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SELF-REPORTED MOBILE HEALTH APP ENGAGEMENT AND HEALTH-PROMOTING BEHAVIOUR AMONG INDONESIAN ADOLESCENTS: THE MODERATING ROLES OF SOCIAL SUPPORT AND DIGITAL LITERACY

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ABSTRACT

Objective: Mobile health applications are increasingly used to support adolescent health promotion, yet the association between adolescents' self-reported engagement with these applications and health-promoting behaviour may depend on psychosocial resources and digital competencies. This study examined the moderating roles of perceived social support and digital literacy in the association between self-reported mobile health app engagement and health-promoting behaviour among Indonesian adolescents**. Methods:** A quantitative cross-sectional study was conducted among 240 adolescents aged 13-18 years from secondary schools in Bandung City and Bandung Regency, West Java, Indonesia, selected using multistage proportionate stratified random sampling. Data were collected using validated self-report instruments and analysed using descriptive statistics, Pearson correlation, hierarchical multiple regression, and regression-based moderation analysis with demographic covariates controlled. **Result:** Self-reported mobile health app engagement was positively correlated with health-promoting behaviour ($r = .42$, $p < .001$). Perceived social support and digital literacy were significant independent predictors, and both interaction terms were significant, suggesting that the association between self-reported mobile health app engagement and health-promoting behaviour was stronger among adolescents with higher perceived social support and digital literacy. The final model explained 44.9% of the variance in health-promoting behaviour. **Consclussion:** These findings suggest that adolescent mobile health programmes should integrate digital health literacy development and socially supported engagement strategies to strengthen health promotion outcomes.

Keywords: Bandung; cross-sectional study; digital literacy; health-promoting behaviour; self-reported mHealth engagement; moderation analysis; perceived social support.

INTRODUCTION

Adolescent health remains a major global public health priority. The World Health Organization estimates that one in seven individuals aged 10-19 years experiences a mental health disorder, contributing substantially to the disease burden in this age group

(World Health Organization, 2025). Indonesia has a large adolescent population, with nearly 46 million people aged 10-19 years, and continues to face persistent challenges related to non-communicable diseases, mental health problems, tobacco exposure, nutritional deficiencies, and other risk behaviours (UNICEF Indonesia, 2025). These challenges require scalable, acceptable, and developmentally appropriate health promotion strategies that can reach adolescents across urban and peri-urban settings.

The rapid expansion of smartphone ownership and internet connectivity has increased interest in mobile health (mHealth) as a channel for adolescent health promotion. mHealth interventions, including smartphone applications, web-based platforms, and interactive digital tools, offer several potential advantages for adolescents, such as accessibility, privacy, personalisation, and repeated exposure to health information. Evidence from systematic reviews, meta-analyses, and recent umbrella reviews suggests that digital and mobile interventions can support physical activity, healthy lifestyle behaviours, mental well-being, and self-management among young people (Baumann et al., 2022; Conley et al., 2022; Sequi-Dominguez et al., 2024; Singh et al., 2025; Talens et al., 2025; Wang et al., 2024). Digital mental health interventions have also been identified as promising approaches for adolescents in low- and middle-income countries, although implementation remains uneven and context-dependent (Wani et al., 2024).

Despite these promising findings, the benefits associated with mHealth tools are not uniform across adolescent groups. Prior reviews have reported heterogeneity in digital health outcomes, suggesting that the effectiveness of mHealth may depend on intervention characteristics, user attributes, implementation context, and the surrounding social environment (Baumann et al., 2022; Colder Carras et al., 2024; Li et al., 2024; Wang et al., 2024). In real-world school and community contexts, access to mobile technology does not automatically translate into effective engagement with health information or the adoption of healthier behaviours. Adolescents may differ in motivation, family and peer support, digital self-efficacy, and the ability to critically evaluate online health content.

Perceived social support is a particularly important contextual factor in adolescent health behaviour. During adolescence, family members, peers, teachers, and other significant persons shape motivation, normative beliefs, self-efficacy, and the perceived relevance of health information. Studies examining mHealth engagement have found that social features, virtual coaching, parental co-participation, and socially supportive application functions may facilitate sustained use of digital health tools (Deslippe et al., 2023; Eaton et al., 2024; Van Baelen et al., 2022). However, whether adolescents' pre-existing social

support outside the mHealth environment moderates the association between mHealth app engagement and health-promoting behaviour remains underexplored, particularly in collectivist and school-based Indonesian contexts.

Digital literacy represents another theoretically plausible moderator of mHealth benefit. The eHealth literacy framework conceptualises digital health literacy as the ability to seek, locate, understand, appraise, and apply health information obtained from electronic sources (Norman & Skinner, 2006). Higher eHealth literacy has been positively associated with health-related behaviours across demographic groups (Kim et al., 2023; Wang et al., 2022). Adolescent-specific evidence indicates, however, that confidence in searching for online health information does not always correspond to the ability to critically evaluate information quality (Taba et al., 2022). Recent studies also emphasise that adolescents need guided, engaging, and co-designed digital health literacy resources to recognise trustworthy online health information and apply it safely (Aloi et al., 2025; Hawkins et al., 2025; Mancone et al., 2024). Accordingly, adolescents with higher digital literacy may be better positioned to show a stronger association between mHealth app engagement and health-promoting behaviour than those with limited digital competencies.

