

Parental Involvement in Adolescents' Healthy Eating Through Karuni Application: A Community Study in Indonesia

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ABSTRACT

Background: Female adolescents in Indonesia frequently skip breakfast and have tea after meals, which leads to iron deficiency anemia. However, only a few interventions have successfully combined parental involvement and technology to promote healthy eating.

Objective: Our hypothesis was that parents' facilitation through the KARUNI mobile app would lead to healthy eating habits in adolescent girls.

Methods: The mixed-methods study recruited 108 female adolescents aged 12-15 years from Gunungkidul, Indonesia (58 intervention, 50 control). The intervention group was instructed to use KARUNI for 21 days with parental involvement, followed by focus group discussions and interviews.

Results: In the intervention group, the frequency of breakfast consumption significantly increased ($p < 0.001$) and tea/coffee intake after meals was significantly reduced ($p = 0.001$) with large effect sizes ($r > 0.48$). KARUNI was instrumental in enhancing parental nutrition knowledge, increasing adolescents' self-efficacy, and facilitating better health communication within the family.

Conclusion: The engagement of parents through KARUNI resulted in a significant improvement in the adolescents' eating behaviors, indicating that family-centered and technology-enabled interventions can effectively tackle nutritional deficiencies in resource-poor environments.



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Introduction

Adolescence is a very significant developmental stage in life that is marked with major changes biologically, cognitively, psychosocially, and emotionally, changes that basically determine the health of the individual for the rest of their life (Bonnie & Backes, 2019; WHO, 2025). This is a very important period which opens up the possibilities of the establishment of positive behavioral patterns, acquiring of decision-making skills, and getting into the habit of a healthy lifestyle which all goes beyond childhood even to adulthood (Moore Heslin & McNulty, 2023). The health implications of the behaviors that children do when they are adolescents are really huge and such behaviors have the power to significantly affect the risks of non-communicable diseases, nutritional disorders, and mental health conditions from that time on (Marques et al., 2020).

Though the importance of adolescence in the formation of health behavior has been acknowledged, the evidence still points to the fact that adolescents do not know much about healthy lifestyles, they are quite averse to practicing health-promoting habits especially in the case of dietary behaviors (Marques et al., 2020; López-Gil et al., 2024). The situation in Indonesia where almost 46 million youths are living, the issue of public health has become more and more dreadful and the problem of low participation in clean and healthy living behaviors has become a matter that causes raising fingers (UNICEF Indonesia, 2025). The national epidemiological data show that 94.5% of teens in Indonesia do not eat enough fruits and vegetables while almost half (45.1%) of them do not do handwashing properly (Ministry of Health of the Republic of Indonesia, 2018). Among adolescent populations globally, breakfast skipping has become a very common and worrying phenomenon that recently several systematic reviews have shown that the omission of breakfast affects 10-30% of adolescents in developed countries and in developing nations the figures are even higher (Sincovich et al., 2022). This kind of behavior is full of terrible consequences for the health of adolescents because regular breakfast has been found to be associated with improved cognitive performance, better academic achievement, lowered risk of nutritional deficiencies, obesity prevention, and lessening of anemia especially in adolescent girls who are nutritionally vulnerable (Feye et al., 2023; López-Gil et al., 2024).

In addition to that, traditional dietary practices such as having tea or coffee immediately after a meal exacerbate the iron deficiency problem by drastically limiting the iron that is readily available for consumption. Iron bioavailability can be cut by over 85% due to tea, thus, pretty much to the iron deficiency anemia that is largely the cause of adolescent girls (Lazrak et al., 2021; He & Chen, 2024; Kusumawati et al., 2024). These interdependent dietary behaviors-food skipping along with behaviors that limit nutrient absorption, the combination of which creates a synergistic threat to adolescent nutritional status and long-term health, definitely need comprehensive interventions that can simultaneously address multiple behavioral targets rather than handle them separately.

The growing stream of evidence reveals that parental involvement is the main factor that determines success in health behavior interventions for adolescents. Parents are the primary role models, the gatekeepers of the household food environment, and the providers of social support that, in turn, profoundly influence adolescents' dietary choices and health behaviors (Ho et al., 2022). Systematic reviews find that children and adolescents are more likely to initiate as well as to continue healthy eating patterns, including routine breakfast consumption, if their parents exemplify such behaviors and get involved in nutrition-related activities like meal planning and food preparation (Giménez-Legarre et al., 2021; Scott et al., 2020). Besides that, parental involvement is believed to boost adolescent self-efficacy, that is, the conviction of one's ability to carry out the behavior necessary to bring about certain results, a very important psychological factor that is the basis for the continuance of the behavior change process (Kieslinger et al., 2021; Christofaro et al., 2024). In spite of this, the majority of adolescent health interventions lack sufficient provision for meaningful parental involvement, especially in resource-limited settings where the influence of family dynamics on adolescent behaviors is even stronger.

