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Integrating Reproductive Health and Diabetes Education for Early Prevention of Gestational Diabetes Mellitus among Adolescent Girls: A Baseline Study in Aceh Besar, Indonesia

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ABSTRACT:

Background: Gestational diabetes mellitus (GDM) is influenced substantially by preconception metabolic health, making adolescence a critical window for early prevention. However, reproductive health and diabetes-related education are rarely integrated within adolescent health promotion programs.

Objective: To assess baseline knowledge, healthy lifestyle behaviours, and metabolic risk profiles as the basis for developing an integrated reproductive health and diabetes education program for the early prevention of GDM among adolescent girls**.**

Methods: A baseline analysis was conducted within a quasi-experimental pretest–posttest control-group study involving 48 adolescent girls aged 15–19 years from three senior/vocational high schools in Aceh Besar, Indonesia. Participants were recruited using purposive sampling. Baseline outcomes included reproductive health and diabetes knowledge, healthy lifestyle behaviours, body mass index (BMI), waist circumference, random blood glucose (RBG), and blood pressure. Associations were examined using Pearson/Spearman correlation, Mann–Whitney U and Kruskal–Wallis tests, and multiple linear regression.

Results: Mean knowledge score was 9.54 ± 3.41 of 16 (59.6%), with only 22.9% of participants classified as having good knowledge. The mean healthy lifestyle behaviour score was 55.94 ± 8.07 of 96 (58.3%), while only 4.2% achieved the good category. Metabolic risk was substantial: 62.5% had obesity (BMI ≥25 kg/m²), 80.9% had central obesity, and 44.7% had blood pressure ≥120/80 mmHg. Overall, 81.2% had at least two of six predefined preconception GDM risk factors. BMI was independently associated with RBG (B = 1.064 mg/dL per kg/m²; $p = 0.023$), whereas knowledge was not significantly associated with healthy lifestyle behaviours ($r = 0.048$; $p = 0.744$) or BMI ($r = 0.037$; $p = 0.802$).

Conclusion: Adolescent girls in this high-risk setting demonstrated concurrent deficits in diabetes and reproductive health knowledge, healthy lifestyle behaviours, and metabolic health, with limited evidence of a direct relationship between knowledge and health-related outcomes. These findings support an integrated intervention that extends beyond information provision to emphasize behavioural skills, self-monitoring, and early metabolic risk reduction. The baseline findings provide an empirical foundation for evaluating the effectiveness of a structured reproductive health and diabetes education program for early GDM prevention.

KEYWORDS: adolescent girls; diabetes education; gestational diabetes mellitus; metabolic risk; reproductive health; preconception prevention**.**

INTRODUCTION

Gestational diabetes mellitus (GDM) is one of the most common metabolic complications of pregnancy and is characterized by glucose intolerance first recognized during pregnancy[1], [2]. Its global burden has increased in parallel with the rising prevalence of obesity, insulin resistance, and type 2 diabetes mellitus (T2DM)[1], [3]. The International Diabetes Federation estimates that hyperglycemia affects approximately 16.7% of pregnancies worldwide, with GDM accounting for approximately 86% of these cases[3], [4]. This substantial burden highlights the need to move beyond pregnancy-centered management toward prevention strategies that address modifiable metabolic risk factors before conception. The clinical significance of GDM extends well beyond the index pregnancy. Women with a history of GDM have an approximately sevenfold higher risk of subsequently developing T2DM, [5], [6] while offspring exposed to maternal hyperglycemia are at increased risk of obesity, metabolic dysfunction, and diabetes later in life.[7], [8] GDM is also associated with a higher incidence of adverse maternal and neonatal outcomes than normoglycemic pregnancies[8], [9]. Collectively, these intergenerational consequences position GDM not merely as a pregnancy-

specific disorder but as an important precursor within the life-course trajectory of cardiometabolic disease.
Increasing evidence indicates that the risk of GDM is substantially influenced by maternal health before conception. Excess body weight, insulin resistance, unhealthy dietary patterns, and physical inactivity established during adolescence may contribute to metabolic vulnerability later in reproductive life[10], [11]. Among these factors, preconception body mass index (BMI) is consistently recognized as one of the strongest modifiable predictors of GDM[11], [12]. Adolescence therefore represents a critical window for primary prevention because health behaviors, dietary practices, physical activity patterns, and perceptions of reproductive health are progressively established during this developmental period. Intervening before pregnancy may consequently offer greater preventive potential than relying exclusively on screening and treatment after pregnancy has begun. Despite this opportunity, adolescent girls frequently have inadequate knowledge regarding reproductive health and metabolic disorders, including diabetes mellitus. Limited understanding of healthy dietary practices and diabetes risk factors has been associated with less favorable health behaviors and greater metabolic vulnerability[13], [14], [15]. More importantly, reproductive health education and metabolic risk prevention are commonly addressed as separate domains, potentially overlooking their biological and preventive interconnections. Although Indonesia has established adolescent-oriented health-service frameworks, including the *Pelayanan Kesehatan Peduli Remaja* (PKPR), systematic educational programs that integrate reproductive health literacy with diabetes-risk management remain limited[16], [17]. This gap is particularly relevant for adolescent girls, who represent the future population of women entering pregnancy and therefore constitute a strategic target for preconception prevention.

