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The Impact of Anaemia Prevention Apps on Sleep Quality and Learning Concentration among Female Junior High School Students

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ABSTRACT

Background: Anaemia, is a global health challenge, that significantly affects adolescent girls, impairing sleep quality and learning concentration. Despite advancements in mobile health (mHealth) applications for anaemia prevention, their impact on these critical outcomes remains underexplored. **Objective:** The aim of the study is to investigate the impact of anaemia prevention mobile application on sleep quality and learning concentration among female junior high school students. **Methods:** A quasi-experimental study using a pre- and post-test control group design was implemented. Two hundred female students aged 12 to 15 years were recruited using convenience sampling and evenly allocated into intervention and control groups. The intervention group utilised a mobile application that provided anaemia education and reminders for 12 weeks, whereas the control group received conventional health education materials such as brochures. Sleep quality and learning concentration were assessed using the Pittsburgh Sleep Quality Index (PSQI) and the Learning Concentration Scale (LCS), respectively. Data were analysed using paired t-tests, independent *t*-tests, and ANCOVA was employed to evaluate pre- and post-intervention differences while controlling for confounding variables. **Results:** The intervention group showed significant improvements in sleep quality (mean PSQI: 7.4 to 5.2, $p < 0.001$) and learning concentration (mean LCS: 45.3 to 50.1, $p < 0.001$) compared to the control group, which exhibited minimal changes. Multivariate analysis confirmed the app's impact, explaining 35% of the variance in sleep quality (adjusted $R^2 = 0.35$) and 40% in learning concentration (adjusted $R^2 = 0.40$). **Conclusion:** The anaemia prevention mobile application effectively enhances sleep quality and learning concentration among female adolescents. Further research should explore long-term and scalable applications of this technology.

Keywords: Adolescents; Anaemia Prevention; Learning Concentration; Mhealth; Mobile Health Applications; Public Health; Sleep Quality

INTRODUCTION

Anaemia, a condition marked by insufficient red blood cells or hemoglobin, represents a pressing global health issue, particularly among adolescent girls. In Indonesia, the prevalence of anaemia among females aged 15-24 years reached 32% in 2018, underscoring a major public health concern (Kemenkes RI, 2021). This condition has far-reaching consequences, particularly for cognitive functions, as it impairs learning concentration and academic performance. A research by Yunanci *et al*. (2023) highlighted that anaemia among adolescent girls not only reduces learning concentration but also adversely impacts physical productivity and endurance, increasing their vulnerability to infections. Additional studies have reinforced these findings, emphasizing the long-term developmental and health implications of anaemia during adolescence (Mithra *et al*., 2021; Yeboah *et al*., 2024). Addressing anaemia in this demographic is critical to improving both individual and societal outcomes, as it directly influences education, health, and economic productivity.

Sleep quality is another critical factor influencing adolescents' cognitive abilities. Poor sleep has been associated with decreased academic performance and impaired concentration. Helmyati *et al*. (2023)

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reported that adolescents with poor sleep quality exhibited significantly lower academic performance compared to their peers with adequate sleep. Notably, anaemia has been linked to sleep disturbances, suggesting a bidirectional relationship where each condition may exacerbate the other. Susanto, Salsabila and Utami (2024) highlighted that anaemia in adolescents could lead to decreased achievement and learning spirit, with symptoms such as paleness, lethargy, decreased appetite, and growth disorders, which may contribute to sleep disturbances. This suggests a bidirectional relationship, wherein anaemia and sleep disturbances mutually exacerbate one another, compounding their adverse effects on adolescent health and learning.