The swift spread of mobile technology has paved the way for personalized, easily scaled health interventions which were hitherto unimaginable. mHealth (mobile health) applications have certain unique advantages such as in-time behavior recording, instant feedback mechanism, easy access, and the probability of engaging both adolescent users and their parents at the same time (Benítez-Andrades et al., 2020; Marashi et al., 2024). Behavioral digital interventions have been effective in fostering new habits through the use of features like daily activity tracking, self-reflecting prompts, and social reinforcement (Zhu et al., 2024). Nevertheless, the mHealth programs that are currently in place for adolescent nutrition are riddled with various challenges. Most of these applications treat adolescents as separate entities and do not consider the family as the primary intervention unit. Furthermore, existing platforms are mainly focused on knowledge transfer and are not yet fully integrated with behavioral science principles such as the raising of self-efficacy, the theory of habit formation, and the social-cognitive mechanisms.

Very few programs have been designed to specifically deal with culturally relevant dietary behaviors, and none have been designed to tackle multiple behavioral targets within a single integrated framework (Al Shoul et al., 2024).

The major departure of the KARUNI model from the existing strategies lies in its culturally contextualized, multi-behavior focus that, at the same time, deals with breakfast habits and the culturally prevalent practices that lead to nutritional status impairment, in particular tea or coffee consumption after meals. The double-target approach here understands that adolescent eating behaviors are the part of the interconnected patterns and not the isolated ones. The intervention takes the form of a 21-day daily activity-based approach with continuous tracking and reflection components aimed at facilitation of behavioral automaticity which is in line with the contemporary habit formation theory that holds that the significant behavioral change requires long-term, structured, and supportive social contexts practice (Gardner et al., 2023, 2024). The innovativeness of this work is in its comprehensive, family-systems model which goes beyond the individual-level interventions to create a synergistic model in which the technology.

This research aimed to investigate the impact of parental involvement facilitated through the KARUNI mobile app on the healthy eating behaviors of adolescent girls with the main focus being the regularity of breakfast consumption and the avoidance of tea or coffee consumption post-meals. Furthermore, the qualitative part of the study aimed at understanding the changes in the parent-adolescent interaction regarding nutrition as a result of the behavioral.

Method

Study Design and Theoretical Framework: This research used a mixed-methods strategy with a sequential explanatory design to not only quantitatively measure the effects of the KARUNI model but also qualitatively explain the changes in behavior. The researchers chose the sequential explanatory design to best utilize the strengths of both quantitative and qualitative methods. Thus, it allowed them to measure the impact of the intervention and to substantially understand how and why the intervention worked. The quantitative part of the study was done first. It employed a quasi-experimental pretest-posttest control group design to objectively measure the changes of the adolescents' healthy eating behaviors. After that, qualitative research was carried out to collect data through Focus Group Discussions (FGDs) with adolescents and in-depth interviews (IDIs) with parents. The purpose was to gain their experiences, perceptions, and insights about the intervention and the underlying processes.

Study Setting and Context: The research took place in Gunungkidul Regency, Yogyakarta Special Region, Indonesia, from June to August 2025. Gunungkidul was a deliberate choice as the study site as it is a district that is resource-limited and rural and has a nutritional problem among adolescents which has been documented, for example, a high rate of anemia and poor dietary practices. Such a place was a perfect setting to test a family-based, technology-enabled intervention in a low- and middle-income country (LMIC) scenario, a situation where there is a great need for scalable, inexpensive health promotion strategies. All the schools that took part were public junior high schools that had almost the same socioeconomic profiles and educational infrastructure.

Population, Sample Size, and Sampling Procedure: The population targeted by the research was female adolescents aged 12-15 years living within Gunungkidul Regency, enrolled in junior high schools. The choice to study only female adolescents was determined by the fact that they are the most vulnerable group to nutritional deficiencies, especially iron deficiency anemia, which not only affects the current health condition but also the future reproductive outcomes. Sample size calculation for the quantitative phase was conducted by means of the Lemeshow formula for population proportion estimation: $n = Z^2 \times p \times (1-p) / d^2$, Z being the Z-score corresponding to the confidence level; p , the expected proportion; and d , the precision or margin of error. The minimum sample size was given as 96 based on 95% confidence level ($Z = 1.96$), expected proportion of 0.5 (to maximize sample size and, thus, ensure adequate power) and precision of 0.1. The number of participants was increased to 100 adolescents, 50 in the intervention group and 50 in the control group, to provide for possible attrition and non-compliance during the 21-day intervention period. Hence, the adolescents were equally divided between the intervention group ($n = 50$) and the control group ($n = 50$).