The Indonesian context makes the interplay among mobile access, social support, and digital literacy especially relevant. National digital health strategies recognise digital literacy as a prerequisite for equitable digital health implementation (Sari, 2023; World Health Organization, 2021). Nevertheless, regional, socioeconomic, and educational disparities may constrain adolescents' ability to fully benefit from digital health resources. This concern is consistent with recent arguments that adolescent digital health promotion should address digital determinants of health, youth engagement, and the risk of widening inequalities if digital interventions are implemented without adequate support (Raeside, 2025). Existing studies have tended to examine mHealth use, digital literacy, or social support as independent predictors rather than as interacting constructs, and formal moderation analyses testing whether social support and digital literacy condition the association between mHealth app engagement and health-promoting behaviour remain limited.

Although previous studies have shown that mobile health interventions may support adolescent health outcomes, less is known about the contextual and competency-related conditions under which mHealth app engagement is associated with health-promoting behaviour. In particular, limited evidence is available from Indonesian adolescent populations regarding whether perceived social support and digital literacy strengthen or weaken the relationship between

mHealth app engagement and health-promoting behaviour. This gap is important because access to mobile health tools alone may not be sufficient for behaviour change. Adolescents may require supportive interpersonal environments and adequate digital literacy to interpret, evaluate, and apply health information in daily life.

Therefore, this study contributes to the adolescent health promotion literature in three ways. First, it examines mHealth app engagement in a school-based Indonesian adolescent sample. Second, it tests perceived social support and digital literacy not only as independent predictors, but also as moderators. Third, it identifies conditional patterns that may help explain why mHealth app engagement is more strongly associated with health-promoting behaviour among some adolescents than others. The study tested three hypotheses: (H1) self-reported mHealth app engagement would be positively associated with health-promoting behaviour; (H2) perceived social support and digital literacy would each be positively associated with health-promoting behaviour; and (H3) the association between mHealth app engagement and health-promoting behaviour would be stronger among adolescents reporting higher perceived social support and higher digital literacy.

METHODS

This study employed a quantitative cross-sectional survey design to examine the moderating roles of perceived social support and digital literacy in the association between self-reported mHealth app engagement and health-promoting behaviour among Indonesian adolescents. A cross-sectional design was appropriate because the primary aim was to estimate associations and interaction patterns within a defined population at a single time point, rather than to establish temporal or causal effects (Setia, 2016). The manuscript was prepared in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies (von Elm et al., 2007). The analytic framework was grounded in regression-based moderation analysis (Hayes, 2022), with mHealth app engagement as the focal independent variable, health-promoting behaviour as the outcome, and perceived social support and digital literacy as moderators.

In this study, mHealth app engagement referred to adolescents' self-reported perceived usability of and engagement with health-related mobile applications used during the previous three months. This operationalisation did not denote assignment to a standardised experimental intervention, objectively logged application-use dosage, or verified clinical exposure. Accordingly, findings should be interpreted as moderated associations between perceived mHealth application engagement and health-promoting behaviour, rather than as evidence that

mHealth app engagement caused changes in health behaviour.

The study was conducted in junior and senior secondary schools located in Bandung City and Bandung Regency, West Java Province, Indonesia. These settings were selected to represent adolescents from urban and peri-urban contexts with heterogeneous access to digital infrastructure, school resources, and social support environments. Bandung City represents a major urban centre, whereas Bandung Regency includes semi-urban and rural subdistricts, allowing the study to capture variability in mHealth app engagement, digital literacy, and perceived social support across different ecological contexts.

The target population comprised adolescents aged 13-18 years enrolled in selected secondary schools in Bandung City and Bandung Regency who had used at least one health-related mobile application during the previous three months. Inclusion criteria were: (i) age 13-18 years; (ii) active enrolment in a selected junior or senior secondary school; (iii) ownership of or regular access to a smartphone; (iv) self-reported use of at least one health-related mobile application within the previous three months; and (v) provision of written assent with parental or guardian consent. Exclusion criteria included inability to complete the Bahasa Indonesia questionnaire, documented severe cognitive or psychiatric conditions precluding valid self-report, concurrent participation in another mHealth-related study, or missing data exceeding 20% on any study instrument.

A multistage proportionate stratified random sampling procedure was employed. Schools were first stratified by geographic area (Bandung City versus Bandung Regency) and school category (junior versus senior secondary; public versus private). Schools were then selected proportionately within each stratum. Classes were subsequently sampled within selected schools, and eligible students from sampled classes were invited to participate. The required sample size was estimated for moderated multiple regression using anticipated small-to-moderate interaction effect sizes (f^2 approximately 0.02-0.05), alpha = .05, power $(1 - \beta) = .90$, and $k = 11$ predictors, computed using G*Power 3.1 (Faul et al., 2009) and inflated to account for non-response, incomplete data, and school-based clustering. The final analytic sample comprised 240 adolescents.

Health app engagement was measured using the mHealth App Usability Questionnaire (MAUQ), a 21-item instrument assessing perceived ease of use, interface quality, usefulness, and engagement with health-related mobile applications (Zhou et al., 2019). Possible scores range from 21 to 147, with higher scores reflecting greater perceived usability and engagement. Cronbach's alpha in the present sample was .88.

