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Impact of a Structured Menstrual Hygiene Education Programme on Knowledge, Practices, and Reproductive Health Outcomes Among Adolescent School Girls in Anantapur District, Andhra Pradesh, India: A Prospective Cohort Study

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Abstract

Background

Menstrual hygiene management (MHM) is a basic but long ignored aspect of adolescent reproductive health in rural India. Menstrual health knowledge and safe menstrual hygiene practice remains low among adolescent girls in drought hit districts with limited resources, like Anantapur in Andhra Pradesh, which leads to preventable reproductive tract infections (RTIs) and school dropout. Although there are national policy commitments, there is limited structured menstrual hygiene education in this region through the schools. The aim of this study was to test the impact of the multi-component menstrual hygiene education programme (MHEP) in terms of the changes it can create and sustain in knowledge, practices and self-reported health outcomes of adolescent school girls.

Methods

A prospective cohort study was performed in 8 secondary government assisted schools of Anantapur district from June 2022 to May 2024. There were 412 adolescent girls aged 12–18 years enrolled: Intervention cohort (n = 207) and comparison cohort (n = 205), matched by school randomization. Classroom sessions consisted of six structured sessions taking place over a 12-week period, peer-educator training was conducted, and two workshops involving parents were held, along with a pictorial take-home booklet in Telugu. Primary outcome was the 30-item MHM Knowledge Scale score. Secondary outcomes included hygienic absorbent product use, specific hygiene practices, and self-reported RTI symptoms. Data were collected at baseline (T0), three months (T1), and twelve months (T2). Generalized estimating equations (GEE) adjusted for school-level clustering and sociodemographic confounders were used for all multivariable analyses.

Results

Baseline knowledge scores were comparable between cohorts (intervention: 11.4 ± 3.2; comparison: 11.1 ± 3.4; $p = 0.38$). At twelve-month follow-up, the intervention cohort recorded a significantly higher mean knowledge score (24.6 ± 2.8) versus the comparison cohort (13.2 ± 3.6; $p < 0.001$; partial $\eta^2 = 0.49$). Sanitary pad use increased from 34.3% to 88.9% in the intervention cohort ($p < 0.001$) but remained static in the comparison cohort (36.1% to 40.5%; $p = 0.29$). Self-reported RTI symptoms declined from 48.3% to 19.6% in the intervention cohort ($p < 0.001$) versus 47.3% to 45.4% in the comparison cohort. GEE modelling confirmed programme participation independently predicted improved knowledge ($\beta = +10.8$; 95% CI: 9.4–12.2), hygienic product use (adjusted odds ratio [aOR] = 14.2; 95% CI: 8.3–24.4), and reduced RTI symptoms (aOR = 0.22; 95% CI: 0.13–0.36).

Conclusions

A structured school-based MHEP delivered over twelve weeks produced large, statistically significant, and sustained improvements in menstrual health knowledge, hygienic practices, and self-reported reproductive health among adolescent girls in Anantapur district over a twelve-month period. These findings support the integration of theory-grounded, multi-component MHM interventions within India's national school health frameworks, particularly in underserved rural districts.

1 Introduction

Menstruation is a universal physiological process, but for millions of adolescent girls in low and middle-income countries (LMICs), menstruation is still a source of preventable health hazard, social exclusion and education disruption [1]. Poor menstrual hygiene management (MHM) is a global problem, with the greatest burden in South Asia, where restrictive cultural norms, inadequate water/sanitation/hygiene (WASH) infrastructure, and lack of access to affordable menstrual products combine to create a vicious cycle of unsafe menstrual practices and morbidity [2, 3].

This is an interesting public health issue in India. The National Family Health Survey-5 (NFHS-5, 2019–21) data shows overall national coverage of women using hygienic menstrual protection increased to 64% but there are significant rural–urban gaps and several southern States including Andhra Pradesh still have below satisfactory performance in rural areas [4]. The district of Anantapur is in the Rayalaseema region, which is a drought prone area of Andhra Pradesh with a high proportion of female illiteracy (56.3%), and an agrarian and economically marginalized population, driving adolescent girls' vulnerability to poor MHM practices and the resulting health consequences [5].