Purposive sampling was used to select schools that met specific criteria such as schools where students have adequate smartphone penetration, the school administration is willing to participate, and comparable baseline characteristics. Adolescents from the selected schools were invited to take part in the study through announcements made in class and during information sessions. The inclusion criteria stipulated that participants should be 12–15 years old, be students of a participating junior high school, have an Android smartphone with internet access, live with at least one parent or primary caregiver, and be willing to give informed consent (for minors, parental consent

should be provided). The exclusion criteria were that adolescents with a diagnosis of chronic illness or medical conditions that affect dietary patterns or nutritional status (such as diabetes, gastrointestinal disorders, or eating disorders), those who cannot commit for the entire 21-day intervention period, and those who did not complete baseline assessments should be excluded from the study. Non-randomly after the recruitment, participants were assigned to intervention or control groups based on their school allocation in order to reduce the risk of contamination between the groups. Thus, one school was designated as the intervention site and a similar school as the control site.

In the qualitative phase, a subsample was purposively selected to ensure maximum variation in experiences and outcomes. Three focus group discussions were held with adolescents of the intervention group. Each FGD consisted of 6-8 participants, and the participants were divided into three groups based on the degree of their adherence to the intervention (high, moderate, and low adherence groups). Besides, two in-depth interviews were held with parents who showed active engagement with the KARUNI application and whose daughters exhibited significant behavioral changes, thus, enabling the exploration of parental perspectives on the facilitators and barriers of supporting adolescent behavior change.

Intervention Description: The KARUNI (Youth Community Empowerment) model is an innovative, theory-driven, family-centered intervention delivered through a mobile application platform specifically designed for Android devices. The intervention incorporated multiple behavioral change components that were synergistically functioning to bring about a positive change in the dietary habits of adolescents via increased parental involvement and improved self-efficacy.

The primary intervention was carried out for 21 consecutive days, a period of time which was chosen based on habit formation research evidence. This research suggested that consistent practice for about three weeks can lead to the initiation of the development of automatic behavioral patterns, although complete habit formation usually takes longer. During this time, adolescents from the intervention group had access to the Daily Activity feature of the KARUNI mobile application, which was not only a tool for self-monitoring but also a reflective practice mechanism. In fact, the users were obliged to keep a record of their breakfast consumption on a daily basis (whether breakfast was consumed, time of consumption, and types of foods eaten) and also note down their tea or coffee consumption patterns after meals. Immediate visual feedback was given by the app through progress charts and achievement badges to help the users realize their positive behaviors and keep them motivated.

One of the main points of the intervention was that parents should set an example for their children as a way to increase the adolescents' belief in their own abilities. Parents were advised to not only keep an eye on and help their children with their behaviors but also, to show these behaviors themselves by, for instance, having breakfast regularly, selecting healthy foods, and refraining from drinking tea or coffee immediately after meals. The method used is in agreement with Social Cognitive Theory which relies on the idea of observational learning. This means that, to get new behaviors, people can watch and then copy those who are for them a source of learning, especially in inner social relationships, i.e., they tend to select as role models those who belong to their closest social group.

Control Group Procedures: Adolescents in the control group were given only the family-based stunting prevention booklet that was handed to their parents. They did not receive any access to the KARUNI mobile application or any of its features. The design of this study allowed for the isolation of the specific effects that are only due to the technology-enabled, parent-involved intervention components beyond general nutrition education. Control group participants underwent the same baseline and endline assessments as the intervention group to enable a rigorous comparison of behavioral outcomes. In order to adhere to ethical standards and maintain the goodwill of participants, control group families were provided with access to the KARUNI application upon completion of all post-intervention assessments. Thus, no participants were permanently deprived of a potentially beneficial intervention.

Data Collection and Instrumentation. Data collection was primarily around three time points: baseline (pretest), intervention immediate post-intervention (posttest after 21 days), and qualitative phase (following completion of quantitative assessments). The study employed different data collection methods to address the different research questions and to comprehensively evaluate the intervention.

