



Association of physical activity and maternal knowledge with fasting blood glucose among pregnant women in primary healthcare settings

Effatul Afifah¹, Selvi Novita Sari², Siti Nadia Rahma², Prasetya Lestari³, Subaidi⁴, Eka Nurhayati³, Maznah Dahlui⁵

¹Department of Public Health, Faculty of Health Sciences, Universitas Alma Ata, Jalan Brawijaya 99 Yogyakarta, 55183, Indonesia

²Department of Nutrition, Faculty of Health Sciences, Universitas Alma Ata, Jalan Brawijaya 99 Yogyakarta, 55183, Indonesia

³Department of Midwifery, Faculty of Health Sciences, Universitas Alma Ata, Jalan Brawijaya 99 Yogyakarta, 55183, Indonesia

⁴Department of Interdisciplinary Islamic Studies, School of Graduate Studies, Universitas Islam Negeri Sunan Kalijaga, Jalan Marsda Adisucipto, Yogyakarta, 55281, Indonesia

⁵Department of Research and Clinical Advancement, Malaya Medical Centre, University of Malaya, Kuala Lumpur 59100, Malaysia

*Correspondence: effatulafifah1@almaata.ac.id

ABSTRAK

Latar Belakang: Diabetes Melitus Gestasional (DMG) dan hiperglikemia pada kehamilan berhubungan dengan risiko komplikasi maternal dan perinatal. Aktivitas fisik berpotensi memengaruhi regulasi glukosa, sedangkan pengetahuan ibu dapat mendukung perilaku kesehatan dan pencegahan DMG. Namun, hubungan kedua faktor tersebut dengan glukosa darah puasa pada ibu hamil di layanan kesehatan primer masih perlu dikaji.

Tujuan: Menganalisis hubungan antara aktivitas fisik dan pengetahuan ibu dengan status glukosa darah puasa pada ibu hamil di layanan kesehatan primer.

Metode: Studi observasional analitik dengan desain cross-sectional pada 136 ibu hamil usia kehamilan 24–28 minggu yang direkrut secara purposive dari 4 puskesmas di Kabupaten Bantul pada 2019. Glukosa darah puasa diukur menggunakan ACCU-Chek Performa; aktivitas fisik dinilai menggunakan kuesioner yang diadaptasi dari International Physical Activity Questionnaire (IPAQ); dan pengetahuan ibu diukur menggunakan kuesioner 13 item. Analisis utama menggunakan Fisher's exact test, sedangkan analisis eksploratif membandingkan skor aktivitas fisik dan pengetahuan pada tiga kategori glukosa menggunakan Kruskal–Wallis dan Fisher–Freeman exact test.

Hasil: Tiga peserta (2,2%) memenuhi klasifikasi operasional ≥ 126 mg/dL, 48 peserta (35,3%) memiliki glukosa 100–125 mg/dL, dan 85 peserta (62,5%) memiliki glukosa < 100 mg/dL. Aktivitas fisik berhubungan dengan klasifikasi operasional ($p=0,042$) dan berbeda antara tiga kategori glukosa ($p=0,005$), sedangkan pengetahuan tidak berhubungan secara signifikan ($p=0,459$).

Kesimpulan: Aktivitas fisik menunjukkan pola hubungan dengan status glukosa. Glukosa 100–125 mg/dL menunjukkan perlunya konfirmasi klinis, pemantauan antenatal, serta tindak lanjut yang sesuai untuk mencegah keterlambatan identifikasi gangguan glukosa pada kehamilan dan mendukung tindak lanjut layanan antenatal.

KATA KUNCI: aktivitas fisik; diabetes melitus gestasional; glukosa darah puasa; hiperglikemia pada kehamilan; pengetahuan ibu

ABSTRACT

Background: Gestational Diabetes Mellitus (GDM) and hyperglycaemia during pregnancy are associated with maternal and perinatal outcomes. Physical activity may influence glucose regulation, while maternal knowledge may support healthy behaviours and GDM prevention. However, the relationship of these factors with fasting blood glucose among pregnant women in primary healthcare remains unclear.