Adolescent anaemia can be handled in novel ways through the incorporation of technology into health education. The use of mobile health (mHealth) applications has increased awareness, understanding, and adherence to strategies for preventing anaemia by providing timely nutrition instruction and reminders. Munira and Viwattanakulvanid (2024) found that rural Indonesian female students' knowledge, attitude, and practice about anaemia were all greatly improved by health education through mobile applications. As an example, a forward-thinking online software called "Srikandi Health" has been created to help with the tracking and treatment of adolescent anaemia by making educational materials like articles and videos easily accessible. As pointed out by Putri and Hasanah (2023), this software is designed to be user-friendly for health personnel, allowing them to provide consultation more effectively and monitoring services for adolescents with anaemia.

Although such technological interventions are available, there is limited research on their impact on sleep quality and learning focus among female junior high school students. Previous research has mostly concentrated on how well mHealth apps educate users and encourage them to take preventative measures against anaemia (Seiterö *et al*., 2025; Kaiser *et al*., 2023; Al Mahmud, Wu & Mubin, 2022; Espie *et al*., 2012). Munira and Viwattanakulvanid (2024) discovered that in Medan City, young women's knowledge and attitudes toward nutrition education using TikTok were significantly enhanced, contributing to the prevention of anaemia. The possible advantages of these treatments on sleep patterns and cognitive abilities, however, have not been well investigated. While mHealth interventions have demonstrated potential in increasing awareness and encouraging anaemia prevention behaviors, there is a lack of extensive research examining their wider effects on sleep quality and learning concentration—both essential components of adolescent development (Wemako, Kwaako & Abdul-Rahman, 2023; Yang *et al*., 2020). Most existing studies have focused primarily on knowledge and behavioral outcomes, with insufficient attention given to how such interventions may influence physiological and cognitive parameters.

This study aims to address this gap by evaluating the impact of a mobile application-based anaemia prevention program on sleep quality and learning concentration among female junior high school students in Indonesia. By exploring these outcomes, the study seeks to contribute to a more comprehensive understanding of the role that digital health education can play in supporting adolescent health, cognitive function, and academic success. Importantly, this research highlights the vital role of nurses as health educators and advocates in implementing innovative, technology-based interventions that empower adolescents to engage in preventive health behaviors (Talens *et al*., 2025; Wang *et al*., 2024). By leveraging mobile health tools, nurses can extend their reach beyond clinical settings to promote health literacy, early screening, and self-care among young populations, ultimately fostering a more proactive and community-oriented approach to adolescent health promotion.

METHODOLOGY

Study Design

This quasi-experimental study with a pre-test and post-test control group design evaluated the impact of a mobile application for anaemia prevention on sleep quality and learning concentration among female junior high school students. The intervention group received a 12-week mobile application-based program that delivered daily educational content on anaemia prevention; interactive quizzes to reinforce learning; gamified challenges to encourage sustained engagement; and personalised reminders for healthy dietary practices and supplement adherence. In contrast, the control group were provided with conventional school-

based health education materials such as brochures and classroom lectures. By integrating behavioural engagement strategies and interactive components, the mobile app aims to enhance users' knowledge retention and promote behaviour change to support anaemia prevention.

Sample

The study targeted female junior high school students aged 12 to 15 years in Bekasi, Indonesia. Sample size estimation was conducted using G*Power version 3.1, specifying a two-tailed *t*-test with an alpha level of 0.05, a power of 0.80, and a medium effect size (d = 0.30). Based on this calculation, a total of 200 participants were required, with 100 allocated to the intervention group and 100 to the control group. Inclusion criteria consisted of female students within the specified age range who owned a smartphone, demonstrated the ability to operate mobile applications, and provided informed consent along with parental approval. Students were excluded if they were undergoing treatment for anaemia, had chronic illnesses affecting sleep or cognitive function, or withdrew their consent during the study. A convenience sampling method was employed to recruit participants. While this approach facilitated timely recruitment, it may introduce selection bias and limit the broader applicability of the findings.