Quantitative data on eating behaviors were obtained through a structured questionnaire designed for this study by adapting and modifying validated instruments from the previous research on adolescent breakfast habits and caffeinated beverage consumption patterns. The questionnaire focused on assessing two primary behavioral outcomes: breakfast consumption frequency and tea or coffee consumption after meals. Each behavioral item was assessed with a four-point Likert scale whose response options were: always (consuming the behavior daily or nearly

daily), often (3-5 times per week), sometimes (1-2 times per week), and never (not consuming the behavior or less than once per week). The questionnaire was pilot tested on 30 adolescents who were not part of the final study sample to determine the degree of their understanding, item clarity, and the distribution of responses. Based on the pilot study, minor changes in the wording were made to ensure that the language was culturally appropriate and age-appropriate.

Since the behavioral data were ordinal due to the use of a Likert scale, the researchers used the appropriate non-parametric statistical tests to analyze them. In particular, the Mann-Whitney U test was used to compare behavioral outcomes between intervention and control groups at posttest. This test was chosen because it does not assume normal distribution and is robust for ordinal data. The Wilcoxon signed-rank test was used to assess the within-group changes from pretest to posttest. The level of statistical significance was set at $\alpha = 0.05$. All the analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). Descriptive statistics such as frequencies, percentages, medians, and interquartile ranges were calculated for all variables. Effect sizes were determined using Cohen's d adjusted for non-parametric data. The effect size gives an idea of the magnitude of intervention effects beyond statistical significance.

In the qualitative phase, semi-structured discussion guides were prepared with reference to quantitative findings and the theoretical framework. The FGD guide for adolescents covered their experience of using the KARUNI application, perceived changes in their eating behaviors and attitudes, challenges experienced during the intervention, the role of parental support, and suggestions for improvement. The IDI guide for parents helped to explore their understanding of adolescent nutrition, before and after the intervention, the specific strategies that they used to support their daughters' healthy eating, perceived changes in family eating patterns, and their assessment of the KARUNI application's usability and value. All FGDs and IDIs were done in Bahasa Indonesia by qualified researchers who have expertise in qualitative methods and adolescent health. With the participants' consent, these were recorded and later transcribed word-for-word for the analysis.

Ethical Considerations: This investigation was given the green light by the Research Ethics Committee of Politeknik Kesehatan Karya Husada Yogyakarta (approval number: 1.538/VI/HREC/2024). The entire set of research operations conformed to the tenets laid down in the Declaration of Helsinki for research with human participants. Detailed information concerning the study aim, procedures, potential risks, and benefits, the voluntary nature of participation, and the right to discontinue at any time without negative consequences were made known to the adolescents and their parents, both in writing and verbally, before the actual enrollment.

Results and Discussions

Table 1. Baseline Characteristics of Study Participants (N = 108)

Characteristic	Intervention Group (n=58)	Control Group (n=50)	Total (N=108)
Age	n (%)	n (%)	n (%)
13 years	20 (34.5%)	0 (0%)	20 (18.5%)
14 years	38 (65.5%)	50 (100%)	88 (81.5%)
Mean age $\pm$ SD	13.7 $\pm$ 0.5	14.0 $\pm$ 0.0	13.8 $\pm$ 0.4
Living with both parents	58 (100%)	50 (100%)	108 (100%)
Own Android smartphone	58 (100%)	50 (100%)	108 (100%)

Based on table 1 the majority of participants were 14 years old (81.5%), while 18.5% were 13 years old, reflecting a relatively homogeneous age distribution appropriate for examining behavior formation during early-to-mid adolescence. This age range is particularly critical as it represents a developmental period when adolescents

begin to establish more autonomous eating behaviors while remaining substantially influenced by family environments and parental modeling (Moore Heslin & McNulty, 2023). The choice to focus exclusively on female adolescents was deliberate and evidence-based, given their heightened vulnerability to nutritional deficiencies, particularly iron deficiency anemia, which has significant implications not only for current health and academic performance but also for future reproductive health outcomes (Sincovich et al., 2022).