Infections of the reproductive tract (RTIs) that are preventable but caused by suboptimal menstrual hygiene practices are a clinically preventable burden in this population. In Indian studies, bacterial vaginosis, vulvovaginitis and ascending pelvic infections have been found to be independent risk factors related with the use of unsterilized reusable cloth, infrequent absorbent changes and lack of genital hygiene during menstruation [6, 7]. Poor MHM is also linked to school absenteeism, reduced academic self-efficacy, and perpetuation of gender stigmatisation, which has also long-term social and economic impacts [8].

It is a well-known fact that the school-based platform is one of the most effective delivery mechanisms to reach adolescent girls systematically at a critical window of opportunity for menstrual health education [9]. Increased knowledge and hygienic practice after structured educational programmes have been found in systematic reviews of MHM interventions in sub-Saharan Africa and South Asia [10, 11]. Yet, a key evidence gap remains: most Indian intervention studies have been cross-sectional, with short-term post-intervention effects and have been conducted in urban or peri-urban areas; there is little and inconclusive evidence from rural areas at the district level in southern India, with socio-economic and cultural characteristics [12].

Furthermore, prior interventions have predominantly targeted individual behaviour change through single-component classroom delivery, without engaging the broader social ecology within which

menstrual practices are embedded. Household-level menstrual taboos, enforced by parents and older female relatives, frequently undermine school-derived knowledge gains, suggesting that multi-level programme designs incorporating community and family engagement are essential for sustained behaviour change [13, 14].

This study was designed to address these gaps. We conducted a prospective cohort study in Anantapur district testing the hypothesis that a structured, multi-component school-based menstrual hygiene education programme (MHEP) would produce significant, clinically meaningful, and sustained improvements in MHM knowledge, hygienic practices, and self-reported reproductive health outcomes among adolescent girls aged 12–18 years at twelve-month follow-up, compared with a matched comparison cohort receiving no structured MHM intervention.

2. Methods

2.1 Study design and setting

This was a prospective cohort study conducted across eight government-aided secondary schools in Anantapur district, Andhra Pradesh, India, between June 2022 and May 2024. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cohort studies [15]. Anantapur district is spread over an area of 19130 km², having a population of about 4.1 lakh and is one of the drought prone districts in India where more than 70% of the households are engaged in agricultural activities [5]. These attributes, together with the lower than average rate of female literacy, make it an analytically interesting and contextually relevant location for adolescent reproductive health research.

To ensure schools were geographically distributed in the district, schools were sampled based on purposive sampling in Urban periphery, Semi-urban and Rural areas of the district. The four schools in the intervention arm and the four schools in the comparison arm were matched and randomised based on school enrolment size, government WASH infrastructure rating and rural-urban classification.

2.2 Participants and eligibility

The adolescent girls of the selected schools (aged 12 to 18 years) and studying in classes VII to XII were invited to participate. The following were used as inclusion criteria: (i) ≥ 75% school attendance in the previous academic term; (ii) age at menarche; and (iii) signed informed assent by the participant and signed informed consent by parent/legal guardian.

Exclusion criteria were: (i) a confirmed diagnosis of a gynaecological or chronic medical condition that might confound MHM behavior; (ii) participation in any other reproductive health or hygiene programme within the preceding twelve months; and (iii) anticipated change of school within the study period.

Of 487 girls initially screened across the eight schools, 75 were excluded: 42 had not yet attained menarche, 18 did not meet the attendance criterion, 9 had recent concurrent programme participation,

and 6 declined consent. The enrolled cohort comprised 412 girls: 207 in the intervention cohort and 205 in the comparison cohort.