Perceived social support was measured using the Multidimensional Scale of Perceived Social Support (MSPSS), a 12-item instrument assessing perceived support from family, friends, and significant others (Zimet et al., 1988). Possible scores range from 12 to 84, with higher scores indicating greater perceived social support. The Indonesian version has demonstrated acceptable psychometric properties in adolescent populations (Laksmita et al., 2020). Cronbach's alpha in the present sample was .90.

Digital literacy was assessed using the Indonesian version of the eHealth Literacy Scale (I-eHEALS), an eight-item instrument measuring perceived knowledge, skills, and confidence in locating, evaluating, and applying online health information (Norman & Skinner, 2006; Wijaya & Kloping, 2021). Possible scores range from 8 to 40. Cronbach's alpha in the present sample was .91.

Health-promoting behaviour was measured using the Health-Promoting Lifestyle Profile II (HPLP-II), a 52-item instrument assessing the frequency of health-promoting activities across six subscales: health responsibility, physical activity, nutrition, interpersonal relations, spiritual growth, and stress management (Walker et al., 1987). Items are rated on a four-point Likert scale (1 = never, 4 = routinely), and a mean composite score was calculated. Cronbach's alpha in the present sample was .92. A sociodemographic questionnaire also collected information on age, sex, school level, school type, study area, socioeconomic status, parental education, smartphone access, and number of mHealth applications used.

Data were collected during scheduled school sessions using a standardised self-administered questionnaire package. Permission was obtained from relevant education authorities and school principals prior to data collection. Students and their parents or guardians received an information sheet explaining the study purpose, procedures, confidentiality protections, voluntary participation, and the right to withdraw at any time without academic consequences. Questionnaires were administered by trained research assistants in classroom settings. Participants completed instruments in the following order: sociodemographic questionnaire, MAUQ, MSPSS, I-eHEALS, and HPLP-II. Completed questionnaires were checked for completeness, coded anonymously, and entered into a password-protected digital dataset.

Ethical approval was obtained from the Health Research Ethics Committee of STIKep PPNI Jawa Barat prior to data collection (Ethics Approval No. III/023.I/KEPK-SLE/STIKEP/PPNI/JABAR/XI/2025). Written informed consent was obtained from parents or guardians for participants aged under 18 years, and written assent was obtained from all adolescent participants. Participants aged 18 years provided independent written informed consent. The study

was conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013) and the CIOMS International Ethical Guidelines (Council for International Organizations of Medical Sciences, 2016). No personally identifying information was retained in the analytic dataset.

All data were analysed using IBM SPSS Statistics (Version 27) and Hayes' PROCESS macro (Version 4; Hayes, 2022). Descriptive statistics were computed for all sociodemographic characteristics and study variables. Internal consistency was assessed using Cronbach's alpha, with values of .70 or higher considered acceptable. Pearson correlation coefficients examined bivariate associations among the four main study variables. Hierarchical multiple regression tested main effects and interaction terms, with all continuous predictors mean-centred prior to the creation of interaction terms to reduce multicollinearity (Aguinis et al., 2005). Categorical covariates were dummy-coded, and socioeconomic status was entered as an ordinal variable (1 = low, 2 = middle, 3 = high). To avoid ambiguity in evaluating interaction effects, the two single-interaction models were estimated separately relative to the same main-effects model, and a final simultaneous model then entered both interaction terms together. Significant interaction terms were probed using conditional associations at low (-1 SD), mean, and high (+1 SD) moderator levels, and the Johnson-Neyman floodlight technique was used to identify regions of significance (Hayes, 2022). Statistical significance was set at alpha = .05 throughout. Regression assumptions were inspected before final interpretation, including linearity, residual distribution, homoscedasticity, and multicollinearity diagnostics. Because school- and class-level identifiers were not retained in the analytic dataset, cluster-robust or multilevel standard errors could not be estimated.

RESULTS

Participant Characteristics

A total of 240 Indonesian adolescents were included in the final analysis. The mean age was 15.82 years (SD = 1.41; range: 13-18 years). The majority were female (n = 132, 55.0%) and senior high school students (n = 154, 64.2%). Participants were approximately evenly distributed between Bandung City (n = 121, 50.4%) and Bandung Regency (n = 119, 49.6%). Most reported personal smartphone access (n = 231, 96.3%), consistent with the study eligibility criteria. Demographic characteristics are presented in Table 1.

Table 1. Demographic Characteristics of Participants (N = 240)

Characteristic	Category	N	%
Age group	13-15 years	103	42.9
	16-18 years	137	57.1
Sex	Male	108	45.0

	Female	132	55.0
School level	Junior high school	86	35.8
	Senior high school	154	64.2
School type	Public school	151	62.9
	Private school	89	37.1
Study area	Bandung City	121	50.4
	Bandung Regency	119	49.6
Socioeconomic status	Low	58	24.2
	Middle	134	55.8
	High	48	20.0
Parental education	Secondary school or below	96	40.0
	Diploma or higher	144	60.0
Smartphone access	Personal smartphone	231	96.3
	Shared smartphone	9	3.7
mHealth apps (last 3 months)	1-2 applications	139	57.9
	3 or more applications	101	42.1

Note. Percentages may not total 100 due to rounding.

