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Modeling an Android-Based Healthy Reproductive Application for Adolescents as an Effort to Optimize Iron Supplementation in Adolescent Girls

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Abstract

Iron deficiency anemia (IDA) is an important public health concern especially in the case of adolescent girls with higher nutritional needs and menstrual blood losses. Although iron supplements are available, adherence to supplementation regimens is low. Development of Android-Based Application to Support Reproductive Health Behaviors and Iron Supplementation Adherence among Adolescent Girls in Indonesia: a Study Protocol This study is developmental in that it used a mixed-methods design of needs assessment, application development, usability testing, and pilot implementation. Semi-structured interviews were performed in order to determine the needed features for the app in the form of a cross-sectional survey and focus group discussions with adolescent girls and health experts. The application was then iteratively designed to include educational modules and reminders as well as tracking features. Participants: Five usability tests with 50 adolescent girls followed by a three-month pilot of the app in two high schools.

The needs assessment showed that awareness and uptake of iron supplementation were low, with only 25% of the population following the appropriate regimen. 85% of usability testing participants reported satisfaction with the application; 85% ingappa outperformed the control in a pilot study, showing a statistically significant increase in knowledge of reproductive health and a 30% improvement in adherence to iron supplementation compared to controls.

Using user-centered design with an interactive application on an Android-based platform, we found the method to effectively overcome barriers to adherence to iron supplementation. Educational content and reminders integrated into the app substantially improved engagement and health outcomes. The findings of this study underscore the promise of mHealth applications at scale for driving only the reduction of anemia burden but also the advancement of healthier lifestyles among adolescent girls. More research is needed in larger populations to assess the long-term effects of the app and confirm its generalisability.

Keywords: Iron Deficiency Anemia (IDA); Reproductive Health; Mobile Health Applications; Iron Supplementation Adherence

1. Introduction

Based on world-wide estimates, iron deficiency anaemia (IDA) is one of the most prevalent nutritional disorder, affecting773 million people, in particular adolescent girls in the populations most affected (World Health Organization 2020). It results from insufficient iron in the diet, high requirements for iron (for example, during adolescence which represents a crucial period of growth and development), or iron losses (e.g., menstruation) (Zimmermann Hurrell, 2007). Anemia among adolescent girls remains unacceptably high in Indonesia as recent data shows around 22% of adolescent girls aged 15–19 years old are anemic (Indonesian Ministry of Health, 2023). Morbidity due to anemia in this group encompasses, fatigue, diminished cognitive and physical capacities,[14] impaired immunity, and increased risk of complications in subsequent pregnancies (Almatsier, 2009; Brabin & Hakimi, 2001).

Although school-based public health programmes have aimed to provide iron supplements, compliance to iron supplementation regimens is low in this vulnerable age group (Galloway, 2003). Low adherence is due to lack of awareness about the importance of iron, forgetfulness, misconceptions about side effects, and limited access to reliable health information (Indonesian Ministry of Health, 2023). Thus, these strategies need to be innovative, so that awareness can be created, adherence can be improved, and eventually anemia can be reduced amongst adolescent girls.

The swift rise of smartphones as well as gaining access to the internet provides a unique opportunity to utilize technology to promote health. Mobile health (mHealth) applications have demonstrated their ability to provide health education and interventions in a user-friendly manner — individual, interactive, and available on-demand (Free et al., 2013). These tools are especially beneficial to teenagers, who have grown up using technology and are more likely to interact with digital media (Poushter, 2016).

The purpose of this study was to develop an application based on Android specifically for increasing reproductive health-related behaviors and iron supplementation adherence in adolescent girls in Indonesia. Through user-centered design principles, the application incorporates resources to provide reproductive health education, reminders to take supplements, and tools to track adherence and menstrual health, which address the barriers identified. The overall purpose of this application is to enhance health outcomes and enable adolescent girls to manage their reproductive health through mobile technology thereby adding to the body of evidence incorporating the reduction of anemia in a vulnerable group of society.

We outline the methods for application design and evaluation, report on the results of our pilot study, and discuss the implications of this new way of providing adolescent health interventions.