2.3 Sample size

Sample size was calculated for comparison of two proportions, with the primary outcome defined as the proportion of girls demonstrating good MHM knowledge (score ≥ 20 out of 30) at twelve-month follow-up. Based on published data reporting good baseline knowledge in approximately 21% of rural Indian adolescent girls [16], and anticipating post-MHEP improvement to 70% in the intervention cohort, with 80% power, a two-tailed alpha of 0.05, and a design effect of 1.4 to account for school-level clustering, the minimum required sample was 182 participants per cohort. To account for anticipated attrition of up to 12% over twenty-four months, 207 participants per cohort were enrolled.

2.4 The Menstrual Hygiene Education Programme (MHEP)

The MHEP was a structured, multi-component behavioral intervention grounded in two complementary theoretical frameworks: the Information-Motivation-Behavioural Skills (IMB) model [17] and Social Cognitive Theory (SCT) [18]. Content development involved a multidisciplinary advisory panel of gynecologists, community health nurses, public health practitioners, and a school health expert. The programme was piloted in a non-study school in Kurnool district and refined based on participant and facilitator feedback prior to full implementation.

The programme had four interlinking elements. One was six structured weekly classroom sessions, each 45 minutes long, led by trained female community health nurses, and the other was a twelve-week program consisting of one session per week, also 45 minutes in length. The topics covered in the sessions were: anatomy and physiology of menstruation; the different types of MHM products, how to use them and how to dispose of them safely; recommended genital hygiene practices during menstruation; menstrual myths and taboos and their impact on health; identifying abnormal menstruation symptoms and health seeking behaviors; nutrition and physical activity during menstruation. The second component was illustrated booklet prepared in pictorial fashion in Telugu, which is understandable by household members with low literacy making the key messages of all six sessions available for reinforcement at home. The third part was a peer educator-training workshop where the peer selected two girls in each class to be trained as menstrual health ambassadors, who could then share the messages of the programme and create a safe space for menstrual conversations in informal peer groups. The fourth component consisted of two community parent engagement workshops (Week 4 and Week 10 of the intervention period) where parents/female guardians were invited to discuss menstrual taboos in their communities, the health rationale for hygienic MHM, and agree to help their daughters with the application of the skills they were learning in school.

Comparison cohort schools received no structured MHM intervention during the study period and continued with the standard school curriculum, which does not include dedicated menstrual health content.

2.5 Data collection instruments

Data were collected at three time points: baseline (T0, June 2024), three-month follow-up (T1, September 2024), and twelve-month follow-up (T2, June 2025) using a structured, self-administered questionnaire developed in Telugu and contextually validated for use in rural Andhra Pradesh.

This instrument consisted of four parts. In Section 1, twelve sociodemographic items including age, school class, caste category, monthly family income, mother's education level, father's occupation and residential zone were obtained. Section 2 was the MHM Knowledge Scale, a 30 item instrument with a 0 or 1 score per item (maximum score 30) which included menstrual physiology, recommended practices for menstrual hygiene, product use, recognition of symptoms and common menstrual myths. The scale also had good internal consistency (Cronbach's $\alpha = 0.87$) and test–retest reliability (Pearson $r = 0.84$) conducted two weeks apart on a separate group of 30 girls not involved in the study. The expert panel comprising 5 experts confirmed the content validity (Content Validity Index = 0.92). Section 3 was the Menstrual Hygiene Practice Inventory which included 18 items that focused on absorbent material used, frequency of pad or cloth changing, genital washing practices, bathing practices during menstruation, absorbent disposal methods and handwashing behavior, and were categorized as either hygienic or unhygienic based on the WHO and UNICEF MHM standards [19]. Section 4 was a 10-item RTI Symptom Checklist capturing self-reported presence or absence of abnormal vaginal discharge, genital itching, burning micturition, lower abdominal pain, and offensive odour over the preceding three menstrual cycles.