Breakfast Consumption Patterns: Baseline Status and Post-Intervention Changes:

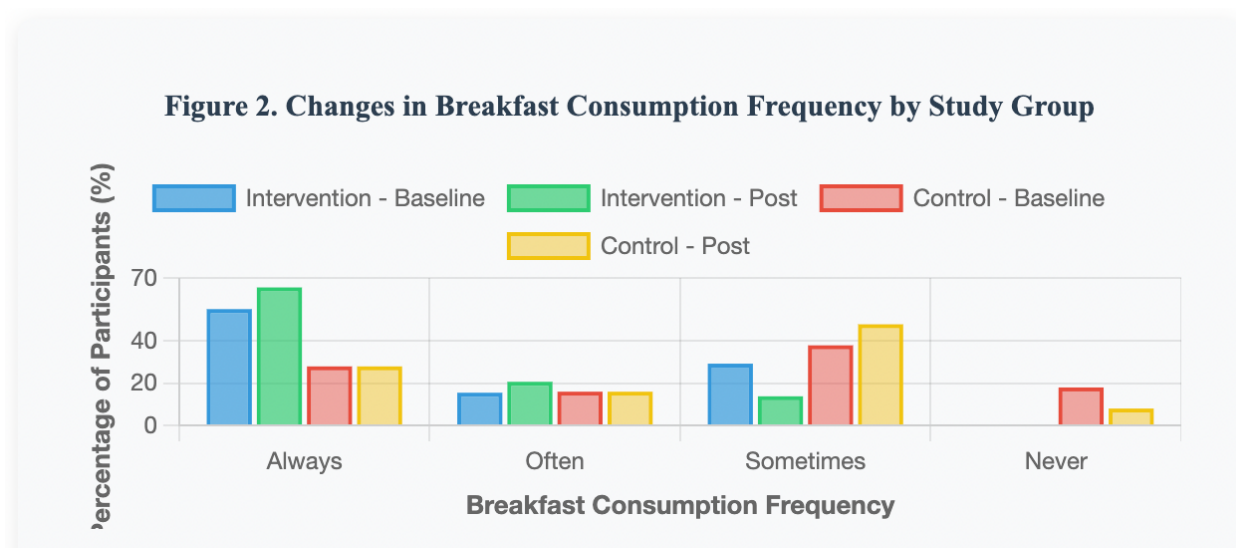
Baseline assessment revealed concerning patterns of breakfast consumption across both groups. Table 2 presents detailed baseline and post-intervention breakfast consumption patterns for both intervention and control groups. These figures align with regional and national data indicating widespread breakfast skipping among Indonesian adolescents, a phenomenon driven by multiple intersecting factors including time constraints, parental work schedules that limit family meal opportunities, lack of appetite upon waking, and socioeconomic barriers to accessing nutritious morning foods (Damara & Muniroh, 2021; Said et al., 2024).

Table 2. Breakfast Consumption Frequency at Baseline and Post-Intervention

Group	Time	Always n (%)	Often n (%)	Sometimes n (%)	Never n (%)	Mean (SD)	Score
Intervention (n=58)	Baseline	32 (55.2%)	9 (15.5%)	17 (29.3%)	0 (0%)	81.5 ± 12.3	
	Post-intervention	38 (65.5%)	12 (20.7%)	8 (13.8%)	0 (0%)	87.9 ± 9.8	
	<i>Change</i>	+6 (+10.3%)	+3 (+5.2%)	-9 (-15.5%)	0	+6.4	
Control (n=50)	Baseline	14 (28.0%)	8 (16.0%)	19 (38.0%)	9 (18.0%)	66.8 ± 15.6	
	Post-intervention	14 (28.0%)	8 (16.0%)	24 (48.0%)	4 (8.0%)	67.5 ± 14.2	
	<i>Change</i>	0	0	+5 (+10.0%)	-5 (-10.0%)	+0.7	
Statistical comparison (Mann-Whitney U test)						p < 0.001***	

Note: Always = daily or 6-7 times/week; Often = 3-5 times/week; Sometimes = 1-2 times/week; Never = <1 time/week.

*****Statistically significant at $\alpha = 0.05$**

Figure 2. Changes in Breakfast Consumption Frequency by Study Group

The clustered bar chart demonstrates the superior effectiveness of the KARUNI intervention in improving breakfast consumption patterns. The intervention group showed a 10.3% increase in daily breakfast consumption (from 55.2% to 65.5%), while the control group remained stable at 28%. The shift from "Sometimes" to "Always/Often" categories in the intervention group indicates meaningful behavior change.

Statistical analysis using the Mann-Whitney U test revealed a highly significant difference between the intervention and control groups at post-intervention ($p < 0.001$), confirming that the KARUNI model produced substantially greater improvements in breakfast habits compared to passive education alone. The mean breakfast behavior score in the intervention group increased by 6.4 points (from 81.5 to 87.9), compared to only 0.7 points in the control group.