A life-course approach that integrates reproductive health education with early metabolic risk management may provide a more comprehensive prevention strategy than conventional, single-domain health education. Such an approach can simultaneously strengthen adolescents' knowledge, promote healthier dietary and physical-activity behaviors, and increase awareness of modifiable risk factors such as excess adiposity and elevated blood glucose[18], [19], [20]. However, evidence regarding the effectiveness of an integrated educational intervention that explicitly links adolescent reproductive health with GDM prevention remains limited, particularly in Indonesian settings. Establishing whether improvements in knowledge and health behaviors are accompanied by measurable changes in anthropometric and metabolic risk indicators is therefore important for informing adolescent health-promotion programs. Accordingly, this study aimed to develop and evaluate an integrated educational program combining reproductive health education and diabetes-risk management as an early prevention strategy for GDM among adolescent girls. Specifically, the study sought to: **(1)** assess changes in knowledge regarding reproductive health and diabetes mellitus before and after the intervention; **(2)** evaluate changes in healthy lifestyle behaviors, particularly dietary practices and physical activity; and **(3)** assess changes in BMI and other indicators of diabetes risk following the intervention

METHODS

This quasi-experimental pretest–posttest controlled study evaluated an integrated reproductive health and diabetes mellitus (DM) education program among adolescent girls in three senior/vocational high schools in Aceh Besar, Indonesia, in 2026. The study comprised baseline assessment, six weekly intervention sessions, and post-intervention evaluation; this article reports the preliminary and baseline findings. Forty-eight unmarried girls aged 15–19 years with overweight or obesity were purposively recruited and allocated to intervention and control groups (n=24 each). Participants with type 1 or type 2 DM or severe chronic disease requiring ongoing treatment were excluded. Primary outcomes included reproductive health and DM knowledge, healthy lifestyle behaviours, and metabolic risk indicators. Knowledge was assessed using a validated 16-item true/false questionnaire (Cronbach's α=0.767), while lifestyle behaviours were assessed using a 24-item four-point frequency questionnaire covering dietary practices and physical activity (Cronbach's α=0.750). Anthropometric and metabolic measures included BMI, waist circumference (WC), random blood glucose (RBG), and blood pressure (BP). BMI was calculated as weight/height^2 and classified according to WHO Asia-Pacific criteria; central obesity was defined as WC $\geq$80 cm, RBG $\geq$100 mg/dL as an early metabolic-risk marker, and elevated BP as $\geq$120/80 mmHg. Knowledge and behavioural scores were categorized as good ($\geq$76%), moderate (56–75%), or poor (<56%). Continuous variables were summarized as means±standard deviations or medians (range), and categorical variables as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Between-group and multi-group comparisons were performed using the Mann–Whitney *U* and Kruskal–Wallis tests, respectively. Associations were examined using Pearson and Spearman correlations, and multiple linear regression was used to identify predictors of RBG. A cumulative metabolic-risk index (0–6) incorporated BMI $\geq$25 kg/m^2, WC $\geq$80 cm, family history of DM, BP $\geq$120/80 mmHg, RBG $\geq$100 mg/dL, and poor knowledge, categorized as low (0–1), moderate (2–3), or high ($\geq$4) risk. The post-intervention analysis was prespecified. Within-group changes will be assessed using paired *t* tests or Wilcoxon signed-rank tests, and between-group changes using independent *t* tests or Mann–Whitney *U* tests, as appropriate. ANCOVA will further adjust post-intervention outcomes for baseline values. Changes in categorical outcomes will be assessed using the McNemar–Bowker test, with Cohen's *d* and 95% confidence intervals reported alongside *P* values. Statistical significance was set at P<0.05. Ethical approval was obtained from the Health Research Ethics Committee of Poltekkes Kemenkes Aceh, and written informed consent was obtained from participants and their parents or legal guardians.

RESULTS

Baseline Characteristics of Participants

A total of 48 adolescent girls were included in the baseline assessment, with an equal distribution across the three participating schools (16 participants per school; 33.3% each). The mean age was 16.90±0.75 years (range, 16–19 years), with 17-year-olds comprising the largest age group (27/48, 56.2%), followed by those aged 16 years (14/48, 29.2%), 18 years (5/48, 10.4%), and 19 years (2/48, 4.2%). Most participants were in Grade 2 (31/48, 64.6%), while 17 (35.4%) were in Grade 1. A family history of diabetes mellitus was reported by 9 participants (18.8%), whereas a family history of hypertension was reported by only 1 participant (2.1%). These baseline characteristics provide the demographic and familial-risk profile of the study population before implementation of the intervention (Table 1).

Table 1. Baseline characteristics of study participants (n=48)

Characteristic	Category	n	%
Age, years	16	14	29.2
	17	27	56.2
	18	5	10.4
	19	2	4.2
School	SMA DRI	16	33.3
	SMA SM	16	33.3
	SMK AM	16	33.3
Grade level	Grade 1	17	35.4
	Grade 2	31	64.6
Family history of diabetes mellitus	Yes	9	18.8
	No	39	81.2
Family history of hypertension	Yes	1	2.1
	No	47	97.9

Baseline Healthy Lifestyle Behaviours

The mean healthy lifestyle behaviour score was 55.94±8.07 on a possible range of 24–96, equivalent to 58.3% of the maximum score or a mean of 2.33 points per item on the four-point frequency scale. Only 2 participants (4.2%) were classified as having good lifestyle behaviour, compared with 28 (58.3%) with moderate and 18 (37.5%) with poor behaviour (Table 2). Across the 24 behavioural items, responses were predominantly concentrated at low weekly frequencies; for 15 items, the modal response corresponded to behaviours performed only 1–2 times per week. The lowest mean item scores were observed for items 17 (1.94), 1 (1.96), and 19 (1.98), whereas items 22 (3.12) and 13 (2.81) had the highest mean scores. The six items with the lowest baseline scores were subsequently designated as specific behavioural targets for weekly monitoring during the intervention.