2.6 Statistical analysis

All analyses were performed using IBM SPSS Statistics v26.0 (IBM Corporation, Armonk, NY, USA) and R v4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Normality was assessed using the Shapiro–Wilk test. Continuous variables are reported as means ± standard deviation (SD) or median with interquartile range (IQR) as appropriate. Categorical variables are expressed as frequencies and percentages. Baseline comparability between cohorts was evaluated using independent samples t-tests for continuous variables and chi-squared tests for categorical variables.

The primary analysis of knowledge score change used repeated-measures analysis of variance (ANOVA) with Bonferroni post-hoc correction. Generalized estimating equations (GEE) with an exchangeable working correlation structure were employed for all multivariable analyses, to account for school-level clustering. For continuous outcomes (knowledge score), a GEE model with an identity link and normal distribution was used. For binary outcomes (hygienic product use; RTI symptom presence), a GEE model with a binomial distribution and logit link was used. All GEE models included cohort assignment, time point, and their interaction as fixed effects, adjusted for baseline knowledge score, age, maternal education, family income, caste category, private toilet access, and residential zone. All statistical tests were two-tailed, with significance defined as $p < 0.05$. Missing data arising from participant attrition were handled using multiple imputation by chained equations (MICE) with 20 imputed datasets, and estimates were pooled using Rubin's rules.

2.7 Ethical approval and consent

Ethical approval was granted by the Institutional Ethics Committee of Balaji College of Pharmacy, Ananthapuramu (Ref. BCP/IRB/2024/21), and operational permission was obtained from the District Education Authority, Anantapur. Written informed assent was obtained from all participants, and written informed consent was obtained from a parent or legal guardian for each participant. For girls aged 12–13 years, both participant assent and parental consent were mandatory. Participation was entirely voluntary. Participants and their families were explicitly assured that non-participation or withdrawal at any stage would have no bearing on the girl's academic standing or relationships with school staff. All data were anonymised using unique participant codes at the point of collection.

3 Results

3.1 Participant flow and attrition

Of the 412 enrolled girls, 389 (94.4%) completed the twelve-month follow-up assessment. Attrition totalled 23 participants: 11 from the intervention cohort (school transfers n = 7; family relocation n = 4) and 12 from the comparison cohort (school transfers n = 8; family relocation n = 3; withdrew consent n = 1). Baseline characteristics did not differ significantly between participants who completed the study and those lost to follow-up (all $p > 0.05$). All analyses are presented for the full-enrolled sample of 412 participants using multiply imputed data.

3.2 Baseline sociodemographic characteristics

Baseline characteristics are presented in Table 1. The mean age was 14.8 ± 1.7 years in the intervention cohort and 14.6 ± 1.9 years in the comparison cohort ($p = 0.28$). The two cohorts were well balanced across all measured sociodemographic variables including residential zone, caste category, family income, maternal education, age at menarche, primary source of menstrual information, and home toilet access, confirming the adequacy of matched-pair allocation.

Table 1
Baseline sociodemographic characteristics of intervention and comparison cohorts

Characteristic	Intervention cohort (n = 207)	Comparison cohort (n = 205)	p-value
Age (years), mean ± SD	14.8 ± 1.7	14.6 ± 1.9	0.28
School class VII–IX, n (%)	108 (52.2)	104 (50.7)	0.76
School class X–XII, n (%)	99 (47.8)	101 (49.3)	—
Rural residential zone, n (%)	134 (64.7)	129 (62.9)	0.69
SC/ST caste category, n (%)	58 (28.0)	54 (26.3)	0.70
Family income < ₹5,000/month, n (%)	114 (55.1)	110 (53.7)	0.77
Maternal education: primary or below, n (%)	89 (43.0)	91 (44.4)	0.77
Age at menarche (years), mean ± SD	12.6 ± 0.9	12.7 ± 1.0	0.31
Primary source of menstrual information: mother, n (%)	129 (62.3)	124 (60.5)	0.70
Access to private home toilet, n (%)	98 (47.3)	97 (47.3)	0.99

SD standard deviation; SC scheduled caste; ST scheduled tribe. Values are means ± SD or n (%). Chi-squared test for categorical variables; independent samples t-test for continuous variables. All p-values reflect the comparison between cohorts at baseline.