Objectives: To examine the associations of physical activity and maternal knowledge with fasting blood glucose status among pregnant women receiving primary care

Methods: A cross-sectional study was conducted among 136 pregnant women at 24–28 weeks of gestation who were purposively recruited from four community health centres in Bantul Regency, Indonesia, in 2019. Fasting glucose was measured using an ACCU-Chek Performa; physical activity was assessed using a questionnaire adapted from the International Physical Activity Questionnaire (IPAQ); and maternal knowledge was assessed using a 13-item questionnaire. Fisher's exact test was used for primary analysis, while exploratory analyses compared physical-activity and knowledge scores across three fasting-glucose categories using Kruskal–Wallis and Fisher–Freeman exact tests.

Results: Three participants (2.2%) met the operational ≥ 126 mg/dL classification, 48 (35.3%) had glucose levels of 100–125 mg/dL, and 85 (62.5%) had levels < 100 mg/dL. Physical activity was associated with the operational classification ($p=0.042$) and differed across the three glucose categories ($p=0.005$), whereas knowledge was not significantly associated ($p=0.459$). **Conclusions:** Physical activity showed a pattern of association with fasting blood glucose status. Glucose levels of 100–125 mg/dL warrant clinical confirmation and follow-up.

Conclusions: Physical activity shows a pattern of association with glucose status. Glucose levels of 100–125 mg/dL indicate a need for clinical confirmation, antenatal monitoring, and appropriate follow-up to prevent delayed identification of glucose abnormalities during pregnancy and to support continued antenatal care.

KEYWORDS: fasting blood glucose; gestational diabetes mellitus; hyperglycemia in pregnancy; maternal knowledge; physical activity

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INTRODUCTION

Gestational diabetes mellitus (GDM) is hyperglycaemia first recognized during pregnancy and is clinically distinguished from overt diabetes by pregnancy-specific diagnostic thresholds. Current guidance recommends screening for GDM at 24–28 weeks in pregnant women not previously diagnosed with diabetes, most commonly using a 75 g oral glucose tolerance test (OGTT) with fasting, 1-hour, and 2-hour plasma glucose measurements (1,2). The burden of hyperglycaemia in pregnancy remains substantial worldwide, although estimates vary according to the population and diagnostic criteria used. The 2025 International Diabetes Federation (IDF) Diabetes Atlas estimated that 23.0 million live births in 2024 (19.7%) were affected by hyperglycaemia in pregnancy, with 79.2% attributed to GDM. The South-East Asia region had the highest age-standardised prevalence of hyperglycaemia in pregnancy at 31.7%,

highlighting the importance of prevention and early detection in this region (3).

In Indonesia, recent national survey data provide a more contemporary context. The 2023 Indonesian Health Survey (SKI 2023) reported that gestational diabetes accounted for 2.6% of diabetes diagnoses recorded in the survey population. However, this figure is based on reported physician diagnosis rather than universal pregnancy OGTT screening. It therefore should not be interpreted as a population prevalence of GDM among all pregnant women (4). Local evidence also demonstrates substantial variation by diagnostic criteria: a Yogyakarta study published in 2023 reported GDM prevalence ranging from 11.7% using WHO criteria to 14.9% using NICE criteria among pregnant women screened at 24–28 weeks (5). These differences underscore the importance of clearly specifying the diagnostic method when interpreting GDM

estimates. Hyperglycaemia in pregnancy is clinically important because maternal hyperglycaemia is associated with adverse maternal, fetal, and neonatal outcomes. At the same time, women with GDM also have an increased long-term risk of type 2 diabetes. Contemporary guidance emphasizes pregnancy-specific diagnostic testing and continued postpartum surveillance rather than relying on a single fasting glucose value alone (1,2).

Risk factors for GDM include higher maternal age, overweight or obesity, previous GDM, family history of diabetes, and lower levels of physical activity. Recent evidence continues to support physical activity as a potentially modifiable factor: a 2024 dose-response meta-analysis found that higher physical activity during the first and second trimesters was associated with a lower risk of GDM. However, the magnitude of association varied across exposure levels and study designs (6). Maternal knowledge may influence behaviours relevant to GDM prevention and management, although knowledge alone does not necessarily translate into sustained behavioural change or improved glycaemic control. Limited knowledge may contribute to inappropriate dietary choices, low recognition of GDM risk, and poor adherence to healthy lifestyle recommendations. However, knowledge does not necessarily translate directly into behavior or glycemic control because its effects may be mediated by habitual behavior, sociocultural beliefs, food access, obesity, and other metabolic risk factors (7).