Table 2. Pretest results for the three outcome indicators (n = 48)

Objective	Outcome indicator	Mean ± SD	Good, n (%)	Moderate, n (%)	Poor, n (%)
1	Knowledge score (0–16)	9.54 ± 3.41 (59.6%)	11 (22.9)	23 (47.9)	14 (29.2)
2	Behavioral score (24–96)	55.94 ± 8.07 (58.3%)	2 (4.2)	28 (58.3)	18 (37.5)
3	Body mass index (BMI, kg/m²)	27.29 ± 5.33	—	—	—
4	Cumulative risk index (0–6)	2.75 ± 1.41	—	—	—

Baseline assessment revealed a substantial gap between knowledge, health behaviours, and the participants' underlying health-risk profile. The mean knowledge score was 9.54 ± 3.41 (59.6%), corresponding to a moderate level, with only 22.9% of participants achieving a good knowledge level. Similarly, the mean behavioural score was 55.94 ± 8.07 (58.3%), although only 4.2% of participants demonstrated good health behaviours. Meanwhile, the mean BMI was 27.29 ± 5.33 kg/m², and the mean cumulative risk score was 2.75 ± 1.41, indicating a considerable burden of metabolic risk. Collectively, these findings suggest that an effective intervention should extend beyond knowledge acquisition by integrating behavioural modification, self-monitoring, and systematic risk-factor management.

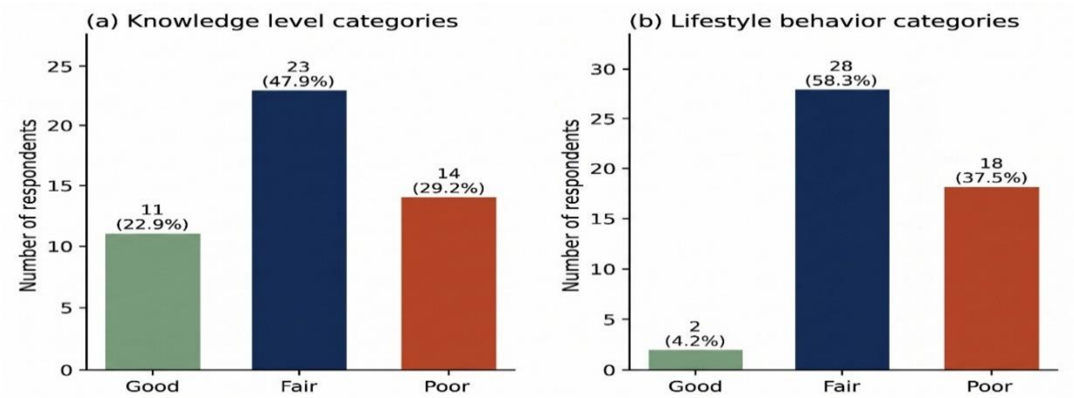

Figure 1. Distribution of knowledge-level categories (a) and healthy lifestyle behaviour categories (b) at baseline (n = 48).

Baseline Anthropometric and Metabolic Risk Indicators

To characterize the baseline cardiometabolic profile of the participants and identify modifiable risk factors relevant to diabetes mellitus prevention, anthropometric and metabolic parameters were assessed before implementation of the intervention. Particular attention was given to body mass index (BMI), waist circumference, random blood glucose (RBG), and blood pressure, as these measures provide complementary information on general adiposity, central adiposity, glycemic status, and cardiovascular risk. The distribution of these parameters was subsequently examined according to established clinical and population-specific thresholds to identify the proportion of participants with potentially elevated metabolic risk.

Anthropometric and Metabolic Parameters

At baseline, the mean BMI was 27.29 ± 5.33 kg/m², with a median of 27.06 kg/m² and a wide range of 17.94–42.41 kg/m². Mean waist circumference was 87.09 ± 9.84 cm, while mean RBG was 99.77 ± 16.81 mg/dL. Mean systolic and diastolic blood pressures were 114.2 ± 14.5 mmHg and 72.3 ± 12.0 mmHg, respectively. The observed variability, particularly in BMI and waist circumference, indicates substantial heterogeneity in adiposity and metabolic risk within the study population (Table 3).