Descriptive Statistics and Reliability

Participants reported moderate-to-high levels of self-reported mHealth app engagement, perceived social support, and digital literacy. The mean HPLP-II score indicated relatively favourable health-promoting behaviour at the group level. All four instruments demonstrated acceptable-to-excellent internal consistency, with Cronbach's alpha values ranging from .88 to .92 (Table 2).

Table 2 Descriptive Statistics and Reliability of Study Variables

Variable	Instrument	Possible range	Mean	SD	Cronbach's alpha
mHealth app engagement	MAUQ	21-147	100.62	17.84	.88
Perceived social support	MSPSS	12-84	60.45	12.10	.90
Digital literacy	I-eHEALS	8-40	30.28	5.40	.91
Health-promoting behaviour	HPLP-II	1-4	2.78	0.42	.92

Note. MAUQ = mHealth App Usability Questionnaire; MSPSS = Multidimensional Scale of Perceived Social Support; I-eHEALS = Indonesian version of the eHealth Literacy Scale; HPLP-II = Health-Promoting Lifestyle Profile II.

Correlation Analysis

Pearson correlation analysis revealed significant positive associations among all four main study variables. Self-reported mHealth app engagement was positively associated with health-promoting behaviour ($r = .42$, $p < .001$). Perceived social support ($r = .49$, $p < .001$) and digital literacy ($r = .45$, $p < .001$) were also positively associated with health-promoting behaviour. Moderate intercorrelations were

observed among predictors (r range: .34-.41), indicating that multicollinearity was unlikely to pose a substantial threat to the regression analyses (Table 3).

Table 3 Pearson Correlations Among Study Variables (N = 240)

Variable	1	z	2	3	4
1. mHealth app engagement	1				
2. Perceived social support	.34***		1		
3. Digital literacy	.38***		.41***	1	
4. Health-promoting behaviour	.42***		.49***	.45***	1

Note. ***p < .001. Moderation Analysis

Regression models were conducted to test the moderation hypotheses (Table 4). In Model 1, mHealth app engagement (β = .26), perceived social support (β = .28), and digital literacy (β = .24) were each significant positive predictors of health-promoting behaviour after adjustment for demographic covariates (R^2 = .391). Socioeconomic status was the only covariate that reached statistical significance (β = .09, p = .039). Models 2 and 3 were specified as separate single-interaction models relative to the same main-effects model. The mHealth app engagement x social support model explained an additional 2.5% of variance relative to Model 1, whereas the mHealth app engagement x digital literacy model explained an additional 3.2% of variance relative to Model 1. In the final simultaneous model (Model 4), both interaction terms remained statistically significant, with the full model explaining 44.9% of the variance in health-promoting behaviour (R^2 = .449, adjusted R^2 = .422, F[11, 228] = 16.88, p < .001). Final model coefficients are presented in Table 5.

Table 4 Regression Model Fit Indices for Main-Effect, Single-Interaction, and Simultaneous Interaction Models

Model	R^2	Adj. R^2	ΔR^2 vs Model 1	Model F	Predictors added
Model 1 (Main effects)	.391	.370	-	16.20***	Covariates + mHealth + SS + DL
Model 2 (+mHealth x SS)	.416	.393	.025	16.31***	mHealth x social support
Model 3 (+mHealth x DL)	.423	.399	.032	16.79***	mHealth x digital literacy
Model 4 (Full simultaneous)	.449	.422	.058	16.88***	Both interaction terms

Note. For Models 2 and 3, ΔR^2 is relative to the main-effects model; these single-interaction models were estimated separately. Model 4 enters both interaction terms simultaneously. F values refer to the full model for each model. The statistical significance of the interaction terms is reported in Table 5. SS = social support; DL = digital literacy. ***p < .001.

Table 5 Final Simultaneous Moderation Model Predicting Health-Promoting Behaviour (N = 240)

Predictor	B	SE	β	t	p	95% CI
Age (years)	.012	.017	.04	0.71	.478	-0.022, 0.046
Sex (0 = male, 1 = female)	.026	.046	.03	0.57	.569	-0.065, 0.117
School level	.046	.052	.05	0.88	.380	-0.056, 0.148
School type	.017	.044	.02	0.39	.697	-0.070, 0.104
Study area	.034	.043	.04	0.79	.430	-0.051, 0.119
Socioeconomic status	.058	.028	.09	2.07	.039*	0.003, 0.113
mHealth app engagement (MAUQ)	.006	.001	.26	5.00	< .001***	0.004, 0.008
Social support (MSPSS)	.010	.002	.28	5.00	< .001***	0.006, 0.014
Digital literacy (I-eHEALS)	.019	.004	.24	4.75	< .001***	0.011, 0.027
mHealth x social support	.00025	.00011	.13	2.27	.024*	0.00003, 0.00047
mHealth x digital literacy	.00074	.00026	.15	2.85	.005**	0.00023, 0.00125

*Note. B = unstandardised regression coefficient; SE = standard error; β = standardised coefficient; CI = confidence interval. All continuous predictors were mean-centred. Final model: R^2 = .449, adjusted R^2 = .422, F[11, 228] = 16.88, p < .001. *p < .05. **p < .01. ***p < .001.*

Conditional Associations and Johnson-Neyman Regions of Significance

Conditional association analysis revealed that the relationship between mHealth app engagement and health-promoting behaviour strengthened progressively as perceived social support and digital literacy increased. At low levels of digital literacy (-1 SD), the association was attenuated and did not reach statistical significance (effect = .002, 95% CI [-.001, .005], p = .084). At mean and high levels of both moderators, the association was significant and of meaningful magnitude (Table 6).