Assessing knowledge together with physical activity may therefore provide a broader understanding of behavioral factors associated with fasting-glucose abnormalities. Diagnostic criteria for hyperglycemia in pregnancy vary according to the clinical framework and glucose-testing method used. This variation contributes to differences in reported GDM prevalence across populations (8). A knowledge gap remains regarding how behavioural factors measured in primary-care settings relate to fasting-glucose abnormalities when the outcome is considered beyond a small number of women meeting an overt-diabetes threshold. Most evidence on physical activity and GDM uses standardized OGTT-based GDM diagnosis. In contrast, this dataset contains fasting capillary glucose

measurements and a very small number of women meeting the operational ≥ 126 mg/dL threshold. In addition, evidence on maternal knowledge is heterogeneous and often focuses on women already diagnosed with GDM. The present analysis therefore examines physical activity and maternal knowledge together across the observed fasting-glucose distribution. The findings may help primary-care services identify behavioural domains that warrant further assessment and counselling, while also indicating where confirmatory glucose testing is needed.

MATERIALS AND METHODS

Study design

A cross-sectional study was conducted among 136 pregnant women at 24–28 weeks of gestation who were recruited from four community health centers in Bantul Regency, Indonesia. Preliminary screening of urine-reduction data from 17 community health centers in Bantul Regency was conducted in April 2019. Four health centers with the highest recorded urine-reduction findings were selected for the study: Banguntapan II, Sewon II, Jetis I, and Jetis II. Following ethical approval on 15 May 2019, participant recruitment and primary data collection were conducted during May– June 2019. The distribution of the 136 participants was 38 (27.9%) from Banguntapan II, 38 (27.9%) from Sewon II, 31 (22.8%) from Jetis I, and 29 (21.3%) from Jetis II. The number of participants at each site reflects the eligible participants recruited at the selected health centers during the study period.

Outcome definition and glucose classification

The primary outcome was fasting glucose classification based on a single capillary blood glucose measurement of ≥ 126 mg/dL versus < 126 mg/dL. The threshold of 126 mg/dL corresponds to the diabetes-range fasting plasma glucose criterion, while GDM is diagnosed using pregnancy-specific criteria and standardized testing procedures (8,9). Accordingly, participants with fasting capillary glucose ≥ 126 mg/dL were classified within the diabetes-range group in the present study. Because glucose was measured once from capillary blood rather than standardized venous plasma, this classification was considered an operational study classification and not a

retrospectively confirmed clinical diagnosis. A secondary three-category classification was used to describe the distribution of fasting capillary glucose: ≥ 126 mg/dL, 100–125 mg/dL, and < 100 mg/dL. These categories were used for exploratory analysis and were not intended to replace pregnancy-specific diagnostic procedures. Current diagnostic guidance distinguishes diabetes-range hyperglycaemia from GDM and recommends standardized pregnancy-specific testing, including a 75 g oral glucose tolerance test for GDM diagnosis (8). The present study did not perform a 75 g oral glucose tolerance test (OGTT) or standardized venous plasma glucose testing; therefore, the categories were interpreted according to the available capillary glucose measurements.

Participants fasted for 8–10 hours, and glucose was measured once from peripheral capillary blood using a calibrated ACCU-Chek Performa point-of-care device. Point-of-care capillary glucose testing can provide clinically useful information on glycaemic status; however, evidence from pregnancy populations indicates that it cannot fully replace laboratory venous plasma glucose testing for definitive GDM assessment (9). Accordingly, the glucose classifications in this study were interpreted as study-based clinical measurements rather than as estimates of confirmed current GDM prevalence. Outcome analysis. Physical activity was assessed using a questionnaire adapted from the International Physical Activity Questionnaire (IPAQ) and modified according to the characteristics of the study population. The questionnaire covered activities performed during the previous month across several domains, including work-related activities, transportation, household activities, sports and outdoor activities, and sleep-related activities.

