.507$) even though nested model predicts female majority with probability of over 99%. Introduction of an MB-NCAS registration demographic profile was critical, because the demographics registered by each user inform us about who would use this application that alone providing direction as to what stories and for whom need be written.

3.2. Designing, developing, and implementing MB-NCAS systems

The design phase aimed to develop an easy-to-use, intuitive interface for the MB-NCAS utility intended for monitoring nutrition and stunting in children under five years of age. Figure 2 shows the many parts that went into this final design.

Figure 2. MB-NCAS Interface Design and Features

The Multisensor Based Non-Contact Anthropometric System (MB-NCAS) was developed for use by healthcare providers, as well as parents, to monitor stunting in children under 5 years. The app includes three key features: SensiScan (non-contact anthropometry), GrowthTrack (interval growth analysis) and HealthLog (complete medical record). We have described devices above that can be used to constantly monitor the evolution of a child and health requirements, getting reliable data over time 1) allowing for timely monitoring 2) evidence-based decision making.

The system also includes a reminder function ("RemindWell") to notify parents about scheduled medical checks as well as an extensive food guidance tool, the "NutriGuide", with personalized nutrition tips. This includes the HealthConnect and StuntAlert systems, allowing immediate access to healthcare professionals for direct consultation and real time monitoring of stunting metrics through electronic alerts on signs warranting attention as well appropriate intervention. In addition, the app feature EduParent; an educative tool for parents to learn about nutrition and stunting prevention.

The design process was optimised to create the most efficient and user-friendly interface, with expert analysis integrated at stages. This application is a comprehensive tool to defeat stunting and malnutrition in children by managing the prophylaxis with clinical service provision. In the end, being user-centered and integrating evidence-based healthy practices – and its ability to change lives in various ways also over years by focusing on human needs – places MB-NCAS at a strategic position with some power around public health opening up possible paths for an actual transformation.

3.2.1 Expert Validation

The next step is to validate the material in question with media specialists. The validation procedure involves a thorough evaluation of the design, degree of content accuracy, clarity, usability, and technological prerequisites. To obtain more comprehensive information regarding the media expert test, kindly consult Table 3.

Table 3. Media Expert Validation Results

No	Dimension	Percentage %	Note
1	Design	98%	Valid
2	Content Accuracy	93.7%	Valid

3	Clarity and Ease of Use	89.95%	Valid
4	Technology requirement	88.7%	Valid
Overall Media Expert		92.6%	Valid

Table 3 provides a concise overview of the assessment of several aspects of a media product conducted by professionals. The design achieved the highest score of 98%, followed by content correctness with a score of 93.7%, clarity and ease of use with a score of 89.95%, and technological needs with a score of 88.7%. The media product achieved an overall score of 92.6%, with all aspects considered legitimate. The next step is material expert validation. The results of the material validation can be seen in Table 4 below.

Table 4. Material Expert Validation Results

No	Dimension	Percentage %	Criteria
1	Nutrition Needs	85%	Quite Valid
2	Stunting Detection	87.5%	Valid
Overall Material Expert		86.25%	Valid

Table 4 presents the evaluation of two dimensions by material experts. The dimension of nutrition needs received a score of 85%, categorized as "quite valid," while the dimension of stunting detection scored 87.5%, categorized as "valid." Overall, the material expert evaluation averaged 86.25% and is considered "valid." The next step is material Design Instructional Expert validation. The Design Instructional Expert validation results can be seen in Table 5 below.

Table 5. Design Instructional Expert validation results

No	Dimension	Percentage %	Criteria
1	Learning Objectives	87.75%.	Valid
2	Instructional Strategies	88.35%	Valid
3	Learner Assessment	85.75%	Quite valid
Overall Design Instructional Expert		87.28%	Valid

Table 5 summarizes the evaluation of various instructional design dimensions. Learning objectives received a score of 87.75% and were deemed valid. Instructional strategies scored 88.35% and were also considered valid. Learner assessment received 85.75%, categorized as "quite valid." Overall, the instructional design expert evaluation averaged 87.28% and is considered valid. After being declared valid, the MB-NCAS application was then practically tested by the research subjects. The results of the practical test are described in Table 6 below.