Table 3. Anthropometric and metabolic parameters at baseline

Parameter	n	Mean ± SD	Median	Range
Body weight (kg)	48	64.64 ± 13.28	64.10	39.3–104.4
Height (cm)	48	153.8 ± 4.0	153.0	143.0–162.9
BMI (kg/m²)	48	27.29 ± 5.33	27.06	17.94–42.41
Waist circumference (cm)	48	87.09 ± 9.84	87.00	66.5–129.0
Random blood glucose (mg/dL)	48	99.77 ± 16.81	96.50	69–154
Systolic blood pressure (mmHg)	48	114.2 ± 14.5	116.0	86–147
Diastolic blood pressure (mmHg)	48	72.3 ± 12.0	72.0	48–97

Distribution of Nutritional Status and Diabetes Risk Indicators

The categorical analysis revealed a substantial burden of excess adiposity. Of the 48 participants, 30 (62.5%) were classified as obese and 8 (16.7%) as overweight, indicating that 79.2% had a BMI above the normal range, consistent with the study's eligibility criteria. Central adiposity was even more prevalent: 38 of 48 participants (80.9%) with available waist circumference measurements met the criterion for central obesity. Glycemic indicators showed a less pronounced but clinically relevant pattern. Only one participant (2.1%) had RBG ≥140 mg/dL, whereas 19 participants (39.6%) had RBG between 100 and 139 mg/dL, resulting in 20 participants (41.7%) with RBG ≥100 mg/dL. Blood pressure findings similarly indicated an emerging cardiometabolic risk profile: 17 of 48 participants (36.2%) were classified as having elevated blood pressure/pre-hypertension and 4 (8.5%) met the threshold for hypertension, meaning that 44.7% had blood pressure values above the normal range. Collectively, these findings indicate that excess general and central adiposity coexisted with early abnormalities in glycemic and blood pressure profiles, underscoring the importance of preventive intervention in this population (Table 4).

Table 4. Distribution of nutritional status and diabetes risk indicators at baseline

Category	n	%	Denominator
Nutritional status based on BMI			n = 48
Underweight (<18.5 kg/m²)	2	4.2	—
Normal (18.5–22.9 kg/m²)	8	16.7	—
Overweight (23.0–24.9 kg/m²)	8	16.7	—

Obesity (≥25.0 kg/m²)	30	62.5	—
Waist circumference			n = 48
Normal (<80 cm)	9	19.1	—
Central obesity (≥80 cm)	38	80.9	—
Random blood glucose			n = 48
<100 mg/dL	28	58.3	—
100–139 mg/dL	19	39.6	—
≥140 mg/dL (hyperglycemia)	1	2.1	—
Blood pressure			n = 48
Normal (<120/80 mmHg)	27	55.3	—
Elevated blood pressure/pre-hypertension (120–139/80–89 mmHg)	17	36.2	—
Hypertension (≥140/90 mmHg)	4	8.5	—

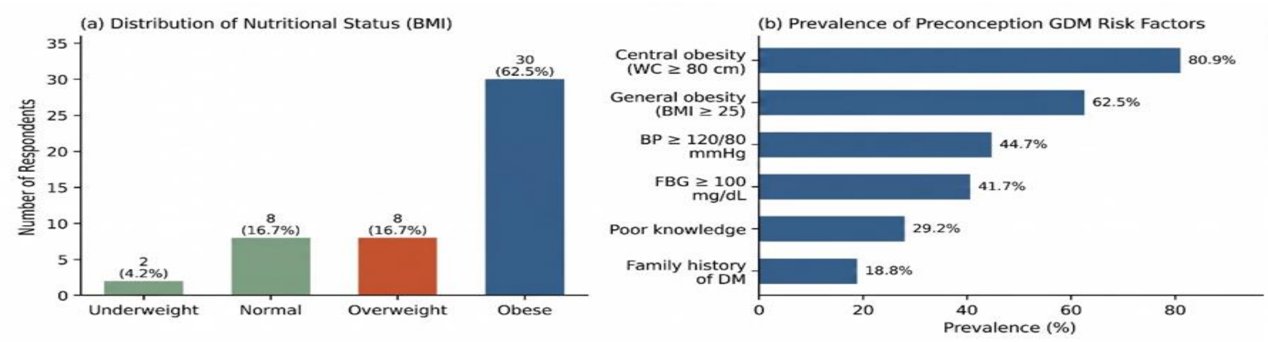

Figure 2. Distribution of nutritional status based on BMI (a) and prevalence of preconception GDM risk factors (b) at baseline

To further characterize the baseline vulnerability to gestational diabetes mellitus (GDM), the individual prevalence and cumulative distribution of preconception risk factors were examined. Rather than considering each risk factor in isolation, the analysis assessed the extent to which multiple metabolic, behavioral, and familial risk factors co-occurred within individual participants. This cumulative approach provides a more comprehensive representation of preconception risk burden and facilitates stratification into low-, moderat , and high-risk groups. The distribution of individual risk factors and their accumulation across participants is presented in Table 5.

Table 5. Prevalence and accumulation of preconceptional GDM risk factors (n = 48)

Risk factor / stratum	Valid n	Positive n	%	Description
Central obesity (waist circumference ≥80 cm)	48	38	80.9	—
General obesity (BMI ≥25 kg/m²)	48	30	62.5	—
Blood pressure ≥120/80 mmHg	48	21	44.7	—
Random blood glucose ≥100 mg/dL	48	20	41.7	—
Poor knowledge	48	14	29.2	<56% correct
Family history of diabetes mellitus	48	9	18.8	—
Number of risk factors per participant			Mean = 2.75 ± 1.41	
Low-risk stratum (0–1 factor)	48	9	18.8	RBG: 88.56 ± 11.08 mg/dL
Moderate-risk stratum (2–3 factors)	48	24	50.0	RBG: 97.29 ± 13.51 mg/dL
High-risk stratum (≥4 factors)	48	15	31.2	RBG: 110.47 ± 19.12 mg/dL

The percentage for each risk factor was calculated using the corresponding number of valid observations as the denominator, whereas risk-stratum percentages were calculated using the total sample of 48 participants. RBG levels differed significantly across risk strata (Kruskal–Wallis H = 10.530; p = 0.005). WC = waist circumference; BMI = body mass index; RBG = random blood glucose; GDM = gestational diabetes mellitus.