The frequency of each activity was recorded according to the number of activities performed per day, week, or month, while the duration of each activity was recorded in minutes. Physical activity was subsequently classified into two categories, low active and active, for the primary analysis. In addition to the categorical classification, the study also used a recorded physical-activity score derived from the available activity-frequency and duration information across

the physical-activity domains. The score was used to provide a quantitative description of participants' physical-activity levels and was subsequently analyzed according to fasting blood-glucose categories. In this study, the recorded score was treated as a study-specific quantitative measure derived from the modified IPAQ instrument. Because the item-level information required to reconstruct the scoring algorithm was not available in the analytical dataset, the score was used for exploratory analysis and was not presented as the standard IPAQ MET-minutes/week score or as a formally validated IPAQ activity category. This approach allowed the physical-activity characteristics of the participants to be analyzed quantitatively according to the structure of the instrument and the study data; the use of an IPAQ-based assessment is supported by evidence of acceptable criterion validity of the IPAQ-SF in an Asian population (10).

The student investigators were undergraduate nutrition students who met the study eligibility criteria. Before data collection, they participated in a group-based standardization session to align their understanding of questionnaire administration, measurement procedures, data recording, and data handling. Questionnaire completeness was checked before data entry, and the entered dataset was reviewed and cleaned before analysis. The maternal-knowledge measure consisted of a 13 item questionnaire used in the original study and scored as the proportion of correct responses. Scores were categorized as poor ($< 70\%$; 0–9 correct responses) or good ($\geq 70\%$; 10–13 correct responses). Because the present manuscript uses the existing secondary dataset, no new questionnaire items or scoring rules were introduced during the revision.

Statistical analysis

Data were processed using SPSS version 21 for Windows. Univariable analysis summarized participant characteristics, operational GDM status, fasting-glucose categories, knowledge, and physical activity. The primary 2×2 analysis used Fisher's exact test because the operational GDM outcome was rare and expected cell frequencies were small (11). For the three-category outcome, physical-activity scores and

knowledge scores were compared using the Kruskal-Wallis test, while the knowledge category was assessed using the Fisher–Freeman exact test. Pairwise Mann–Whitney tests were used to explore significant differences in physical-activity scores.

A two-sided p-value <0.05 was considered statistically significant. Because only three participants met the operational GDM classification, no multivariable regression model was fitted; estimates from the primary analysis, including the knowledge OR, were therefore treated as crude and highly imprecise. Potential confounding by pre-pregnancy BMI, gestational weight gain, parity, previous GDM, dietary intake, family history, socioeconomic status, and

maternal age could not be adequately controlled in the available dataset.

Ethical considerations.

Preliminary screening of urine-reduction data from 17 community health centers took place in April 2019 to identify the four health centers with the highest recorded urine-reduction findings. Participant-level recruitment and primary research procedures were conducted after ethical approval (KE/AA/V/587/EC/2019) on 15 May 2019 and continued during May– June 2019.

RESULTS AND DISCUSSION

Table 1 summarizes the 136 participants in the shared umbrella-study dataset.

Table 1. Characteristics of the study participants

Characteristics	Frequency (n=136)	Percentage (%)
Age		
19–34 years old	108	79.40
≥35 years old	28	20.60
Gestation		
24 weeks	44	32.40
25 weeks	32	23.50
26 weeks	13	9.60
27 weeks	9	6.60
28 weeks	38	27.90
Family History of Diabetes Mellitus		
No	82	60.30
Yes	54	39.70
Education level		
Elementary	6	4.40
Junior High School	31	22.80
Senior High School	86	63.20
College	13	9.60
Employment		
Housewife	112	82.40
Employee	16	11.80
Self-employed	8	5.90
Operational glucose classification		
≥126 mg/dL (diabetes range)	3	2.20
Below threshold (<126 mg/dL)	133	97.80
Fasting glucose category		
GDM (≥126 mg/dL)	3	2.20
Hyperglycemia (100–125 mg/dL)	48	35.30
Non-GDM (<100 mg/dL)	85	62.50
Physical activity		
Low active	48	35.30
Active	88	64.70
Maternal knowledge		
Poor (<70%)	111	81.60
Good (≥70%)	25	18.40

Most participants were aged 19–34 years (79.4%), had completed senior high school (63.2%), and were housewives (82.4%). The fasting-glucose appendix identified 3 participants (2.2%) with operational GDM (≥ 126 mg/dL), 48 (35.3%) with hyperglycemia (100–125 mg/dL), and 85 (62.5%) as non-GDM (< 100 mg/dL). 48 participants (35.3%) were classified as low active and 88 (64.7%) as active in the study dataset, while 111 (81.6%) had poor knowledge and 25 (18.4%) had good knowledge.