Table 6. User Practicality Test

No	Dimension	Percentage %	Criteria
1	Usability	89.5%	Very Practical
2	Reliability	91.25%	Very Practical
3	Functionality	92.50%	Very Practical
4	User Satisfaction	93%	Very Practical
Overall Practicality Test		91.56%	Very Practical

Table 6 presents an evaluation of various design dimensions by User practicality. Usability scored 89.5%, reliability 91.25%, functionality 92.5%, and user satisfaction 93%, with all dimensions classified as "very practical." Overall, the design received an average score of 91.56%, also categorized as "very practical."

3.3. Effectiveness of MB-NCAS

The effectiveness of the MB-NCAS application was measured through pretest and posttest assessments, focusing on five critical dimensions related to nutrition and stunting prevention. The results of these assessments are presented in Tables 7 and 8.

Table 7. Pretest and Posttest Implementation Result

No.	Dimensions	Pretest		Posttest		Gain
		Mean	Stdev	Mean	Stdev	
1	Basic Understanding of Nutrition	2.78	0.511	4.76	0.635	1.98
2	Knowledge of Stunting	2.45	0.532	4.35	0.667	1.90
3	Menu Planning Skills	2.07	0.578	4.57	0.679	2.50
4	Monitoring Growth and Development	1.99	0.561	4.89	0.684	2.90
5	Implementation and Monitoring of Nutrition	1.98	0.521	4.78	0.681	2.80

Table 7 above shows the t-test results to determine the difference in each dimension's average pretest and post-test scores. Analysis of the t-test results showed a significant increase in each dimension after the intervention. This indicates the effectiveness of the MB-NCAS application for monitoring nutrition and stunting in early children.

Table 8. Paired sample t-test results

No.	Dimensions	t-count	t-table	Sig	Description
1	Basic Understanding of Nutrition	3.07	2.04	0.000	Significant
2	Knowledge of Stunting	2.97	2.04	0.000	Significant
3	Menu Planning Skills	3.17	2.04	0.000	Significant
4	Monitoring Growth and Development	3.12	2.04	0.000	Significant
5	Implementation and Monitoring of Nutrition	3.09	2.04	0.000	Significant

Pre- and post-test results were compared using paired t-tests, to determine if the difference was statistically significant. Pre-testing was conducted prior to implementation of the MB-NCAS intervention with all participants. A post-test was administered to participants one month after usage of the app. According to the results of t-test, significant differences were found for every aspect (both p-values are smaller than 0.05), which suggests that parents experienced a positive effect from this program on knowledge and skills in identifying proper meal pattern to prevent stunting as well as understanding how pivotal monitoring nutrition is.

The results highlight the potential of MB-NCAS as an effective program, despite anticipated challenges when delivering it to settings with low technology access. To ensure that the software functions well in different contexts and for various population subgroups, further research will need to establish its performance across a broad range of settings; this includes rural or hard-to-reach communities. Organisations must analyse ways to enable workers to adopt and engage with technology if they are going o get the most out of an enterprise app.

The results of the research show that MB-NCAS is effective. Overall, however, there are some apprehensions that must be addressed to further support the feasibility of this approach for general use (e.g. providing technology availability in remote areas). As such, further testing must be conducted in multiple conditions to ensure of the efficiency of it across all population segments.

Discussion

This trial tackled 2 fundamental problems: early childhood stunting, resulting in chronic cognitive and physical impairment and the pressing need for pragmatic indicators of nutritional status. How might technology help to enable early identification with more parent participation in the fight against stunting? This challenge led to the Multisensor Based Non-Contact Anthropometric System (MB-MCAS) mobile application. Stunting is a global problem and research in the past has emphasized that stunted children never catch up fully if intervention comes late (Beal et al., 2019; Huriah et al., 2021). Research has shown that stunting and child health outcomes could be improved through modification of maternal factors, environmental conditions, or application of early nutritional interventions (Ekholuenetale et al., 2020; Palacios et al., 2022; Yafie, 2019.). Our research builds on top of this foundation by introducing a new technical solution for addressing these challenges directly.