Between-Group Differences and Predictors of Random Blood Glucose

To further examine whether anthropometric and metabolic characteristics differed according to obesity status, family history of diabetes mellitus, school, and cumulative risk burden, nonparametric between-group analyses were performed. The Mann–Whitney *U* test showed that participants with central obesity had significantly higher random blood glucose (RBG) levels than those without central obesity (101.97 ± 16.87 vs. 88.22 ± 11.01 mg/dL; $p = 0.024$) and significantly higher systolic blood pressure (116.30 ± 13.86 vs. 103.22 ± 11.21 mmHg; $p = 0.015$). Participants with general obesity also had significantly higher systolic blood pressure than those without general obesity (118.72 ± 13.66 vs. 107.00 ± 13.14 mmHg; *p* = 0.008). In contrast, neither knowledge nor behavioral scores differed significantly according to obesity status. Similarly, a family history of diabetes mellitus was not associated with differences in RBG (*p* = 0.484) or BMI (*p* = 0.316) (Table 6).

Table 6. Comparison of outcome indicators according to obesity status and family history of diabetes mellitus using the Mann–Whitney *U* test

Comparison	Group (+)	Group (−)	U	p
Central obesity (waist circumference ≥80 cm)	n = 39	n = 9		
RBG (mg/dL)	101.97 ± 16.87	88.22 ± 11.01	255.0	0.024*
Systolic blood pressure (mmHg)	116.30 ± 13.86	103.22 ± 11.21	254.5	0.015*
Knowledge score	9.74 ± 3.39	8.67 ± 3.77	192.5	0.568
Behavioral score	55.29 ± 7.23	59.11 ± 11.19	140.0	0.409
General obesity (BMI ≥25 kg/m²)	n = 30	n = 18		
Waist circumference (cm)	91.53 ± 8.84	79.25 ± 5.89	476.5	<0.001*
Systolic blood pressure (mmHg)	118.72 ± 13.66	107.00 ± 13.14	383.5	0.008*
RBG (mg/dL)	102.30 ± 18.43	95.56 ± 13.12	316.5	0.327
Knowledge score	9.53 ± 3.57	9.56 ± 3.24	276.0	0.906
Behavioral score	55.20 ± 7.31	57.17 ± 9.28	247.5	0.639
Family history of diabetes mellitus	n = 9	n = 39		
RBG (mg/dL)	94.11 ± 12.43	101.08 ± 17.54	148.5	0.484
BMI (kg/m²)	25.62 ± 4.33	27.68 ± 5.51	137.0	0.316

*Values are presented as mean ± standard deviation. *Statistically significant at α = 0.05. BMI = body mass index; RBG = random blood glucose.*

Three-group comparisons using the Kruskal–Wallis test demonstrated significant heterogeneity in RBG across schools (H = 6.749; p = 0.034) and across cumulative risk strata (H = 10.530; p = 0.005). Mean RBG increased progressively across the cumulative risk categories, from 88.56 ± 11.08 mg/dL in the low-risk group to 97.29 ± 13.51 mg/dL in the moderate-risk group and 110.47 ± 19.12 mg/dL in the high-risk group. Knowledge scores showed a non-significant trend across schools (H = 5.525; p = 0.063) and across cumulative risk strata (H = 4.926; p = 0.085). Behavioral scores did not differ significantly across either grouping (p > 0.05). BMI also did not differ significantly across schools (H = 3.294; p = 0.193) (Table 7).

Table7. Comparison of outcome indicators across schools and cumulative risk strata using the Kruskal–Wallis test

Grouping / indicator	Group 1	Group 2	Group 3	*H*	*p*
Across schools	SMA DRI (n = 16)	SMA SM (n = 16)	SMK AM (n = 16)		
Knowledge score	8.31 ± 3.07	9.12 ± 4.16	11.19 ± 2.26	5.525	0.063
Behavioral score	54.69 ± 7.93	55.31 ± 6.92	57.81 ± 9.35	0.845	0.656
BMI (kg/m²)	28.07 ± 4.55	28.02 ± 5.29	25.78 ± 6.04	3.294	0.193
RBG (mg/dL)	107.19 ± 17.07	98.81 ± 14.77	93.31 ± 16.50	6.749	0.034*
Across cumulative risk strata	Low (n = 9)	Moderate (n = 24)	High (n = 15)		
RBG (mg/dL)	88.56 ± 11.08	97.29 ± 13.51	110.47 ± 19.12	10.530	0.005*
Knowledge score	9.44 ± 3.13	10.50 ± 3.26	8.07 ± 3.49	4.926	0.085
Behavioral score	61.78 ± 9.61	55.00 ± 5.91	53.93 ± 8.98	4.222	0.121