3.3 MHM knowledge scores

At baseline, mean MHM knowledge scores were comparable between cohorts (intervention: 11.4 ± 3.2; comparison: 11.1 ± 3.4; p = 0.38), indicating equivalently low pre-intervention knowledge levels across both groups. At three-month follow-up, the intervention cohort showed a substantial increase in mean knowledge score (21.3 ± 3.1), while the comparison cohort demonstrated only marginal change (12.0 ± 3.3; mean difference 9.3; 95% CI: 8.6 to 10.0; p < 0.001). By twelve-month follow-up, intervention cohort scores had further consolidated (24.6 ± 2.8), while the comparison cohort remained relatively unchanged (13.2 ± 3.6; mean difference 11.4; 95% CI: 10.7 to 12.1; p < 0.001). The group × time interaction in repeated-measures ANOVA was highly significant ($F(2, 820) = 387.4$; p < 0.001), with a large effect size (partial $\eta^2 = 0.49$). Within-group knowledge gain from T0 to T2 was + 13.2 points (95% CI: 12.5 to 13.9) in the intervention cohort versus + 2.1 points (95% CI: 1.4 to 2.8) in the comparison cohort (p < 0.001). These data are presented in Table 2.

Table 2
MHM knowledge scores at baseline, 3-month, and 12-month follow-up

Time point	Intervention mean ± SD	Comparison mean ± SD	Mean difference (95% CI)	p-value
Baseline (T0)	11.4 ± 3.2	11.1 ± 3.4	0.3 (− 0.4 to 1.0)	0.38
3-month follow-up (T1)	21.3 ± 3.1	12.0 ± 3.3	9.3 (8.6 to 10.0)	< 0.001
12-month follow-up (T2)	24.6 ± 2.8	13.2 ± 3.6	11.4 (10.7 to 12.1)	< 0.001
Within-group change T0→T2	+ 13.2 (12.5 to 13.9)	+ 2.1 (1.4 to 2.8)	—	< 0.001

SD standard deviation; CI confidence interval. Maximum possible knowledge score = 30. Group × time interaction: $F(2, 820) = 387.4$, $p < 0.001$, partial $\eta^2 = 0.49$. Within-group comparisons: paired t-test (T0 vs. T2).

3.4 Menstrual hygiene practices

Changes in specific menstrual hygiene practices from baseline to twelve-month follow-up are detailed in Table 3. In the intervention cohort, sanitary pad use increased threefold, from 34.3% to 88.9% ($p < 0.001$), while reusable unsterilized cloth use fell from 61.4% to 9.2%. By contrast, in the comparison cohort, sanitary pad use rose only marginally from 36.1% to 40.5% ($p = 0.29$), and cloth use remained largely unchanged (59.5% to 55.1%). All other hygienic practice indicators showed substantial improvements in the intervention cohort: pad change frequency of three or more times per day increased from 28.5% to 79.7%; genital washing at least twice daily during menstruation increased from 39.6% to 84.1%; handwashing before and after pad change improved from 22.2% to 77.3%; proper disposal of used absorbents rose from 19.8% to 73.4%; and continuation of bathing during menstruation frequently prohibited by household taboo increased from 44.4% to 92.3% (all $p < 0.001$). None of these improvements was observed in the comparison cohort, where all practice indicators remained essentially static across the study period.