Table 6 Conditional Associations Between mHealth App Engagement and Health-Promoting Behaviour at Low, Mean, and High Moderator Levels

Moderator	**Level**	**Effect**	**SE**	**95% CI**	**p**	**Significant**
Social support	Low (-1 SD)	.003	.001	0.0001, 0.0060	.043	Yes
	Mean (0 SD)	.006	.001	0.004, 0.008	< .001	Yes
	High (+1 SD)	.009	.002	0.006, 0.012	< .001	Yes
Digital literacy	Low (-1 SD)	.002	.001	-0.001, 0.005	.084	No
	Mean (0 SD)	.006	.001	0.004, 0.008	< .001	Yes
	High (+1 SD)	.010	.002	0.007, 0.013	< .001	Yes

Note. CI = confidence interval; SE = standard error. Low = -1 SD, mean = 0 SD, and high = +1 SD of the moderator.

Johnson-Neyman analysis identified specific threshold values of each moderator above which the association between mHealth app engagement and health-promoting behaviour was statistically significant (Table 7). Among participants with MSPSS scores above 48.20, mHealth app engagement was significantly associated with health-promoting behaviour. Similarly, among those with I-eHEALS scores above 26.10, the association was statistically significant. These thresholds indicate that a substantial proportion of the sample fell within the regions of significance for both moderators.

Table 7 Johnson-Neyman Regions of Significance for Each Moderator

Moderator	Threshold score	Interpretation
Perceived social support (MSPSS)	>48.20	The association between mHealth app engagement and health-promoting behaviour was statistically significant above this threshold of perceived social support.
Digital literacy (I-eHEALS)	>26.10	The association between mHealth app engagement and health-promoting behaviour was statistically significant above this threshold of digital literacy.

Note. Threshold scores indicate the moderator values above which the conditional association between mHealth app engagement and health-promoting behaviour reached statistical significance (alpha = .05). MSPSS = Multidimensional Scale of Perceived Social Support; I-eHEALS = Indonesian version of the eHealth Literacy Scale.

DISCUSSION

Principal Findings

This study examined whether perceived social support and digital literacy moderated the association between self-reported mHealth app engagement and health-promoting behaviour among Indonesian adolescents. Three main findings emerged. First, self-reported mHealth app engagement was positively and significantly associated with health-promoting behaviour, supporting H1. Second, perceived social support and digital literacy were each independently associated with health-promoting behaviour, supporting H2. Third, both constructs significantly moderated the association between mHealth app engagement and health-promoting behaviour, supporting H3. The final model explained 44.9% of the variance in health-promoting behaviour, and Johnson-Neyman analyses clarified that the association was conditional on reaching threshold levels of perceived social support (>48.20 on the MSPSS) and digital literacy (>26.10 on the I-eHEALS).

Interpretation and Comparison With Previous Research

The findings indicate that self-reported mHealth app engagement

was positively associated with health-promoting behaviour among adolescents, but this association was not uniform across all participants. The significant moderating effects of perceived social support and digital literacy suggest that mHealth app engagement may be more strongly associated with health-promoting behaviour when adolescents have both interpersonal reinforcement and the ability to process digital health information effectively. This finding supports the view that mHealth should not be treated merely as a technological tool, but as part of a broader health promotion ecosystem involving families, peers, schools, and digital competency development.

The positive association between mHealth app engagement and health-promoting behaviour aligns with evidence that mobile technology-delivered interventions can support youth well-being and health behaviour change. Conley et al. (2022) reported beneficial associations of mobile technology-delivered programmes with youth mental health and well-being outcomes in a three-level meta-analysis, while Wang et al. (2024) found that mHealth application-based interventions were associated with improvements in physical activity and fitness-related outcomes among children and adolescents. More recent reviews also indicate that eHealth and mHealth interventions may support healthy behaviours, dietary knowledge, physical activity, and digital well-being in young populations, although effect sizes and sustainability vary across intervention design and context (Colder Carras et al., 2024; Sequi-Dominguez et al., 2024; Singh et al., 2025; Talens et al., 2025). These findings are consistent with the present results, although interpretation remains cautious given the cross-sectional design and reliance on self-reported engagement rather than experimentally assigned intervention receipt.

The moderating role of perceived social support is consistent with the adolescent health promotion literature emphasising the centrality of family, peer, and school contexts in shaping health behaviour. Tabrizi et al. (2024) identified social factors, including family cohesion, peer norms, and teacher support, as among the most influential determinants of adolescent health-promoting behaviour. Deslippe et al. (2023) found that social support features, including parental co-participation and virtual coaching, were associated with greater mHealth engagement in an obesity management programme. In the present study, adolescents with higher perceived social support demonstrated a stronger association between mHealth app engagement and health-promoting behaviour, suggesting that supportive social environments may reinforce adolescents' engagement with digital health information in daily behaviour contexts.

This pattern is developmentally plausible. Adolescents frequently rely on family members, peers, teachers,

and other significant persons for encouragement, modelling, reminders, and emotional reinforcement of health-relevant actions. mHealth messages may therefore be more strongly associated with behaviour when they are embedded within or reinforced by interpersonal relationships that render health recommendations motivationally salient. Conversely, adolescents with limited social support may encounter digital health information but lack sufficient reinforcement to apply recommendations consistently.