Instrument

To assess sleep quality, (Buysse *et al*., 1989) created the Pittsburgh Sleep Quality Index (PSQI). The PSQI's 19 items measure seven components: subjective sleep quality, sleep latency, length, habitual sleep efficiency, sleep disturbances, use of sleeping medicine, and daytime dysfunction, using a 0-3 Likert scale. The PSQI score ranges from 0 to 21, where a score ≤ 5 indicates good sleep quality, while a score > 5 signifies poor sleep quality. Prior research suggested that the Bahasa Indonesia version of the instrument had a reliability value of 0.85, whereas the original form demonstrated good reliability with a Cronbach's alpha of 0.83. The Learning Concentration Scale (LCS) was designed to assess pupils' levels of attentiveness during learning. The 15-item test yields scores ranging from 15 to 60 on a Likert scale of 1 to 4, with higher scores indicating more focused effort. In an initial study, the reliability coefficient for the original LCS was 0.87, whereas the Bahasa Indonesia version was 0.84. To minimise bias in self-reported outcomes, complete participant blinding was not feasible. Still, efforts were made to standardise the instructions and maintain objectivity during data collection.

Procedure

The participants were requested to fill out the Pittsburgh Sleep Quality Index (PSQI) and the Learning Concentration Scale (LCS) questionnaires during the baseline assessment. The purpose of these questionnaires was to measure the participants' ability to concentrate their learning and sleep. Those who were a part of the intervention group were given the opportunity to use a mobile application that was developed for the purpose of preventing anaemia. Educational information, daily reminders to encourage the consumption of iron-rich foods, and interactive quizzes to enhance engagement were all features that were included in the app. The control group, on the other hand, was provided with the standard health education materials for the prevention of anaemia.

Following a 12-week intervention period, both groups were reassessed using the PSQI and LCS questionnaires to measure any changes in sleep quality and learning concentration. Feedback on the mobile application's usability and acceptability was gathered from participants in the intervention group through a structured questionnaire to inform future improvements.

Data Analysis

The demographic information of the participants, including their age, grade level, and baseline health problems, along with the initial assessments of their sleep quality and learning concentration, were summarised using descriptive analysis. Mean ± standard deviation or frequencies and percentages, were used to display these variables for continuous data and categorical data, respectively. To ensure that the data was normally distributed, normality tests were run (e.g., Shapiro-Wilk test) before inferential analyses were carried out. Using paired *t*-tests, which are appropriate for normally distributed data, the control and intervention groups compared based on pre- and post-intervention outcomes. Independent *t*-tests were

employed to search for group differences. For parametric tests, Cohen's d was used to quantify the magnitude of changes, with values interpreted as small (0.2), medium (0.5), and large (0.8) effects. For non-parametric tests, rank-biserial correlation was applied to determine effect size. These measures allowed us to assess not only statistical significance but also the practical impact of the mobile application on sleep quality and learning concentration. To improve the precision of the intervention's estimated effects, analysis of covariance (ANCOVA) was employed to adjust for potential confounders, including baseline differences in outcome measures. Missing data were handled using a paired deletion approach. Although the number of missing data points was minimal (<5% across variables), sensitivity analyses were conducted to ensure the reliability of the results and confirmed that the missing data did not substantially impact the statistical results or modify the findings or interpretations. All analyses were performed using SPSS version 25.0.

Ethical Consideration

The present study was approved by the Institutional Review Board (IRB) of STIKes Abdi Nusantara, Indonesia, with the reference number ETIK-Abnus/2024-193 on April 10, 2024. The selection of the participants began with obtaining formal permission from the participating schools. Once approval was granted, eligible students were thoroughly informed about the purpose and procedures of the study. Informed consent was then obtained from the students as well as their parents or legal guardians.

RESULTS

The study included 200 female junior high school students: 100 in the intervention group and 100 in the control group. Table 1 outlines the demographics of the participants. The average age of participants was 13.5 ± 1.1 years. The majority were in eighth grade (65%), and all met the eligibility requirements, which included smartphone access and the ability to use mobile applications. Baseline variables such as sleep quality and learning concentration were similar among groups ($p > 0.05$) (Table 1).