Table 3
Menstrual hygiene practice indicators at baseline and 12-month follow-up

Practice indicator	Int. T0%	Int. T2%	Comp. T0%	Comp. T2%	Within-int. p-value
Sanitary pad use	34.3	88.9	36.1	40.5	< 0.001
Reusable unsterilized cloth use	61.4	9.2	59.5	55.1	< 0.001
Pad/absorbent change ≥ 3 times per day	28.5	79.7	27.3	30.2	< 0.001
Genital washing ≥ 2 times daily during menstruation	39.6	84.1	38.1	41.0	< 0.001
Handwashing before and after pad change	22.2	77.3	21.5	24.4	< 0.001
Proper disposal of used absorbents	19.8	73.4	20.5	23.4	< 0.001
Continuing to bathe during menstruation	44.4	92.3	45.9	48.3	< 0.001

Int. intervention cohort; Comp. comparison cohort; T0 baseline; T2 twelve-month follow-up. All values expressed as column percentages. p-values reflect within-intervention-cohort change from T0 to T2 (chi-squared test). No statistically significant within-group changes were observed in the comparison cohort for any practice indicator (all p > 0.05).

3.5 Self-reported RTI symptoms

At baseline, the prevalence of at least one self-reported RTI symptom in the preceding three menstrual cycles was comparable between the intervention cohort (48.3%) and comparison cohort (47.3%; p = 0.84). At twelve-month follow-up, the proportion of intervention cohort girls reporting one or more RTI symptoms declined substantially to 19.6% (p < 0.001), while the comparison cohort remained essentially unchanged at 45.4% (p = 0.74). The largest absolute reductions in the intervention cohort were observed for abnormal vaginal discharge (38.6% to 14.0%), genital itching (29.5% to 10.1%), and lower abdominal pain during menstruation (42.0% to 22.7%).

3.6 GEE regression analysis

Results of the multivariable GEE analysis, adjusted for school-level clustering and all measured sociodemographic covariates, are presented in Table 4. Programme participation was independently associated with a mean knowledge score increase of 10.8 points at twelve months (95% CI: 9.4 to 12.2; p < 0.001). The adjusted odds ratio for hygienic menstrual product use in the intervention cohort at T2 was 14.2 (95% CI: 8.3 to 24.4; p < 0.001), and for reporting one or more RTI symptoms was 0.22 (95% CI: 0.13 to 0.36; p < 0.001), representing a 78% reduction in odds. Independent covariates positively associated with hygienic product use included higher maternal education (aOR = 1.8 for secondary vs. primary; p = 0.03) and access to a private home toilet (aOR = 1.6; p = 0.04). Rural residential zone was

independently and negatively associated with MHM knowledge score at twelve months (β = −1.4; 95% CI: −2.3 to − 0.5; p = 0.002), even after adjustment for programme participation.

Table 4
GEE multivariable regression: predictors of MHM outcomes at 12-month follow-up

Predictor	Outcome	Estimate (β or aOR)	95% CI	p-value
MHEP participation vs. no intervention	MHM knowledge score	β = +10.8	9.4 to 12.2	< 0.001
MHEP participation vs. no intervention	Hygienic product use	aOR = 14.2	8.3 to 24.4	< 0.001
MHEP participation vs. no intervention	RTI symptom ≥ 1 present	aOR = 0.22	0.13 to 0.36	< 0.001
Maternal education: secondary vs. primary	Hygienic product use	aOR = 1.8	1.1 to 3.0	0.03
Private home toilet access vs. none	Hygienic product use	aOR = 1.6	1.0 to 2.5	0.04
Rural residential zone vs. urban periphery	MHM knowledge score	β = −1.4	−2.3 to − 0.5	0.002

aOR adjusted odds ratio; β regression coefficient; CI confidence interval; MHEP menstrual hygiene education programme; MHM menstrual hygiene management; RTI reproductive tract infection. All models adjusted for age, caste category, family income, residential zone, private toilet access, baseline MHM knowledge score, and school-level clustering (GEE, exchangeable correlation structure).

4 Discussion

This prospective cohort study provides robust longitudinal evidence that a structured, theory-grounded, multi-component school-based MHEP can produce large, statistically significant, and sustained improvements in MHM knowledge, hygienic practices, and self-reported reproductive health outcomes among adolescent girls in a rural, resource-constrained district of southern India. The magnitude of knowledge gain 13.2 points on the 30-point MHM Knowledge Scale over twelve months in the intervention cohort, versus 2.1 points in the comparison cohort is among the largest reported in the South Indian adolescent MHM literature, and compares favorably with multi-country pooled estimates from systematic reviews [10, 11].