*Values are presented as mean ± standard deviation. *Statistically significant at α = 0.05. BMI = body mass index; RBG = random blood glucose.*

Program Formulation and Evaluation Framework Based on Pretest Findings

Based on the three preceding pretest findings, a six-session weekly integrated education program was developed incorporating educational, reflective, and practical approaches. The program was designed according to three core principles. First, cognitive content was prioritized around knowledge items with the lowest baseline mastery. Second, each session established a specific weekly behavioral target that could be independently monitored by participants and was derived from the lowest-scoring behavioral items. Third, anthropometric measurements were incorporated as periodic feedback mechanisms to support self-monitoring and behavioral adjustment rather than being used solely as end-point evaluation measures (Table 8)

Table 8. Six-session integrated education program and its alignment with pretest findings

Session	Topic	Rationale based on pretest findings	Weekly behavioral target
1	Adolescent reproductive health and preparedness for future motherhood	Reproductive health knowledge items with <30% mastery	Self-monitoring and recording of the menstrual cycle
2	Understanding diabetes mellitus, gestational diabetes mellitus, and their relationship with pregnancy	Only 22.9% of respondents demonstrated good knowledge	Identification of individual diabetes risk factors
3	Balanced nutrition and dietary sugar control	41.7% of respondents had RBG ≥100 mg/dL	Three-day food diary and reduction of sugar-sweetened beverages
4	Structured physical activity for adolescents	Five behavioral items had the lowest scores, ranging from 1.94 to 2.06	Engage in physical activity ≥3 times/week for 30 minutes per session
5	Healthy body weight, waist circumference, and self-monitoring	62.5% had obesity and 80.9% had central obesity	Weekly measurement of body weight and waist circumference
6	Sustaining healthy habits: barriers, peer support, and maintenance planning	Knowledge was not significantly correlated with behavior (p = 0.744;	Development of a personal behavioral contract and peer-support plan

RBG = random blood glucose; DM = diabetes mellitus; GDM = gestational diabetes mellitus.

DISCUSSION

The baseline assessment identified substantial gaps across the cognitive, behavioural, and metabolic domains, providing an empirical basis for tailoring the intervention. Mean knowledge attainment was only 59.6%, with more than three-quarters of participants failing to reach the predefined good-knowledge category, consistent with previous evidence of limited adolescent knowledge regarding dietary practices and diabetes risk [10]. Importantly, the deficit was not uniformly distributed across items: three knowledge items were correctly answered by fewer than 28% of participants, whereas five items were correctly answered by more than 77%. This item-level heterogeneity has direct implications for intervention efficiency. Rather than allocating instructional time uniformly across all content, the six-session programme prioritized poorly mastered concepts, thereby concentrating instructional exposure where the greatest learning needs existed and increasing the likelihood of detecting meaningful post-intervention changes. The behavioural domain demonstrated an even more pronounced deficit. Only 4.2% of participants achieved a good behavioural score, while the modal response for 22 of the 24 behavioural items indicated that the targeted healthy practices were performed only once or twice per week. This pattern suggests that the principal challenge was not necessarily the complete absence of health-related practices, but their insufficient frequency and lack of behavioural routinization. Accordingly, an intervention limited to information provision would be unlikely to produce substantial behavioural change. The programme therefore incorporated specific weekly behavioural targets, self-monitoring, and repeated facilitator reinforcement to support the transition from intermittent practice to sustained routine. From an evaluative perspective, the low baseline behavioural scores also reduce the likelihood of a ceiling effect, providing sufficient measurement space to detect post-intervention improvement.

The anthropometric findings further indicated a substantial metabolic-risk burden. Although the observed prevalence of general obesity (62.5%) and central obesity (80.9%) should not be interpreted as population prevalence estimates because these characteristics were incorporated into participant selection, they demonstrate the high-risk profile of the study population. The internal consistency of the anthropometric findings was supported by the strong correlation between BMI and waist circumference (r = 0.795) and the moderate correlation between BMI and systolic blood pressure (r = 0.453). BMI was also positively associated with random blood glucose (RBG) in the Pearson analysis (r = 0.341; p = 0.018) and was the only statistically significant predictor of RBG in the multivariable model (B = 1.064; p = 0.023). These findings are broadly consistent with evidence identifying preconception adiposity as an important determinant of GDM risk [7,9], potentially mediated through obesity-related insulin resistance and visceral adiposity [6]. However, because the overall regression model did not reach statistical significance, the BMI coefficient should be interpreted as an adjusted association rather than definitive evidence of an independent predictive effect. Only one participant had RBG ≥140 mg/dL, which is unsurprising in a predominantly adolescent sample and further indicates that random glucose may have limited sensitivity for detecting short-term metabolic changes. In this context, waist circumference may provide a more responsive, non-invasive indicator of adiposity-related risk during short-term intervention. A particularly important finding for programme design was the absence of statistically significant associations between knowledge and behaviour, BMI, or RBG. Participants with higher knowledge did not necessarily exhibit healthier behaviours or more favourable metabolic profiles. This observation does not necessarily contradict previous evidence linking inadequate nutritional knowledge with diabetes risk. rather, it highlights the limitations of knowledge as a standalone determinant of health behaviour. Contemporary behavioural models recognize that knowledge is necessary but insufficient for sustained behaviour change, with self-efficacy, social support, environmental conditions, food availability, and peer norms potentially exerting greater influence on behavioural implementation. Consequently, an intervention evaluated solely through knowledge gain could overestimate its practical effectiveness by demonstrating cognitive improvement without corresponding behavioural or metabolic change. The present programme therefore adopted a multidimensional evaluation framework encompassing knowledge, behaviour, and metabolic-risk indicators, with effect sizes and confidence intervals reported alongside statistical significance to facilitate interpretation of both statistical and practical relevance[21], [22].