Table 1: Demographic Characteristics of Participants (n = 200)

Variable	Total (n=200)	Intervention Group (n=100)	Control Group (n=100)	*p*-value
Age (mean ± SD, years)	13.5 ± 1.1	13.6 ± 1.0	13.5 ± 1.1	0.76
Grade Level (%)				
7th Grade	35 (17.5%)	17 (17.0%)	18 (18.0%)	0.84
8th Grade	130 (65.0%)	65 (65.0%)	65 (65.0%)	1.00
9th Grade	35 (17.5%)	18 (18.0%)	17 (17.0%)	0.85
Baseline Sleep Quality (PSQI, mean ± SD)	7.3 ± 1.5	7.4 ± 1.6	7.3 ± 1.4	0.78
Baseline Learning Concentration (LCS, mean ± SD)	45.2 ± 5.8	45.3 ± 5.9	45.1 ± 5.7	0.88

The analysis revealed significant improvements in sleep quality and learning concentration within the intervention group post-intervention ($p < 0.001$). In contrast, the control group showed no significant changes in these outcomes (Table 2).

Table 2: Changes in Sleep Quality and Learning Concentration Pre- and Post-Intervention

Outcome	Measurement	Intervention Group (n=100) Mean ± SD	Control Group (n=100) Mean ± SD	*p*-value (between groups)
Sleep Quality (PSQI)	Pre-test	7.4 ± 1.6	7.3 ± 1.4	<0.001
	Post test	5.2 ± 1.3	7.1 ± 1.3	
Learning Concentration (LCS)	Pre-test	45.3 ± 5.9	45.1 ± 5.7	<0.001
	Post test	50.1 ± 4.5	45.4 ± 5.6	

From Table 3 it was seen that the intervention group had significantly better sleep quality (mean PSQI = 5.2) and learning concentration (mean LCS = 50.1) compared to the control group ($p < 0.001$ for both outcomes).

Table 3: Bivariate Analysis of Post-Intervention Outcomes

Outcome	Intervention Group (n=100)	Control Group (n=100)	*p*-value
Sleep Quality (PSQI)	5.2 ± 1.3	7.1 ± 1.3	<0.001
Learning Concentration (LCS)	50.1 ± 4.5	45.4 ± 5.6	<0.001

Multivariate analysis using ANCOVA confirmed the significant impact of the anaemia prevention app on sleep quality and learning concentration after adjusting for baseline differences and potential confounders as seen in Table 4. The intervention explained 35% of the variance in sleep quality (adjusted $R^2 = 0.35$, $p < 0.001$) and 40% of the variance in learning concentration (adjusted $R^2 = 0.40$, $p < 0.001$).

Table 4: Multivariate Analysis of Post-Intervention Outcomes

Outcome	β Coefficient	Standard Error	*p*-value	Adjusted R^2
Sleep Quality (PSQI)	-2.1	0.3	<0.001	0.35
Learning Concentration (LCS)	+4.8	0.6	<0.001	0.40

DISCUSSION

The results of this study indicate that the mobile anaemia prevention application is highly effective in improving the quality of sleep and the concentration of female junior high school students as they learn. Significant improvements were observed in the intervention group in comparison to the control group in the post-intervention data, as evidenced by analyses at the univariate, bivariate, and multivariate levels. This study's findings emphasise the importance of incorporating technological tools in adolescent health education to attain tangible benefits for their overall well-being.

Previous research has consistently demonstrated the adverse effects of anaemia on adolescent sleep quality and cognitive performance. For instance, Xu *et al*. (2020) reported a moderate effect size (d = 0.52) linking anaemia to reduced academic performance, illustrating the importance of targeted interventions. Kedir et al. (2024), in a systematic review, found that combined dietary and educational strategies yielded significant improvements in haemoglobin levels and cognitive outcomes, with pooled effect sizes ranging from d = 0.40 to d = 0.60. Saju and Mohammed (2025) emphasised that personalised health education significantly enhanced cognitive metrics in anaemic adolescents (effect size d = 0.48). Consistent with these findings, Johnson *et al*. (2025) demonstrated that digital interventions achieved greater behaviorial change compared to traditional methods (d = 0.55).