These results play a significant part in bolstering the evidence base that family-centered and tech-enabled interventions are a viable solution to adolescent breakfast skipping problem effectively (Karuniawait et al., 2025). The amount of change that was observed in this research is similar to that of other adolescent nutrition interventions that have been reported in the recent literature. A systematic review by López-Gil et al. (2024), which included data from 42 countries and examined breakfast consumption, revealed that interventions that combined parental engagement with self-monitoring were most effective in promoting sustained breakfast habits. The success of the KARUNI model is due to the integration of various evidence-based components: daily self-monitoring via the app, immediate feedback and reinforcement, parental involvement as both supporters and role models, and the use of habit formation principles through consistent 21-day practice.

The significance of breakfast consumption on a daily basis to the health and growth of teenagers is beyond the point. Several longitudinal studies have been showing how the habitual breakfast consumption of adolescents can lead to academic achievement, better concentration and memory, improved nutritional status, healthier body weight, and lesser chances of metabolic disorders (Feye et al., 2023; López-Gil et al., 2024). In the case of female adolescents, it is especially vital that they take their breakfast regularly as it offers them an excellent chance to include iron-rich food in their diet and thus, prevent anemia that, among other things, impairs cognitive function, physical capacity, and general well-being (Moore Heslin & McNulty, 2023).

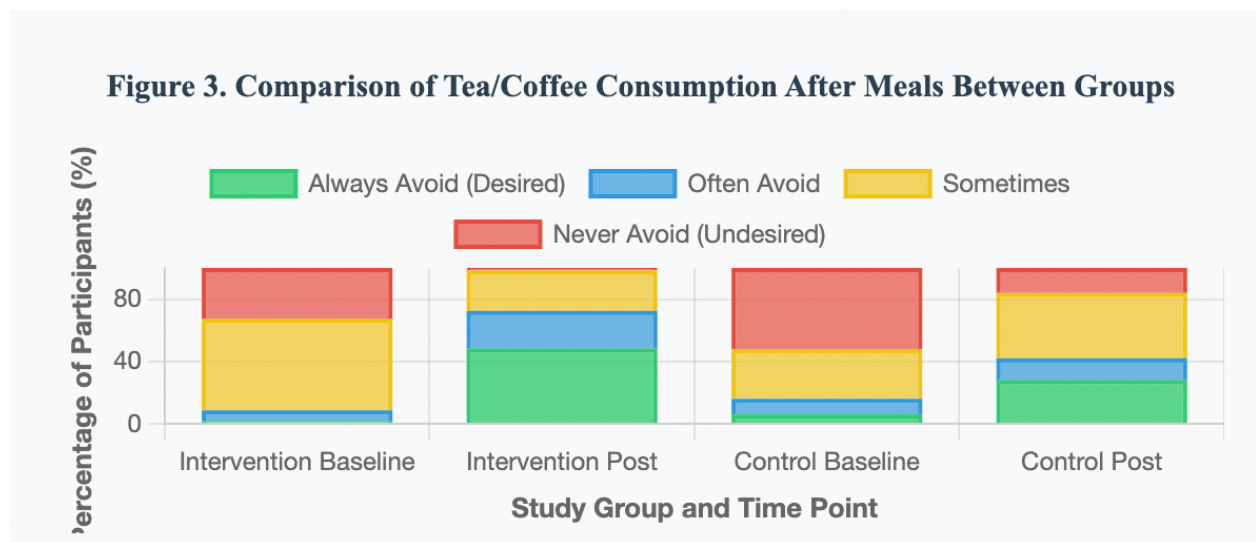
Tea and Coffee Consumption After Meals: Addressing a Culturally Embedded Practice. The second behavioral target of the KARUNI intervention reduction of tea or coffee consumption immediately after meals revealed equally compelling results, as detailed in Table 3. Baseline data indicated that this practice was highly prevalent across both groups, reflecting its deep cultural embedding in Indonesian society where tea drinking is often viewed as an essential component of hospitality, social bonding, and post-meal ritual (Jeong & Lee, 2021).

Table 3. Tea/Coffee Consumption After Meals at Baseline and Post-Intervention

Group	Time	Always Avoid n (%)	Often Avoid n (%)	Sometimes n (%)	Never Avoid n (%)	Mean Score (SD)
Intervention (n=58)	Baseline	1 (1.7%)	4 (6.9%)	34 (58.6%)	19 (32.8%)	44.4 ± 18.2
	Post-intervention	28 (48.3%)	14 (24.1%)	15 (25.9%)	1 (1.7%)	79.7 ± 15.8
	Change	+27 (+46.6%)	+10 (+17.2%)	-19 (-32.7%)	-18 (-31.0%)	+35.3
Control (n=50)	Baseline	3 (6.0%)	5 (10.0%)	16 (32.0%)	26 (52.0%)	44.4 ± 19.5
	Post-intervention	14 (28.0%)	7 (14.0%)	21 (42.0%)	8 (16.0%)	63.5 ± 17.3
	Change	+11 (+22.0%)	+2 (+4.0%)	+5 (+10.0%)	-18 (-36.0%)	+19.1
Statistical comparison (Mann-Whitney U test)						p = 0.001***