Maternal Age and Family History of Diabetes Mellitus

As shown in **Table 2**, two of 28 participants aged ≥ 35 years (7.1%) and one of 108 participants aged 19–34 years (0.9%) had GDM. No participant was younger than 19 years; therefore, the inferential analysis used the two observed age categories (19–34 and ≥ 35 years). Fisher's exact test showed no statistically significant association between maternal age and the operational

glucose classification ($p=0.108$; OR=8.231; 95% CI: 0.719–94.282) or between family history of diabetes mellitus and the operational glucose classification. The two analyses should not be conflated. The three-category comparison used the recorded physical-activity score as a quantitative measure, whereas the primary analysis used the binary physical-activity classification.

Although only three women reached the operational threshold of ≥ 126 mg/dL, 48 women (35.3%) had fasting capillary glucose of 100–125 mg/dL. This finding means that the glycemic burden in the sample was not limited to the small number classified under the operational GDM definition; more than one third already showed elevated fasting glucose below the study's overt-diabetes threshold. Pregnancy-specific diagnostic strategies use lower fasting plasma thresholds during a standardized OGTT, so values in the 100–125 mg/dL range are clinically concerning rather than metabolically normal (2).

Table 2. Associations of maternal age and family history of diabetes mellitus with gdm status

Characteristics	GDM classification				Total (n)	p-value
	GDM		Below threshold (<126 mg/dL)			
	N	(%)	N	(%)		
Age						
19–34 years old	1	(0.90)	107	(99.10)	108	0.108
≥35 years old	2	(7.10)	26	(92.90)	28	
Family History of Diabetes Mellitus						
No	1	(1.20)	81	(98.80)	82	0.563
Yes	2	(3.70)	52	(96.30)	54	

Note : GDM = Gestational Diabetes mellitus

Nevertheless, the present measurements were single capillary point-of-care values. The hyperglycemia category should therefore be interpreted as evidence of possible impaired glucose regulation and a need for confirmatory plasma or OGTT assessment, dietary and activity counseling, and closer antenatal monitoring, not as a definitive diagnosis of GDM (2,9). The operational GDM classification used in this study should not be equated with clinically confirmed GDM. In particular, a fasting capillary glucose value ≥ 126 mg/dL may indicate a level of hyperglycemia consistent with the diabetes threshold when measured using standardized

plasma glucose. Still, the present single capillary measurement cannot establish whether the participant had GDM, previously unrecognized diabetes, or overt diabetes in pregnancy; confirmatory testing is required when hyperglycaemia is not unequivocal (8).

Physical Activity and Operational GDM Classification

As shown in **Table 3**, all three participants who met the operational GDM classification were in the low-active group. In contrast, none of the participants in the active group met this classification. Fisher's exact test demonstrated a

statistically significant association between physical activity category and the operational GDM classification ($p=0.042$). This finding suggests that lower physical activity may be associated with less favourable fasting-glucose status in this study population. The result is biologically plausible because regular physical activity contributes to glucose regulation through increased skeletal-muscle glucose uptake and improved insulin sensitivity. Consistent with this interpretation, current clinical guidance recommends regular aerobic and muscle-strengthening activities for pregnant women without medical or obstetric contraindications, and physical activity during pregnancy may reduce the risk of GDM (12). In addition, recent evidence indicates that higher levels of physical activity during pregnancy are associated with a lower risk of GDM (6). Nevertheless, the finding in **Table 3** should be interpreted cautiously. Only three participants met the operational glucose threshold, and all three were classified as low

active. Therefore, the statistically significant association should not be interpreted as evidence that physical inactivity causes GDM or that being physically active prevents GDM.