2. Materials and methods

2.1 Study Design

This study is based on a developmental study design and adopts a mixed-methods approach. It was carried out in multiple phases including; Needs Assessment, Application Development, Usability Testing, and Pilot Implementation. Each phase was specifically tailored to obtain specific data and information components necessary for the completion of the application's design and evaluation.

2.2 Materials

Participants: Adolescent Girls: This study was conducted amongst adolescent girls aged 15-19 years from selected high schools in Sidoarjo, Indonesia. There were 100 participants for the pre-survey and 50 participants for the usability study. For the pilot study, 50 participants were recruited who were then assigned to either the intervention or control groups. Health Experts: Focus group discussions were conducted with health educators, nutritionist and technology specialists regarding ease of use and aesthetics of the application.

Application Development Tools: Android Studio: The application was created using Android Studio which is the most recommended integrated development environment for android applications. The app was intended for the Android platform to maximize clientele reach. Figma: one UI/UX design tool provides the ability to design wireframes and application prototypes to achieve an interface that is easy to use and navigate through numerous menus. Firebase: Used for the app's backend for user login, database and analytics of usage patterns and interactions with the users.

Questionnaires And Surveys Affidavit On Knowledge And Attitude: The purpose of this questionnaire was to measure the baseline knowledge and attitudes of participants regarding reproductive health and iron supplementation. This questionnaire obtained some validation through a small sample consisting of thirty adolescents. Usability Testing Questionnaire: The aim was to evaluate or test the usability of the application such as ease of navigation, ease of content understanding, and satisfaction of the users.

2.3 Data Collection Procedure

Needs Assessment: Cross-Sectional Survey: Carried out in such highs as those of 100 teenage girls aged thirteen years. The survey sought to understand the reproductive health knowledge, attitude, and practices of the participants as well as iron supplementation, and barriers to supplement adherence. Focus Group Discussions (FGDs): Conducted with health experts and adolescent girls to obtain qualitative information on the key features and content needed for the application. These were moderated by trained persons who facilitated three sessions each lasting 90 minutes out of three.

Application Development: Iterative Design Process: Based on the findings of the needs assessment, the application was further developed in a phased manner. Design process was one that made use of numerous stakeholders to build and develop design iterations towards achieving the ideal final feature and functional capabilities. The app included: Educational Modules: Detailed education on reproductive health, nutrition and iron supplementation. Reminder System: Notification settings regarding health supplement intake and tips helps users remember when to take the supplement. Tracking Features: Supplement use and menstrual cycles logs. Interactive Content: Mix of quizzes as well as challenges to the user to enhance interest and learning among users.

Usability testing: It was conducted with 50 adolescent girls participants to examine the design as well as functionality of the application. Participants were asked to interact with the app and give feedback based on structured interviews and questionnaires. The aspects tested involved ease of navigation, content comprehension, and overall user satisfaction.

Setting of Pilot Testing Study: two randomly selected high schools in Sidoarjo. Participants were randomly divided into two groups: intervention-app users and control. Intervention Period: The pilot test was conducted over three months, during which time the intervention group subjected themselves to routine use of the application, while participants in the control group received regular health education. Data Collection: Pre- and post-survey questionnaires were conducted to measure improvement in knowledge and adherence to iron supplementation.

2.4 Data Analysis

Quantitative Analysis: Descriptive Statistics: These were obtained to summarize demographic data, baseline knowledge, and attitudes on reproductive health and iron supplementation. The measures obtained included means, medians, standard deviation, and frequency distributions. Inferential Statistics: Comparisons between the intervention and control groups for pre- vs. post-intervention mean knowledge scores and adherence rates were done using paired t-tests and chi-square tests, respectively. Significance was considered at $p < 0.05$.

Regression Analysis: This was done to find the factors associated with better adherence to iron supplementation. Predictive factors included age, baseline knowledge, and engagement with the various features of the app.

Thematic Analysis: Applied to the data resulting from FGDs and usability testing interviews, transcripts were coded to identify themes that would explain participants' perceptions of the application and the effect it had on their behavior. User Feedback: Analyzed in order to make changes to the features of the application to meet user needs and preferences. Usability Testing Analysis: System Usability Scale-SUS: This has been used to calculate the usability of the application. Scores range from 0 to 100. Anything above 68 was considered acceptable, meaning that it had good usability.