Collectively, these baseline findings informed the design of the six-session weekly integrated education programme. Cognitive content was prioritized according to the lowest-performing knowledge items; each session incorporated a specific, self-monitorable behavioural target derived from the lowest-scoring behavioural domains; and anthropometric measurements were incorporated as periodic feedback rather than being restricted to the final assessment[17], [22]. The prespecified sample-size assessment indicated that, with 25 participants per group at post-test, the study had approximately 80% power to detect a between-group effect of Cohen's $d \geq 0.79$, corresponding to approximately 2.70 points for the knowledge score and 6.39 points for the behavioural score. In contrast, detecting a between-group BMI difference of approximately 4.22 kg/m² over six weeks would require a change beyond what is physiologically realistic within the intervention period. Accordingly, failure to demonstrate a statistically significant between-group difference in BMI at post-test should not be interpreted as evidence that the intervention was ineffective. Rather, the relatively short follow-up and limited statistical power for anthropometric change should be considered when interpreting this outcome. Waist circumference and the cumulative metabolic-risk index may therefore represent more responsive intermediate indicators for evaluating short-term changes in metabolic risk.

CONCLUSIONS

The three baseline domains examined in this study converge on a consistent pattern: adolescent girls in Aceh Besar entered a critical period of future reproductive life with substantial gaps in reproductive health and diabetes-related preparedness. Knowledge attainment was limited, with a mean score equivalent to 59.6% of the maximum, and only 22.9% of participants achieving the predefined good-knowledge category. Healthy lifestyle behaviours were similarly suboptimal. The mean behavioural score reached only 58.3% of the maximum, and merely 4.2% of participants met the criteria for good behavioural practice. Importantly, the behavioural deficit appeared to reflect insufficient consistency rather than complete absence of healthy practices, indicating an opportunity for interventions that emphasize habit formation and sustained implementation rather than information delivery alone. The metabolic profile further underscored the vulnerability of this population. General obesity was present in 62.5% of participants, central obesity in 80.9%, and 81.2% had at least two preconception GDM risk factors. BMI emerged as the only statistically significant predictor of random blood glucose in the adjusted regression analysis. Given that the sample was deliberately enriched for adolescents with overweight or obesity, these findings should be interpreted as evidence of a high-risk study population rather than estimates of obesity or GDM risk prevalence among adolescent girls in the general population. The most consequential finding for intervention development, however, was not the magnitude of any individual indicator but the lack of meaningful interrelationships between the cognitive, behavioural, and metabolic domains. Higher knowledge was not accompanied by significantly healthier behaviours or more favourable metabolic indicators. This pattern suggests that knowledge acquisition alone is unlikely to produce meaningful risk reduction and supports a behavioural approach in which knowledge is translated into self-monitoring, repeated practice, and sustained lifestyle modification. These findings provided the empirical foundation for the six-session integrated intervention. Rather than simply increasing the volume of health information, the programme was designed to address the observed disconnect between knowledge, behaviour, and metabolic risk through targeted education, behavioural goal-setting, self-monitoring, and periodic risk assessment. The analytical framework and evaluation strategy were also prespecified to strengthen the validity of subsequent intervention-effect estimates and minimize post hoc analytical decisions. Whether this integrated approach can translate improvements in knowledge into sustained behavioural change and measurable reductions in metabolic risk will be determined by the post-intervention assessment and reported in the subsequent analysis.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

1) X.-Y. Wang, E. M. Cleary, S. F. Thung, K. K. Venkatesh, and E. O. Buschur, "Gestational Diabetes," *Endotext*, Aug. 2024, Accessed: Aug. 17, 2026. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK572755/
2) L. Janeline *et al.*, "Overlap of Gestational Diabetes Mellitus and Pre-eclampsia: A Scoping Review," *Diabetes Therapy*, vol. 17, no. 7, p. 937, Jul. 2026, doi: 10.1007/S13300-026-01880-6.
3) J. H. Moon and H. C. Jang, "Gestational Diabetes Mellitus: Diagnostic Approaches and Maternal-Offspring