Digital literacy also appeared to strengthen the association between mHealth app engagement and health-promoting behaviour. Adolescents with higher digital literacy may be better able to search for relevant health information, assess its credibility, understand health messages, and apply recommendations in daily routines. This finding is consistent with theoretical predictions and prior empirical evidence. Kim et al. (2023) reported a positive meta-analytic relationship between eHealth literacy and health-related behaviours across demographic groups. Wang et al. (2022) found associations between eHealth literacy and health-promoting behaviours among Chinese adolescents. Taba et al. (2022) noted that adolescents' self-reported confidence in online health information seeking may exceed their demonstrated ability to critically appraise information quality, suggesting that subjective eHealth literacy does not always correspond to effective behaviour change. Recent adolescent digital health literacy studies further show that interactive and co-designed educational resources can improve adolescents' appraisal of online health information and make digital literacy education more relevant to their lived digital experiences (Aloi et al., 2025; Hawkins et al., 2025).

These findings are particularly important in the Indonesian context, where smartphone access is increasingly widespread but digital literacy may vary across socioeconomic backgrounds, school settings, and geographic areas. The use of culturally validated instruments, including the Indonesian versions of the MSPSS and I-eHEALS, strengthens the construct validity of the measures employed (Laksmita et al., 2020; Wijaya & Kloping, 2021). Collectively, the findings support the view that mHealth should not be treated as a stand-alone technological solution but rather as a component within a broader adolescent health promotion ecosystem that incorporates digital education, family and peer support, school engagement, youth-friendly health services, and attention to digital equity (Li et al., 2024; Raeside, 2025).

LIMITATIONS AND FUTURE DIRECTIONS

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inference and does not establish temporal ordering between mHealth app engagement and health-promoting

behaviour. Reverse causality cannot be excluded, as adolescents who already engage in health-promoting behaviours may be more likely to seek and use mHealth applications. Second, all measures were self-reported, introducing the possibility of social desirability bias and shared-method variance. In particular, the MAUQ assessed perceived usability and engagement rather than objectively logged or verified mHealth use. Third, although multistage sampling was used, detailed recruitment-flow counts, including the number of eligible students, refusals, incomplete consent forms, and the overall response rate, were not available in the analytic file. Future reports should document the full participant flow in accordance with STROBE recommendations. Fourth, because students were nested within schools and classes but cluster identifiers were not retained for analysis, the regression models did not estimate cluster-robust or multilevel standard errors.

Fifth, the study was conducted within a single region of one Indonesian province, and the degree to which findings generalise to other regions or countries requires further investigation. Sixth, only two moderators were examined. Other potentially relevant constructs, including general health literacy, intrinsic motivation, technology self-efficacy, teacher support, counsellor support, and application quality, were not assessed.

Future research should employ longitudinal or experimental designs to clarify whether strengthening digital literacy and social support causally improves behavioural outcomes among adolescents engaged in mHealth programmes. Randomised controlled trials incorporating digital literacy training modules or social support enhancement components alongside mHealth interventions would permit stronger causal inferences. Multi-provincial or national-level studies are needed to evaluate the generalisability of the present moderation findings. Future investigations should also incorporate objective indicators of mHealth use, such as application usage logs, screen time data, and digital health task performance assessments, to complement self-report measures and improve construct validity.

CLINICAL IMPLICATIONS

The findings carry practical implications for clinical, school-based, and public health practice. Healthcare providers, school nurses, public health practitioners, and adolescent programme planners should consider assessing digital literacy before implementing mHealth interventions at scale. Adolescents with lower digital literacy may require orientation sessions, simplified content, visual explanations, guided information appraisal, or structured digital health education before strong associations between mHealth engagement and

health-promoting behaviour can reasonably be expected.

mHealth interventions for adolescents should also incorporate structured social support components, such as peer discussion groups, teacher facilitation, parental guidance materials, counsellor feedback mechanisms, or moderated group activities embedded within the digital platform. The significant moderation by perceived social support suggests that health promotion messages delivered through mobile channels are more likely to be associated with healthier behaviour when reinforced by trusted individuals in adolescents' daily environments.

School-based and community-based mHealth programmes should integrate digital health content with broader health education, counselling, and peer mentoring activities. Adolescents who fall below the observed social support and digital literacy thresholds should not be excluded from mHealth initiatives. Rather, they may require additional preparatory support to reduce the possibility that digital health interventions widen existing health inequalities.

CONCLUSIONS

Self-reported mHealth app engagement was positively associated with health-promoting behaviour among Indonesian adolescents from Bandung City and Bandung Regency. Perceived social support and digital literacy each independently predicted health-promoting behaviour and significantly moderated the association between self-reported mHealth app engagement and health-promoting behaviour. The associations were stronger among adolescents with higher perceived social support and digital literacy, and Johnson-Neyman analyses identified specific threshold values of each moderator above which the association between mHealth app engagement and health-promoting behaviour reached statistical significance. These findings suggest that adolescent mHealth programmes should integrate structured digital health literacy development and socially supported engagement strategies that may help strengthen and more equitably support health promotion outcomes across diverse adolescent populations.