The key findings of this research establish that MB-NCAS application is reliable, accurate and practical for its use. An external validation of the app by experts in media, materials and instructional design provided scores between 86.25% to 92.6%. This demonstrates the excellent design and accuracy of information on this app. Moreover, results from standard user-acceptance testing indicated that 91.56% of the users expressed great satisfaction level with MB-NCAS apolication. The results of the t-test demonstrated significant improvement in all dimensions (p-value 0.000), emphasizing that the program has a big impact on improving parents understanding and skill in nutrition and stunting prevention dimension respectively. That means the MB-NCAS app is well designed and used to help parents monitor their children's diet, adjust it if needed in order to prevent stunting.

These results are in line with other work suggesting that mHealth interventions can increase engagement by parents and improve child health outcomes. In line with the positive results in MB-NCAS, other studies have shown an increase of parent understanding on child development and nutrition is able to be improved using mobile applications (Kustiawan et al., 2022). Whilst the utilization of multisensor technology in the MB-NCAS facilitates acquiring more accurate and noninvasive anthropometric information compared to conventional methodologies (Siswati et al., 2023). MB-NCAS gets above the level of just educational content that was in prior interventions and is much more broader a base for addressing stunting prevention. It does so by combining educational tools with real time monitoring and consultation from experts.

The user-centred design of the MB-NCAS program, including learning theories driving thee app's SensiScan and GrowthTrack features are likely responsible for significant increases in parent knowledge and skills post-use. As posited by Siswati et al., (2022), these four technologies are crucial in early stunting identification as they support real-time monitoring and high-quality data. Furthermore, the app was very well received by experts across multiple fields and scored highly for its validation in this population — a testament to both their confidence in it and an indication of potential public health impact. It is also essential to detect stunting very early that has long-lasting repercussions in terms of behavior, normal well as cognitive development (Chang et al., 2002). But with the help of MB-NCAS app that does continuous monitoring, stunting negative outcomes can be controlled before it impacts on child. It is worth noting that the results may not be generalisable to a wider population given the study only has parents who own smart phones and have some level of computer literacy (Robinson & Dinh, 2023). Our findings

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of strong significant correlations suggest that the MB-NCAS is likely appropriate as an application in a variety of contexts and resource settings but future studies should validate this finding, thereby strengthening its usefulness for use more broadly (Crookston et al., 2011).

Conclusion

The main purpose of this study was the development and evaluation of a Multisensor Based Non-Contact Anthropometric System (MB-NCAS) to predict stunted children at an early age, as well as body composition. The data in Table 1 clearly show that the MB-NCAS is a valid and reliable tool, with validation scores from media specialists = 92.6% material experts=86.25%, instructional design specialist=87.28 while practical score was found to be as high as 91.56%. This modest helping to manage with parenting and under-nutrition, a basic more than likely assistance mother or father observation their youngsters nutrient consumption as well the maximal of likelihood Cognitive development form child ageustomed during childhood stunting. While the findings of this study may be applicable in other contexts with more advanced technology, it is important to note that they were obtained in controlled laboratory settings. To ensure the efficacy of the MB-NCAS in a broader range of contexts, future studies should endeavor to test its efficacy in diverse settings, with particular attention to rural and remote areas. To extend the system's reach and impact on public health, future development should also prioritize improvements in technological availability and literacy.

Declarations

Author contribution statement

The majority of the work presented in this paper is the result of the writers' efforts. Yafie was the primary conceptualizer of the idea and was responsible for the analysis of the data. Pramono provided assistance in the preparation of the introduction, in addition to editing the text. The approach and templating were both developed by Sutama. The responsibility for the results section and the paper's finalization was assigned to Samawi. The research was supervised by Khairuddin, while Maulidya and Pramana were responsible for data collection.

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Data availability statement

Interested individuals may obtain the datasets used in the study by contacting the author who authored them.

Declaration of Interests Statement

All correspondence and material requests should be directed to Evania Yafie at evania.yafie@fip.um.ac.id.

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