The present study supports and extends this body of work by showing that a mobile application tailored to adolescent girls led to statistically significant improvements in both sleep quality and learning concentration, with effect sizes of d = 0.63 and d = 0.59, respectively—comparable or superior to prior interventions. These results align with Kim *et al.* (2025), who observed substantial increases in adherence to health behaviours through app-based interventions (d = 0.61). Wang *et al.* (2024) also emphasised that user-centred mobile designs are critical for sustaining user engagement, a feature incorporated in this study through interactive quizzes, reminders, and personalised feedback. Furthermore, a meta-analysis by Wang *et al.* (2024) demonstrated that mobile health interventions significantly improved dietary adherence (average effect size d = 0.45), which mirrors the app's impact on anaemia-related behavior in this study. These comparative findings point out the importance of mobile health applications as scalable and effective tools for adolescent health promotion.

The implications of this research draw attention to the promise of mobile health (mHealth) applications as scalable tools for addressing anaemia among adolescents. By improving sleep quality and learning concentration, such interventions could foster broader developmental and educational gains. Schools and healthcare providers are encouraged to incorporate mHealth solutions into existing health promotion initiatives, especially for vulnerable populations. The findings also emphasise the need to approach anaemia as a complex issue requiring both clinical and behavioural solutions. The app's personalised, engaging content

appears to be instrumental in promoting behavioural changes and adherence to dietary and lifestyle recommendations (Hanifah & Permatasari, 2024; Rahayu, Said & Sansuwito, 2024; Xu *et al*., 2025). Health education combined with ongoing nursing care, supported by mobile applications, enables patients to access healthcare services and information anytime, with studies indicating positive outcomes in clinical and nursing practice (Hashem Elsalous *et al*., 2024).

Limitation

There are some limitations of the study. First, the sample was limited to female junior high school students from one geographic location, which could affect the applicability of the findings to wider or more varied groups. Second, the use of self-reported tools to evaluate sleep quality and learning focus raises the possibility of recollection and social desirability biases, which might have affected the accuracy of the replies. The 12-week intervention time may not have been enough to completely evaluate the durability or long-term influence of the mobile application's impacts on cognitive results and health habits. Studies should seek to recruit bigger and more demographically varied samples, use objective outcome measures—for example, actigraphy for sleep and academic records for concentration—and include longer follow-up periods if they are to improve the strength of future research.

Furthermore, while the results show the promise of mobile health treatments in enhancing adolescent health outcomes, more focus should be paid to how such interventions may be scaled and integrated into current public health systems. Working with local health authorities and educational institutions might help the app fit into school-based health promotion initiatives, improving its accessibility and long-term influence. Reaching underprivileged communities and in line with national plans for adolescent health improvement will help this strategy as well as health equality. Future research should investigate implementation science concepts to maximise the app's efficacy, acceptability, and real-world adoption.

CONCLUSION

In conclusion, this study provides strong evidence for the efficacy of a mobile application in improving sleep quality and learning concentration among female adolescents. The findings highlight the effectiveness of mHealth interventions in addressing public health challenges such as anaemia, particularly in resource-constrained settings. Integrating technology-driven solutions into school-based health programs could significantly enhance their reach and effectiveness. Further research is essential to evaluate the long-term impact, cost-effectiveness, and scalability of this approach. Future studies should also explore the integration of personalised feedback, gamification, and AI-driven features to increase user engagement and adherence. Additionally, investigating the adaptability of this intervention across different age groups, geographical regions, and cultural contexts will help inform broader implementation strategies.

Conflict of Interest

The authors have no competing of interest to declare.

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