Note: For this behavior, "Always Avoid" means always avoiding tea/coffee after meals (desired behavior); "Never Avoid" means always drinking tea/coffee after meals (undesired behavior). ***Statistically significant at $\alpha = 0.05$

Figure 3. Comparison of Tea/Coffee Consumption After Meals Between Groups



The stacked bar chart visualizes the dramatic shift in tea/coffee consumption patterns following the KARUNI intervention. The intervention group showed a remarkable 46.6% increase in participants who always avoid tea/coffee after meals (from 1.7% to 48.3%), demonstrating substantial behavior change in this culturally embedded practice. The control group showed modest improvement, likely attributable to the educational booklet alone.

The intervention group demonstrated the largest effect size in this study, with a mean score surge from 44.4 at baseline to 79.7 post-intervention, representing a 35.3-point improvement. Statistical comparison between groups yielded $p = 0.001$, indicating highly significant differences attributable to the intervention. This finding is particularly noteworthy given the entrenched nature of tea-drinking traditions in Indonesian culture.

The health implications of this behavioral change are profound. Recent isotope studies have demonstrated that polyphenols in tea, particularly tannins, form complexes with non-heme iron (the primary form of iron in plant-based foods that constitute the majority of Indonesian diets), thereby dramatically reducing iron absorption. Lazrak et al. (2021) reported that tea consumption can reduce iron bioavailability by more than 85%, while He and Chen (2024) documented a case of severe iron-deficiency anemia in a woman that directly resulted from regular green tea consumption, which resolved upon cessation but recurred when tea drinking resumed.

For adolescent girls in Indonesia, where anemia prevalence is already high due to factors including inadequate dietary iron intake, menstrual blood loss, and rapid growth demands, the practice of drinking tea immediately after meals represents a significant modifiable risk factor (Kusumawati et al., 2024). By successfully reducing this behavior, the KARUNI intervention addresses not only immediate dietary habits but also creates conditions for improved iron status, which has cascading effects on cognitive function, academic performance, physical capacity, and long-term health trajectories.

Table 4. Statistical Analysis Summary and Effect Sizes

Outcome Variable	Intervention Group Median (IQR)	Control Group Median (IQR)	Statistical Test	p-value	Effect Size (r)
Breakfast consumption	88.0 (82.0-94.0)	66.0 (58.0-75.0)	Mann-Whitney U	<0.001***	0.52 (large)
Avoiding tea/coffee after meals	82.0 (72.0-88.0)	64.0 (54.0-72.0)	Mann-Whitney U	0.001***	0.48 (large)

Note: Effect size interpretation: small (0.1-0.3), medium (0.3-0.5), large (>0.5). ***Statistically significant at $\alpha = 0.05$. The effect sizes for both behavioral outcomes exceeded 0.4, indicating large practical significance beyond statistical significance. These substantial effect sizes demonstrate that the KARUNI intervention produced meaningful, real-world changes in adolescent eating behaviors that are likely to translate into tangible health benefits.

Qualitative Insights: Mechanisms of Change and Lived Experiences. The qualitative phase of this study, conducted through Focus Group Discussions with adolescents and in-depth interviews with parents, provided essential insights into how and why the KARUNI intervention produced behavioral changes. Three primary themes emerged from the thematic analysis: enhanced parental understanding and engagement, adolescent self-efficacy development through daily practice, and the role of technology in facilitating family communication around health.

Enhanced Parental Understanding and Engagement. Parents interviewed expressed that the KARUNI intervention fundamentally changed their understanding of adolescent nutrition. Prior to the intervention, many parents viewed breakfast as desirable but not essential, or believed that afternoon and evening meals could compensate for breakfast skipping. The educational materials and daily engagement with the application shifted these perceptions, leading parents to prioritize breakfast preparation and family eating routines. Importantly, parents reported that the application's parent interface which allowed them to view their daughter's progress—opened new channels for supportive communication.

This transformation in the parent-adolescent dynamic around food represents a crucial mechanism through which the KARUNI intervention operated. Research consistently demonstrates that parental involvement characterized by support, encouragement, and modeling is far more effective than authoritarian or controlling approaches in promoting healthy adolescent behaviors (Ho et al., 2022). The KARUNI model facilitated what Kieslinger et al. (2021) term "parental self-efficacy" parents' confidence in their ability to influence their children's health behaviors which in turn enhanced adolescents' own self-efficacy.