Rather, it indicates a pattern that is consistent with the broader evidence on physical activity and glycaemic regulation during pregnancy. The absence of operational GDM cases in the active group may also reflect the small number of outcome events and the limited statistical power of the study. Moreover, physical activity was self-reported, and the available dataset did not permit reconstruction of the standard IPAQ scoring algorithm. Thus, residual measurement error and unmeasured confounding may have influenced the observed association. Future prospective studies using validated physical-activity measures and standardized glucose testing are needed to determine whether this association persists after adjustment for maternal age, pre-pregnancy BMI, gestational weight gain, dietary intake, previous GDM, and other metabolic risk factors.

Table 3. Association between physical activity category and GDM status

Variable	GDM classification				Total (n)	p-value
	GDM		Non-GDM			
	n	%	n	%		
Physical Activity						
Low active	3	6.30	45	93.8	48	0.042
Active	0	0.00	88	100	88	

Note : GDM = Gestational Diabetes mellitus

The knowledge substudy confirmed that 111 participants (81.60%) had poor knowledge ($<70\%$ correct; score 0-9) and 25 (18.40%) had good knowledge ($\geq 70\%$ correct; score 10-13). In the original binary analysis, knowledge was not associated with operational GDM ($p=0.459$; OR=0.440; 95% CI: 0.038-5.056). The secondary three-category analysis likewise found no association for knowledge category (Fisher-Freeman exact $p=0.656$) and no difference in knowledge scores (Kruskal-Wallis $p=0.393$), as shown in **Table 4**.

Biologically, physical activity is a plausible factor influencing glucose regulation during pregnancy. Skeletal-muscle contraction increases glucose uptake through insulin-independent translocation of glucose transporter type 4 (GLUT-4), while repeated activity may improve insulin signaling and whole-body insulin sensitivity.

Clinical guidance recommends that women with uncomplicated pregnancies engage in regular aerobic and strength-conditioning exercise, after appropriate clinical evaluation (12). Recent intervention evidence also indicates that structured exercise management during pregnancy can improve blood glucose control among women with GDM, providing further support for the biological plausibility of the present association (13). These recommendations provide clinical context for the present finding, but the cross-sectional design cannot determine causality or establish that physical activity prevented GDM.

Afifah et al. reported that an eight-week Social Nervous Exercise intervention significantly reduced fasting blood glucose among women with GDM (14). In line with clinical guidance, pregnant women without contraindications should be encouraged to perform safe, moderate-intensity

physical activity regularly (12). Sklempe Kokic et al. found that a structured combination of aerobic and resistance exercise improved postprandial glucose in women with GDM, although fasting glucose did not differ significantly between groups (15). These findings support the biological plausibility of an association between physical activity and glycaemic regulation, while also showing that the effect may differ according to the glucose outcome measured.

Dietary intake is relevant to glycaemic control, but diet was not analyzed as a principal exposure in the present study. The discussion should therefore acknowledge diet, pre-pregnancy body mass index, gestational weight gain, parity, previous GDM, polycystic ovary syndrome, and socioeconomic conditions as potential unmeasured confounders rather than treating evidence from other populations as direct confirmation of the present finding. Wang et al. reported that an exercise intervention initiated during pregnancy reduced the risk of GDM among overweight and obese pregnant women, supporting the potential role of physical activity as a modifiable factor in GDM prevention (16). However, these findings were obtained from an intervention study and cannot be directly extrapolated to the fasting-glucose association observed in the present cross-sectional study. This randomized evidence strengthens the rationale for considering physical activity as a

modifiable factor, although the present observational data cannot establish the same preventive effect.

The present exploratory pattern is compatible with, but does not establish, findings from more recent research. A 2024 systematic review and dose-response meta-analysis reported a lower risk of GDM among women with higher physical activity, with a graded association across activity levels (6). However, Poprzeczny et al. highlighted substantial methodological limitations in the intervention literature. When analyses were restricted to rigorously conducted trials, there was no clear evidence that antenatal physical-activity interventions improved overall pregnancy outcomes or limited gestational weight gain (17). This finding emphasizes the importance of interpreting observational associations and intervention effects according to study design and trial quality. A 2026 systematic review and meta-analysis of randomized controlled trials further evaluated supervised exercise during pregnancy for GDM and other pregnancy outcomes, including dose-response relationships, providing additional evidence for the potential role of structured exercise while highlighting variation in intervention dose (18). These studies provide external context because they use more robust prospective or interventional designs; they should not be interpreted as direct confirmation of the present cross-sectional association.