Complications," *Diabetes Metab. J.*, vol. 46, no. 1, pp. 3–14, Jan. 2022, doi: 10.4093/DMJ.2021.0335.
4) V. Kunarathnam, E. S. Vadakekut, and H. Mahdy, "Gestational Diabetes," Sep. 2025, Accessed: Aug. 17, 2026. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK545196/
5) S. L. O'reilly, "Prevention of Diabetes after Gestational Diabetes: Better Translation of Nutrition and Lifestyle Messages Needed," *Healthcare*, vol. 2, no. 4, p. 468, Dec. 2014, doi: 10.3390/HEALTHCARE2040468.
6) H. Herath, R. Herath, and R. Wickremasinghe, "Gestational diabetes mellitus and risk of type 2 diabetes 10 years after the index pregnancy in Sri Lankan women—A community based retrospective cohort study," *PLoS One*, vol. 12, no. 6, p. e0179647, Jun. 2017, doi: 10.1371/JOURNAL.PONE.0179647.
7) Y. Zhu and C. Zhang, "Prevalence of Gestational Diabetes and Risk of Progression to Type 2 Diabetes: a Global Perspective," *Curr. Diab. Rep.*, vol. 16, no. 1, p. 7, Jan. 2016, doi: 10.1007/S11892-015-0699-X.
8) M. V. Diaz-Santana, K. M. O'brien, Y. M. M. Park, D. P. Sandler, and C. R. Weinberg, "Persistence of Risk for Type 2 Diabetes After Gestational Diabetes Mellitus," *Diabetes Care*, vol. 45, no. 4, p. 864, Apr. 2022, doi: 10.2337/DC21-1430.
9) E. Vounzoulaki, K. Khunti, S. C. Abner, B. K. Tan, M. J. Davies, and C. L. Gillies, "Progression to type 2 diabetes in women with a known history of gestational diabetes: systematic review and meta-analysis," *The BMJ*, vol. 369, p. m1361, May 2020, doi: 10.1136/BMJ.M1361.
10) M. Fu *et al.*, "Prediction of Gestational Diabetes Mellitus: A Nomogram Model Incorporating Lifestyle, Nutrition and Health Literacy Factors," *Nutrients*, vol. 17, no. 21, p. 3400, Nov. 2025, doi: 10.3390/NU17213400.
11) U. Kampmann, S. Knorr, J. Fuglsang, and P. Ovesen, "Determinants of Maternal Insulin Resistance during Pregnancy: An Updated Overview," *J. Diabetes Res.*, vol. 2019, p. 5320156, 2019, doi: 10.1155/2019/5320156.
12) A. Tranidou *et al.*, "Pre-Conception Physical Activity and the Risk of Gestational Diabetes Mellitus: Findings from the BORN 2020 Study," *Nutrients*, vol. 17, no. 11, p. 1832, Jun. 2025, doi: 10.3390/NU17111832.
13) C. Sun *et al.*, "The impact of environmental and dietary exposure on gestational diabetes mellitus: a comprehensive review emphasizing the role of oxidative stress," *Front. Endocrinol. (Lausanne).*, vol. 16, p. 1393883, 2025, doi: 10.3389/FENDO.2025.1393883.
14) A. Jahan-Mihan *et al.*, "The Impact of Parental Preconception Nutrition, Body Weight, and Exercise Habits on Offspring Health Outcomes: A Narrative Review," *Nutrients*, vol. 16, no. 24, p. 4276, Dec. 2024, doi: 10.3390/NU16244276.
15) C. Zhang and Y. Ning, "Effect of dietary and lifestyle factors on the risk of gestational diabetes: review of epidemiologic evidence1," *Am. J. Clin. Nutr.*, vol. 94, no. 6 Suppl, p. 1975S, Dec. 2011, doi: 10.3945/AJCN.110.001032.
16) F. Violita and E. N. Hadi, "Determinants of adolescent reproductive health service utilization by senior high school students in Makassar, Indonesia," *BMC Public Health*, vol. 19, no. 1, p. 286, Mar. 2019, doi: 10.1186/S12889-019-6587-6.
17) K. I. Cini *et al.*, "Towards responsive policy and actions to address non-communicable disease risks amongst adolescents in Indonesia: insights from key stakeholders," *The Lancet Regional Health - Southeast Asia*, vol. 18, p. 100260, Nov. 2023, doi: 10.1016/J.LANSEA.2023.100260.
18) W. R. Garney, S. A. Flores, K. M. Garcia, S. Panjwani, and K. L. Wilson, "Adolescent Healthcare Access: A Qualitative Study of Provider Perspectives," *J. Prim. Care Community Health*, vol. 15, p. 21501319241234584, Jan. 2024, doi: 10.1177/21501319241234586.
19) [M. Nair, V. Baltag, K. Bose, C. Boschi-Pinto, T. Lambrechts, and M. Mathai, "Improving the Quality of Health Care Services for Adolescents, Globally: A Standards-Driven Approach," *The Journal of Adolescent Health*, vol. 57, no. 3, p. 288, Sep. 2015, doi: 10.1016/J.JADOHEALTH.2015.05.011.
20) Muthmainnah, I. Nurmala, P. Siswantara, R. D. Rachmayanti, and Y. P. Devi, "Implementation of adolescent health programs at public schools and religion-based schools in Indonesia," *J. Public Health Res.*, vol. 10, no. 4, p. 1954, Oct. 2021, doi: 10.4081/JPHR.2021.1954.
21) L. Zhang, H. Li, T. Huang, M. Yang, X. Yu, and Y. Liu, "Nutritional self-management in chronic diseases: a conceptual analysis," *Front. Public Health*, vol. 13, p. 1680903, 2025, doi: 10.3389/FPUBH.2025.1680903/FULL.
22) G. Y. Lee *et al.*, "Presenting a comprehensive multi-scale evaluation framework for participatory modelling programs: A scoping review," *PLoS One*, vol. 17, no. 4, p. e0266125, Apr. 2022, doi: 10.1371/JOURNAL.PONE.0266125.