Adolescent Self-Efficacy Through Daily Practice. Adolescent participants consistently described the KARUNI application's Daily Activity feature as a catalyst for self-awareness and reflection. Many reported that the act of daily recording—even when they had not performed the desired behavior created a form of accountability that motivated change. This finding aligns with self-regulation theory, which posits that self-monitoring increases awareness of behavior-goal discrepancies and activates motivation to reduce these discrepancies (Marashi et al., 2024). The immediate visual feedback provided by the application progress charts, streak counters, and achievement badges served as positive reinforcement that strengthened the behavior-outcome association, a key mechanism in habit formation (Gardner et al., 2023, 2024; Zhu et al., 2024).

Technology as a Bridge for Family Communication. The qualitative data revealed important insights about the social support mechanisms activated by the intervention. Several adolescents reported that their mothers began preparing breakfast more regularly and diversifying breakfast options to match their preferences. Some families instituted new routines of eating breakfast together before school and work, transforming breakfast from an individual responsibility into a shared family activity. This shift from individual behavior change to family-level behavior change likely contributed to sustainability, as the supportive environment reduced the burden on adolescents to maintain behaviors through willpower alone (Singh et al., 2024).

Theoretical Contributions and Practical Implications. This study makes several important theoretical contributions to understanding adolescent behavior change. First, it provides empirical support for Social Cognitive Theory's proposition that behavior change is most effectively achieved through simultaneous targeting of personal factors (knowledge, attitudes, self-efficacy), environmental factors (parental support, food availability, family routines), and behavioral factors (daily practice, reinforcement). The KARUNI intervention operationalized all three components, creating a comprehensive behavioral ecosystem rather than relying on any single mechanism (Marashi et al., 2024).

Second, the study advances understanding of how digital technologies can enhance rather than replace human relationships in health behavior change. The KARUNI model demonstrates that thoughtfully designed digital platforms can actually strengthen family communication and support, serving as a tool that facilitates rather than substitutes for interpersonal connection (Benítez-Andrades et al., 2020).

Third, the study contributes to habit formation theory by demonstrating that meaningful habit initiation can occur within three weeks when supported by consistent practice, self-monitoring, and environmental support. While complete automaticity typically requires longer periods, the 21-day intervention successfully transitioned behaviors from requiring substantial effort to becoming more routine and self-sustaining (Gardner et al., 2024; Singh et al., 2024).

Conclusions

This research study offers persuasive evidence that parental participation facilitated through the KARUNI mobile application has a very significant influence on the healthy eating behaviors of adolescent girls, particularly by making them eat breakfast more regularly and by reducing their intake of tea or coffee after meals—two of the main factors that determine iron status and, thus, nutritional health. The intervention was associated with large effect sizes ($r > 0.48$) and highly statistically significant differences ($p < 0.001$) as compared to passive education alone, thus, showing the worth of the technology-enabled engagement of families along with the use of behavior change principles grounded in evidence.

The success of the KARUNI project is due to its comprehensive model that not only enhances the individual's self-efficacy via daily self-monitoring, but also provides environmental support through parental involvement, and finally, it secures habit formation through the consistent 21-day practice, thus, the positive effects become multiplicative and go beyond traditional single-component interventions.

These results carry significant implications for the prevention of anemia during the adolescent period, as well as for the promotion of health, in the long run, especially in the areas with limited resources, where affordable and scalable interventions are critically needed. We advise that health policymakers and program implementers consider the use of family-centered, technology-integrated approaches for health promotion among adolescents. They should also be careful to culturally adapt the methods and ensure equitable access so that vulnerable groups can also benefit.

The upcoming research should be based on long-term follow-up to find out if the behavior change lasts beyond the initial intervention period. It should also include the use of objective biomarkers, e.g., hemoglobin and

serum ferritin, to directly quantify nutritional impacts and expansion to the inclusion of male adolescents as well as various geographical locations to increase generalizability. Moreover, a cost-effectiveness study to inform resource allocation decisions and implementation science research to identify the barriers and facilitators of large-scale deployment in actual public health systems should also be considered.

The KARUNI model is an innovative, evidence-based approach to the problem of unhealthy lifestyles among youth through engaging parents in a meaningful way. Its potential for modification and extension should be seriously considered not only in local and regional health programs but also at the level of national health agendas targeting adolescent nutrition and the prevention of the intergenerational transmission of health problems.

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