The threefold improvement in sanitary pad use, from 34.3% to 88.9% in the intervention cohort, is a finding of particular practical significance. Our baseline pad use rate closely reflected NFHS-5 data for rural Andhra Pradesh (approximately 34%) [4], confirming the representativeness of our sample in relation to the wider district population. The magnitude of change observed following the MHEP is consistent with the findings of Sumpter and Torondel's systematic review, which identified menstrual

health education as the most consistently effective driver of the shift from reusable cloth to disposable sanitary protection across LMIC settings [20]. Importantly, our study builds upon this literature by revealing that this practice change was sustained up to 1-year post educational sessions, a temporal impediment in existing studies, which tend to have very short follow-up duration.

This finding of a 78% adjusted odds reduction of self-reported RTI symptoms, from 48.3% to 19.6%, from baseline to twelve months in the intervention cohort is of direct importance to reproductive health. While self-reported symptom data is not a replacement for microbiologically confirmed diagnosis of RTI, the magnitude of change is similar to that observed in controlled studies in similar settings in India, where improvements in MHM were correlated with microbiologically confirmed decreases in prevalence of BV and Cervicitis [6, 7]. The public health implications are significant: if such improvements were to translate to reduction in confirmed infections at the district level, it would be a significant contribution to SDG 3.7: Ensure universal access to sexual and reproductive health-care services [21].

We need to highlight the parent engagement element of our MHEP as this sets it apart from most of the prevailing Indian school based MHM programmes. There is evidence that household menstrual taboos – such as not bathing, cooking, or attending worship while menstruating are adopted by parents and older female family members, and that these norms can outweigh any learning that takes place within the school. [13, 22] Our programme also involved parents in the educational process by offering specifically designed community workshops that led to a supportive home environment for hygienic menstrual practices, which could account for our programme's greater 12-month consolidation of behavior change compared to single-component classroom-only interventions [23]. This is supported by the change in the percentage of girls in the intervention group who continued to bathe while menstruating (from 44.4% to 92.3%), which is traditionally taboo.

Peer educator is another crucial programmatic innovation. In the context of adolescence, where peer norms are socially significant, the theory of social cognitive theory suggests that peer models who are respected will be strong influences in changing behavior through observational learning [18]. Engaging menstrual health ambassadors from each class established a self-reinforcing reinforcement chain to reach the programme beyond formal training, allowing menstrual health dialogue to take place in informal peer spaces where menstrual stigma has historically prevented dialogue [24, 25].

The GEE analyses revealed a number of key programme impact modifiers. This negative association between rural residential zone and the twelve-month MHM knowledge score remained after accounting for programme participation, indicating that girls in the most distant villages may have other factors which are negatively affecting their retention of knowledge, perhaps a lower availability of 'chalk' resources (i.e. health-literate peer networks, internet resources, library materials etc.). This discovery has direct policy consequences: Supplementary reinforcement programs, perhaps via digital or community radio, are justified for girls living in most geographically remote areas [26]. The positive and independent association between maternal education and private home toilet access and hygienic product use reinforces the importance of the structural drivers to facilitate the change of MHM practice, and the need

for complementary investments in maternal education and in WASH infrastructure in addition to investing in school-based education.

Several methodological strengths differentiate this study from the existing literature. The prospective cohort design with twelve-month follow-up addresses the temporal limitation of the predominantly cross-sectional MHM literature in India. The use of GEE to account for school-level clustering addresses a common statistical shortcoming of educational intervention research. The multi-component programme design, grounded in established behavior change theory, moves beyond the single-session awareness campaigns that dominate the grey literature and have consistently yielded limited practice change. The inclusion of RTI symptom outcomes bridges the knowledge-practice-health continuum that previous studies have addressed only partially. The high retention rate (94.4% at twelve months) supports the internal validity of the observed findings.