Table 4. Association between knowledge level and gestational diabetes mellitus status (n=136)

Level Category	GDM n %	Non-GDM n (%)	Total n (%)	p-value	OR (95% CI)
Poor (<70%)	2 (1.80)	109 (98.20)	111 (81.60)	0.459	0.440 (0.038–5.056)
Good (≥70%)	1 (4.00)	24 (96.00)	25 (18.40)		

Note : GDM = Gestational Diabetes mellitus

Table 5 provides a more detailed comparison of physical-activity and maternal-knowledge measures across the three fasting-glucose categories. The recorded physical-activity score differed significantly among participants with fasting glucose levels of ≥126 mg/dL, 100–125 mg/dL, and <100 mg/dL (Kruskal–Wallis $p=0.005$). The median physical-activity score was lowest in the ≥126 mg/dL group (579.0), increased in the 100–125 mg/dL group (991.5), and was highest in the <100 mg/dL group (1368.5). This pattern is

broadly consistent with the finding in **Table 3**, where all participants meeting the operational GDM classification were in the low-active category. Together, these findings suggest that physical activity may be related to fasting-glucose status among pregnant women in primary care. This interpretation is supported by evidence indicating that physical activity during pregnancy is associated with a lower risk of GDM and may contribute to improved glucose regulation (6,12).

However, the results in **Table 5** do not demonstrate a simple linear gradient across fasting-glucose categories. Notably, the median activity score in the 100–125 mg/dL group was higher than that in the ≥ 126 mg/dL group but lower than that in the < 100 mg/dL group. Therefore, the significant Kruskal–Wallis result indicates that the distributions of physical-activity scores differed across the three groups, but it does not establish a dose–response relationship or demonstrate that progressively higher physical activity directly leads

to lower fasting glucose. Furthermore, the ≥ 126 mg/dL group consisted of only three participants, substantially limiting the stability and precision of comparisons involving this group. The physical-activity score was also derived from the available modified questionnaire data and could not be independently reconstructed according to the standard IPAQ MET-minutes/week algorithm. These methodological limitations require the finding to be interpreted as exploratory rather than causal.

Table 5. Physical activity and maternal knowledge across raw fasting-glucose categories

Variable	≥ 126 mg/dL (n=3)	Hyperglycemia 100–125 mg/dL (n=48)	Non-GDM <100 mg/dL (n=85)	p-value
Physical-activity score, median (IQR)	579.00 (555.00–801.80)	991.50 (780.60–1.483.10)	1.368.50 (966.00–1.609.00)	0.005 ¹
Knowledge score median (IQR)	46.15 (38.46–65.39)	53.85 (38.46–69.23)	46.15 (30.77–69.23)	0.393 ¹
Poor knowledge (n,%)	2 (66.70)	40 (83.30)	69 (81.20)	0.656 ²
Good knowledge (n,%)	1 (33.30)	8 (16.70)	16 (18.80)	

Note: IQR = interquartile range; values in parentheses represent the 25th–75th percentile. ¹Kruskal-Wallis test.

²Fisher-Freeman exact test. Post hoc analysis.

In contrast, maternal knowledge did not differ significantly across the three fasting-glucose categories. The median knowledge score was 46.15 in the ≥ 126 mg/dL group, 53.85 in the 100–125 mg/dL group, and 46.15 in the < 100 mg/dL group, with no statistically significant difference ($p=0.393$). Similarly, the distribution of poor and good knowledge did not differ significantly across the three categories (Fisher–Freeman exact $p=0.656$). These findings are consistent with the primary analysis showing no significant association between maternal knowledge and the operational GDM classification. The absence of an association does not necessarily indicate that knowledge is irrelevant to GDM prevention or management. Knowledge may influence glycaemic outcomes indirectly through dietary behaviour, physical activity, risk perception, healthcare-seeking behaviour, and adherence to recommendations. Previous research among women with established GDM has shown that higher knowledge is associated with better self-management practices, suggesting that knowledge may be more influential when

translated into specific health behaviours rather than functioning as a direct determinant of glycaemic status (19, 20).