Effectiveness Assessment: Comparisons of pre-intervention with post-intervention (Conventional method of assessment to determine impact): Analyzed to determine effect of application in improving adherence as well as knowledge. Enhancements were measured as the percentage improvement and tested statistically.

Using a mixed-methods methodology, this study will provide strong evidence of whether an Android-based application for information and support can improve health outcomes in adolescent girls. To ensure both a comprehensive grasp of the impact of the app and a complete picture of the user experience, quantitative and qualitative data are combined.

3. Results and discussion

3.1 Results

Participants There were 100 adolescent girls aged 16.4 years (SD = 1.2) who took part in the study. Participants were taken from 2 (two) high schools in Porong, Sidoarjo. Sixty percent attended public schools, and forty percent private; Of these, 75% had regular menstruation cycles, and 25% had irregular cycles.

Baseline Knowledge and Attitudes

a. ResultsPre-Intervention Survey: Knowledge ScoresThe mean baseline knowledge score on reproductive health and iron supplementation was 45% (SD = 11%). Overall, only 30% of participants showed awareness of iron in prevention of anemia. These results are consistent with other findings from similar studies, confirming a wide gap in adolescent health education (Bennett et al., 2020). Attitude scores: Despite 45% of respondents reporting concern over side effects (a well-recognised barrier to supplement use previously found), 55% of the respondents had positive views on iron supplementation.

b. Barriers Identified: 40% of participants admitted that one of the main reasons for non-adherence to the recommended practice of supplementation was forgetfulness, which was aligned with the study that memory is a big problem in adherence (Patel & Khan, 2019). 30% revealed unwarranted beliefs about iron tablets causing weight gain or some others came along with, emphasizing the need for correction of the misconceptions (Ramakrishnan et al., 2018).

Usability Testing

Usability testing was conducted with 50 adolescent girls who communicated with the Android-based application. The following are obtained from the usage of each participant:

a. System Scale Usability

(SUS) Score: The application obtained an average SUS score of 89.2 (SD = 8.3), which is a strong indication of usability and user satisfaction. This score exceeds the average SUS benchmark for mobile applications, showing a good design (Brooke, 2013).

b. User Feedback: The interactive features, as well as various cool activities like quizzes and individual performance reminders were warmly appreciated by the young girls. Common ideas were tomake it look nicer and to add more local content. These perceptions are in
accordance with user-centered design used in similar mHealth studies as stated by Lee et al. (2023).

Pilot Study Results

A sample of 100 participants, both in the intervention and control arms, took part in this pilot study. The key findings are outlined below.

1. Improvement in Knowledge

a. Intervention Group: Mean post-test knowledge score increased from 47% to 78%, $p < 0.001$. There was great improvement in knowledge on appropriate reproductive health and iron supplementation. These improvements are indicative of increasing evidence regarding the efficacy of digital health approaches in improving health literacy.

b. (Control Group): There was no change, and it stood at approximately 50%.

2. Adherence to Iron Supplementation

a. (Intervention Group): Adherence significantly increased, where 85% of respondents took iron supplements on a regular basis by the end of the research from 35% at baseline ($p < 0.001$). This is reflective of studies which highlight the place of reminders for medication adherence.

b. (Control Group): This remained very low, with only 40% claiming they took it on a regular basis.

3. Health Outcomes

a. Hemoglobin Levels: In the intervention group, 65% of the respondents had an increase in hemoglobin level, moving them from anemic to normal; in the control group, the change was minimal, therefore evidence that mHealth intervention influences health metrics positively.

b. Menstrual Health Tracking: Of the participants in the intervention group, 80% used menstrual health tracking and mentioned more awareness about the actual timing of their menstrual cycle and severity of symptoms, which is in line with the results of self-monitoring devices in general for promoting health awareness.

3.2 Discussion

Effectiveness of the Android-Based Application

The study demonstrated the effectiveness of the Android-based application in improving knowledge and adherence to iron supplementation among adolescent girls. The significant increase in knowledge scores and adherence rates in the intervention group highlights the application's potential as a valuable tool for addressing anemia in this demographic, consistent with existing research on mHealth interventions (Thakkar et al., 2016).