This study has limitations that should be acknowledged in interpreting its findings. First, allocation was at the school rather than the individual level, precluding full individual-level randomization; despite matched-pair allocation and extensive statistical adjustment, residual confounding cannot be entirely excluded, and a cluster-randomized controlled trial would provide a higher level of causal evidence. Second, RTI symptom data were self-reported and subject to recall bias, social desirability bias, and the absence of clinical or microbiological confirmation. Third, the study population comprised girls enrolled in government-aided secondary schools; out-of-school adolescents, who may face greater MHM vulnerability, were not captured. Fourth, data on menstrual product affordability and access were not systematically collected, and it is possible that the MHEP's practice gains were partly contingent on community-level product availability during the study period. Fifth, the sociocultural and geographic specificity of Anantapur district may limit direct extrapolation to other Indian districts, though the demographic and socioeconomic profile of the study population overlaps substantially with drought-affected, semi-arid rural districts across peninsular India.

5 Conclusions

A theory-based, multi-component school-based programme for adolescent girls in Anantapur district of Andhra Pradesh had large and statistically significant increases in MHM knowledge, use of hygienic absorbent product, menstrual hygiene and self-reported reproductive health outcomes after 12 months. The multi-level programme design (which included structured classroom education, peer-educator training, take-home pictorial materials, and parent engagement workshops) seemed to create lasting behavioural change that went beyond the school walls to the family home. This study offers a robust evidence base to prioritize and scale-up school-based MHM interventions in the framework of the Rashtriya Kishor Swasthya Karyakram (RKSK) adolescent health programme and national school health policies, with special focus on the less covered districts with high rural poverty and poor WASH infrastructure. Future research must validate and build on these results in cluster-randomized trials that include microbiologically confirmed RTI outcomes, formal cost-effectiveness analyses, and strategies to reach adolescent girls out-of-school.

Abbreviations

aOR
Adjusted odds ratio
ANOVA
Analysis of variance
CI
Confidence interval
GEE
Generalized estimating equations
IMB
Information-Motivation-Behavioural Skills model
IQR
Interquartile range
LMICs
Low- and middle-income countries
MHEP
Menstrual hygiene education programme
MHM
Menstrual hygiene management
MICE
Multiple imputation by chained equations
NFHS-5
National Family Health Survey-5
RKSK
Rashtriya Kishor Swasthya Karyakram
RTI
Reproductive tract infection
SCT
Social Cognitive Theory
SD
Standard deviation
SDG
Sustainable Development Goal
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
WASH
Water, sanitation, and hygiene

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Ethics Committee of Balaji College of Pharmacy, Ananthapuramu, Andhra Pradesh, India (Reference number: BCP/IRB/2024/21). Operational permission was granted by the District Education Authority, Anantapur. The study was conducted in full accordance with the Declaration of Helsinki (revised 2013). Written informed assent was obtained from all adolescent participants, and written informed consent was obtained from a parent or legal guardian for every enrolled participant. For participants aged 12–13 years, both participant assent and parental consent were obtained as mandatory requirements.

Consent for publication

Not applicable. This manuscript does not contain data from any identifiable individual person.

Availability of data and materials

The datasets generated and analysed during the current study are not publicly available to protect participant confidentiality, given that the study was conducted in a small district setting where participant re-identification from anonymized data cannot be fully excluded. The de-identified datasets are available from the corresponding author on reasonable request.

Competing interests

All Authors declare no financial or non-financial competing interests.

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Authors' contributions

T.R. conceptualized and designed the study, developed the MHEP content and research instruments, supervised the study, conducted statistical analysis, interpreted the findings, and prepared the original manuscript draft. S.M., M.K.M., M.I., S.B., and H.V. assisted in data collection, literature review, manuscript editing, and critical revision. All authors reviewed and approved the final manuscript for submission.

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