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AUTHOR CONTRIBUTIONS

LJ: conceptualisation, methodology, investigation, data curation, formal analysis, interpretation of findings, writing original draft preparation, writing, review and editing, and approval of the final manuscript. MI: methodology, data collection, writing, review and editing, and approval of the final manuscript. RI: supervision, writing, review and editing, and approval of the final manuscript.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The dataset supporting the findings of this study is available from the corresponding author upon reasonable request. Due to ethical and privacy considerations pertaining to adolescent participants, the dataset is not publicly archived.

REFERENCES

Aguinis, H., Beaty, J. C., Boik, R. J., & Pierce, C. A. (2005). Effect size and power in assessing moderating effects of categorical variables using multiple regression: A 30-year review. Journal of Applied Psychology, 90(1), 94-107. https://doi.org/10.1037/0021-9010.90.1.94

Aloi, M. A., Caldwell, P. H., Taba, M., Kang, M., Skinner, S. R., Bray, L., & Scott, K. M. (2025). Co-designing an online educational resource to help adolescents improve their digital health literacy. BMC Public Health, 25, Article 1870. https://doi.org/10.1186/s12889-025-22949-0

Baumann, H., Fiedler, J., Wunsch, K., Woll, A., & Wollesen, B. (2022). mHealth interventions to reduce physical inactivity and sedentary behavior in children and adolescents: Systematic review and meta-analysis of randomized controlled trials. JMIR mHealth and uHealth, 10(5), e35920. https://doi.org/10.2196/35920

Colder Carras, M., Aljuboori, D., Shi, J., Date, M., Karkoub, F., Garcia Ortiz, K., Abreha, F. M., & Thrul, J. (2024). Prevention and health promotion interventions for young people in the context of digital well-being: Rapid systematic review. Journal of Medical Internet Research, 26, e59968. https://doi.org/10.2196/59968

Conley, C. S., Raposa, E. B., Bartolotta, K., Broner, S. E., Hareli, M., Forbes, N., Christensen, K. M., & Assink, M. (2022). The impact of mobile technology-delivered interventions on youth well-being: Systematic review and 3-level meta-analysis. JMIR Mental Health, 9(7), e34254. https://doi.org/10.2196/34254

Council for International Organizations of Medical Sciences. (2016). International ethical guidelines

for health-related research involving humans. CIOMS.

Deslippe, A. L., De-Jongh Gonzalez, O., Buckler, E. J., Ball, G. D. C., Ho, J., Bucholz, A., Morrison, K. M., & Masse, L. C. (2023). Do individual characteristics and social support increase children's use of an mHealth intervention? Findings from the evaluation of a behavior change mHealth app, Aim2Be. Childhood Obesity, 19(7), 435-442. https://doi.org/10.1089/chi.2022.0055

Eaton, C., Vallejo, N., McDonald, X., Wu, J., Rodriguez, R., Muthusamy, N., Mathioudakis, N., & Riekert, K. A. (2024). User engagement with mHealth interventions to promote treatment adherence and self-management in people with chronic health conditions: Systematic review. JMIR mHealth and uHealth, 12, e50508. https://doi.org/10.2196/50508

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavior Research Methods, 41(4), 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Hawkins, A., Taba, M., Caldwell, P. H. Y., Kang, M., Skinner, S. R., & McCaffery, K. (2025). Enhancing digital health literacy in adolescents: Evaluation of a co-designed educational app. BMC Public Health, 25, Article 3869. https://doi.org/10.1186/s12889-025-25022-y

Hayes, A. F. (2022). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach (3rd ed.). Guilford Press.

Kim, K., Shin, S., Kim, S., & Lee, E. (2023). The relation between eHealth literacy and health-related behaviors: Systematic review and meta-analysis. Journal of Medical Internet Research, 25, e40778. https://doi.org/10.2196/40778

Laksmita, O. D., Chung, M.-H., Liao, Y.-M., & Chang, P.-C. (2020). Multidimensional Scale of Perceived Social Support in Indonesian adolescent disaster survivors: A psychometric evaluation. PLOS ONE, 15(3), e0229958. https://doi.org/10.1371/journal.pone.0229958

Li, Z., Lu, F., Wu, J., Bao, R., Rao, Y., Yang, Y., & Wang, H. (2024). Usability and effectiveness of eHealth and mHealth interventions that support self-management and health care transition in adolescents and young adults with chronic disease: Systematic review. Journal of Medical Internet Research, 26, e56556. https://doi.org/10.2196/56556

Mancone, S., Corrado, S., Tosti, B., Spica, G., & Diotaiuti, P. (2024). Integrating digital and interactive approaches in adolescent health literacy: A comprehensive review. Frontiers in Public Health, 12, 1387874. https://doi.org/10.3389/fpubh.2024.1387874

Norman, C. D., & Skinner, H. A. (2006). eHEALS: The eHealth Literacy Scale. Journal of Medical Internet Research, 8(4), e27. https://doi.org/10.2196/jmir.8.4.e27

Raeside, R. (2025). Advancing adolescent health promotion in the digital era. Health Promotion International, 40(2), daae172. https://doi.org/10.1093/heapro/daae172

Sari, E. N. (2023). The Indonesian digital health landscape. Health Intervention and Technology Assessment Program. https://www.hitap.net/en/documents/187528