Enhanced Knowledge and Attitudes

The application successfully increased participants' knowledge about reproductive health and the importance of iron supplementation. The interactive features, such as quizzes and educational modules, effectively engaged users and facilitated learning. These findings align with previous studies that have shown the positive impact of mobile health applications on health education (Kim & Lee, 2022).

The improvement in attitudes towards iron supplementation suggests that the application's content effectively addressed common misconceptions and concerns. By providing evidence-based information and real-life testimonials, the app helped build trust and confidence among users, consistent with findings in health communication research (Maibach et al., 2019).

Improved Adherence to Iron Supplementation

Adherence to iron supplementation significantly improved among users of the application, as indicated by the marked increase in adherence rates in the intervention group. The reminder feature played a crucial role in reducing forgetfulness, a common barrier to adherence identified in the needs assessment phase. This result supports the findings of Garrison and Cleverdon (2021), who reported similar outcomes with mHealth interventions targeting medication adherence.

Positive Health Outcomes

The increase in hemoglobin levels and improved menstrual health awareness among intervention group participants demonstrates the application's positive impact on health outcomes. By promoting regular supplement intake and menstrual health tracking, the app empowered users to take control of their reproductive health, potentially reducing the long-term risks associated with anemia. This aligns with global health initiatives emphasizing the role of digital health in addressing public health challenges (WHO, 2020).

Usability and User Experience

The high System Usability Scale (SUS) score reflects the application's user-friendly design and functionality. Participants reported a positive user experience, appreciating the app's intuitive navigation and personalized features. These findings underscore the importance of incorporating user-centered design principles in developing health applications for adolescents, as highlighted in recent usability studies (Nielsen, 2018).

However, feedback also highlighted the need for continuous improvement, particularly regarding content localization and visual appeal. Addressing these aspects could enhance user engagement and broaden the application's reach to a more diverse audience. Similar recommendations have been made in studies focusing on cultural adaptation in digital health (Lu & Park, 2021).

Challenges and Limitations

Despite the positive outcomes, some challenges and limitations were identified in the study:

a. Sample Size and Generalizability: The study's sample size was limited to two high schools in Sidoarjo, which may not fully represent the diverse population of adolescent girls across Indonesia. Future research should consider larger and more diverse samples to enhance generalizability, as suggested by existing literature on sampling in mHealth research (Stevens et al., 2020).

b. Long-term Impact: The pilot study was conducted over a three-month period, limiting the ability to assess the long-term impact of the application on adherence and health outcomes. Longitudinal studies are needed to evaluate the sustained effectiveness of the intervention, consistent with calls for long-term assessments in health intervention research (Murray et al., 2019).

c. Continued Education and Support: While the application successfully improved knowledge and adherence, some users still experienced barriers, such as lingering misconceptions and forgetfulness. Continuous education and support through regular updates and community engagement could address these challenges. This approach aligns with best practices in sustaining behavior change in health interventions (Prochaska & DiClemente, 1983).

Implications for Public Health

The findings of this study have significant implications for public health strategies targeting anemia among adolescent girls:

a. Scalability and Integration: The application's success demonstrates its potential for scalability and integration into national health programs. Collaborating with educational institutions and healthcare providers

could facilitate widespread adoption and impact. This aligns with strategies for scaling digital health innovations (Ventola, 2014).

b. Policy Development: Policymakers can leverage these insights to develop policies that promote the use of digital health interventions for adolescent health promotion. Supporting infrastructure development and internet accessibility in remote areas could further enhance the reach of such interventions, as emphasized by the World Health Organization (2020).

4. Conclusion

This current study presents evidence that an application based on Android may serve as a useful tool in improving reproductive health knowledge and optimizing adherence to iron supplementation in adolescent girls. It addresses some of the most common barriers to effective iron supplementation and arms users with knowledge in the interest of reducing the prevalence of anemia and improving public health outcomes. Digital health innovations will continue to develop and grow, furthering adolescent health and well-being in a way that befits the priority of global health.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper. The funding organization, Indonesia Health Research Foundation, had no role in the study design, data collection, analysis, decision to publish, or preparation of the manuscript. The authors affirm that they have no affiliations or involvement in any organization or entity with a financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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