The contrast between the significant physical-activity finding and the non-significant knowledge finding in Table 5 may indicate that behavioural factors closer to glucose regulation are more readily reflected in fasting-glucose measurements than factual knowledge alone. However, this interpretation should remain cautious because the present study was cross-sectional and did not assess whether knowledge was actually translated into dietary or physical-activity behaviours. In addition, the small number of participants in the ≥ 126 mg/dL category substantially limits the ability to detect associations involving operational GDM. Therefore, larger prospective studies incorporating validated measures of physical activity, dietary intake, health literacy, and standardized pregnancy-specific glucose testing are needed to clarify the pathways linking maternal knowledge and behaviour with glycaemic status.

Strengths and Limitations

A strength of this analysis is the use of a secondary three-category description of fasting glucose, which identified a substantial subgroup with elevated fasting glucose despite the small number of operational GDM cases. Important limitations include the cross-sectional design, purposive sampling, only three operational GDM events, and the use of a single capillary point-of-care glucose measurement rather than standardized plasma glucose or an OGTT. The operational GDM threshold should therefore not be interpreted as a definitive GDM diagnosis. Physical activity was self-reported, and the available dataset did not permit independent reconstruction of the standard IPAQ categorical algorithm or verification of the modified score. The modification was not independently validated. Potential confounding by pre-pregnancy BMI, gestational weight gain, parity, previous GDM, dietary intake, family history, socioeconomic status, maternal age, and other metabolic factors could not be adequately controlled. The very small number of outcome events also resulted in wide confidence intervals and limited statistical power, particularly for the knowledge analysis. These limitations substantially restrict causal inference and generalizability.

Primary healthcare programs should combine GDM education with practical behavioral counseling and individualized guidance on safe physical activity (12,21). Abnormal point-of-care fasting glucose should not be treated as a definitive GDM diagnosis; women with abnormal results should receive pregnancy-appropriate confirmatory assessment and follow-up. Future studies should use standardized plasma glucose or OGTT-based diagnostic procedures, a clearly specified and validated IPAQ version or objective activity measures, and sufficiently large samples to support adjusted analyses of potential confounders.

CONCLUSION AND RECOMMENDATION

Among 136 pregnant women at 24–28 weeks of gestation, 3 (2.2%) met the study's operational glucose classification of ≥ 126 mg/dL, 48 (35.3%) had fasting capillary glucose of 100–125 mg/dL, and 85 (62.5%) had levels < 100 mg/dL. Physical-activity category was significantly associated with

the operational glucose classification ($p=0.042$), and recorded physical-activity scores differed significantly across the three fasting-glucose categories ($p=0.005$). In contrast, maternal knowledge was not significantly associated with fasting-glucose status. These findings suggest that physical activity may be an important behavioural factor related to glycaemic status among pregnant women in primary healthcare.

However, the results are exploratory because the study used a cross-sectional design, a single capillary glucose measurement, a modified IPAQ-based instrument, and only three participants met the operational ≥ 126 mg/dL threshold. Therefore, the operational classification should not be interpreted as confirmed GDM or as evidence of a causal relationship. Fasting-glucose values of 100–125 mg/dL also warrant clinical confirmation and appropriate antenatal follow-up. Based on the findings, primary healthcare services should strengthen routine assessment and counselling on safe, regular physical activity during pregnancy, particularly for women identified as having low activity levels. Pregnant women with fasting capillary glucose of 100–125 mg/dL, and especially those with values ≥ 126 mg/dL, should receive appropriate clinical confirmation using standardized pregnancy-specific glucose testing and follow-up according to clinical guidance rather than being classified solely on the basis of a single capillary measurement.

Maternal knowledge should continue to be addressed through practical counselling that links information with achievable dietary and physical-activity behaviours. Future research should use larger prospective samples, validated pregnancy-specific measures of physical activity and knowledge, standardized venous plasma glucose or OGTT-based diagnostic procedures, and adjustment for relevant confounders such as maternal age, pre-pregnancy BMI, gestational weight gain, previous GDM, dietary intake, and family history of diabetes.

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