Sequi-Dominguez, I., Cavero-Redondo, I., Alvarez-Bueno, C., Lopez-Gil, J. F., Martinez-Vizcaino, V., & Pascual-Morena, C. (2024). Effectiveness of eHealth interventions promoting physical activity in children and adolescents: Systematic review and meta-analysis. Journal of Medical Internet Research, 26, e41649. https://doi.org/10.2196/41649

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. Indian Journal of Dermatology, 61(3), 261-264. https://doi.org/10.4103/0019-5154.182410

Singh, B., Ahmed, M., Staiano, A. E., Vasiloglou, M. F., Gough, C., Petersen, J. M., Yin, Z., Vandelanotte, C., Kracht, C., Fiedler, J., Timm, I., Dallinga, J., Sivakumar, B., Baumann, H., Huong, C., Wunsch, K., Suarez-Reyes, M., Schoeppe, S., Button, A. M., Spring, K., & Maher, C. (2025). Lifestyle eHealth and mHealth interventions for children and adolescents: Systematic umbrella review and meta-meta-analysis. Journal of Medical Internet Research, 27, e69065. https://doi.org/10.2196/69065

Taba, M., Allen, T. B., Caldwell, P. H. Y., Skinner, S. R., Kang, M., McCaffery, K., & Scott, K. M. (2022). Adolescents' self-efficacy and digital health literacy: A cross-sectional mixed methods study. BMC Public Health, 22, 1223. https://doi.org/10.1186/s12889-022-13599-7

Tabrizi, J. S., Doshmangir, L., Khoshmaram, N., Shakibazadeh, E., Abdolahi, H. M., & Khabiri, R. (2024). Key factors affecting health-promoting behaviors among adolescents: A scoping review. BMC Health Services Research,

24, 58. https://doi.org/10.1186/s12913-023-10510-x

Talens, C., da Quinta, N., Adebayo, F. A., Erkkola, M., Heikkila, M., Bargiel-Matusiewicz, K., Ziolkowska, N., Rioja, P., Lys, A. E., Santa Cruz, E., & Meinila, J. (2025). Mobile- and web-based interventions for promoting healthy diets, preventing obesity, and improving health behaviors in children and adolescents: Systematic review of randomized controlled trials. Journal of Medical Internet Research, 27, e60602. https://doi.org/10.2196/60602

UNICEF Indonesia. (2025). Indonesia adolescent health profile 2024. UNICEF. https://www.unicef.org/indonesia/health/reports/adolescent-health-profile

Van Baelen, F., De Regge, M., Lariviere, B., Verleye, K., Schelfout, S., & Eeckloo, K. (2022). Role of social and app-related factors in behavioral engagement with mHealth for improved well-being among chronically ill patients: Scenario-based survey study. JMIR mHealth and uHealth, 10(8), e33772. https://doi.org/10.2196/33772

von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., & Vandenbroucke, J. P. (2007). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. PLOS Medicine, 4(10), e296. https://doi.org/10.1371/journal.pmed.0040296

Walker, S. N., Sechrist, K. R., & Pender, N. J. (1987). The Health-Promoting Lifestyle Profile: Development and psychometric characteristics. Nursing Research, 36(2), 76-81.

Wang, J.-W., Zhu, Z.-C., Zhang, S.-L., Fan, J., Jin, Y., Gao, Z.-L., Chen, W.-D., & Li, X. (2024). Effectiveness of mHealth app-based interventions for increasing physical activity and improving physical fitness in children and adolescents: Systematic review and meta-analysis. JMIR mHealth and uHealth, 12, e51478. https://doi.org/10.2196/51478

Wang, X., Yue, T., & Mo, P. K. H. (2022). The associations among cognitive social factors, eHealth literacy and health-promoting behaviors in Chinese adolescents. Health Promotion International, 37(6), daac143. https://doi.org/10.1093/heapro/daac143

Wani, C., McCann, L., Lennon, M., & Radu, C. (2024). Digital mental health interventions for adolescents in low- and middle-income countries: Scoping review. Journal of Medical Internet Research, 26, e51376. https://doi.org/10.2196/51376

Wijaya, M. C., & Kloping, Y. P. (2021). Validity and reliability testing of the Indonesian version of the eHealth Literacy Scale during the COVID-19 pandemic. Health Informatics Journal, 27(1), 1460458220975466. https://doi.org/10.1177/1460458220975466

World Health Organization. (2021). Global strategy on digital health 2020-2025. World Health Organization. https://www.who.int/docs/default-source/documents/gs4dhdaa2a9f352b0445bafbc79ca799dce4d.pdf

World Health Organization. (2025). Mental health of adolescents. https://www.who.int/news-room/fact-sheets/detail/adolescent-mental-health

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA, 310(20), 2191-2194. https://doi.org/10.1001/jama.2013.281053

Zhou, L., Bao, J., Setiawan, I. M. A., Saptono, A., & Parmanto, B. (2019). The mHealth App Usability Questionnaire (MAUQ): Development and validation study. JMIR mHealth and uHealth, 7(4), e11500. https://doi.org/10.2196/11500

Zimet, G. D., Dahlem, N. W., Zimet, S. G., & Farley, G. K. (1988). The Multidimensional Scale of Perceived Social Support. Journal of Personality Assessment, 52(1), 30-41. https://doi.org/10.1207/s15327752jpa5201_2