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The Relationship Between Sleep Quality, Glycemic Control, and Maternal-Neonatal Outcomes Among Women with Gestational Diabetes Mellitus in Tanzania

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Abstract

Background: Gestational diabetes mellitus (GDM) is a common pregnancy complication associated with significant maternal and neonatal risks. In low- and middle-income countries such as Tanzania, the rising burden of GDM is compounded by limited healthcare resources. Poor sleep quality has emerged as a modifiable factor linked to worsened insulin resistance and adverse pregnancy outcomes. However, data on sleep quality among women with GDM in sub-Saharan Africa remain scarce. This study aimed to assess sleep quality and its associations with glycemic control and maternal and neonatal outcomes among Tanzanian women with GDM.

Methods: A prospective longitudinal study was conducted in seven regional referral hospitals in Tanzania from August to October 2025. Convenience sampling enrolled pregnant women (18-45 years) diagnosed with GDM in the second trimester. The Pittsburgh Sleep Quality Index (PSQI) was administered at enrollment to evaluate participants' sleep quality over the preceding month retrospectively. Demographic and glycemic data were collected at enrollment, while maternal-neonatal outcomes were extracted within 24 hours post-delivery. Data were analyzed using Stata 19.5 with descriptive statistics and linear and multivariate logistic regressions.

Results: A total of 360 women with GDM were enrolled in this study. The mean PSQI score was 10.8 ± 4.83, with poor sleep quality (PSQI >5) highly prevalent at 91.4%. Higher education and being separated/widowed were associated with worse sleep. The overall glycemic control of participants was poor, with a mean fasting blood glucose of 13.6 ± 5.80 mmol/L. Poor sleep quality was independently associated with higher fasting blood glucose (β = 0.28, 95% CI: 0.20–0.36, P < 0.001). For maternal outcomes, each 1-point increase in PSQI score raised the risk of gestational hypertension (AOR=1.11, 95% CI: 1.01–1.22*, P*= 0.036) and sepsis/infection (AOR=1.14, 95% CI: 1.03–1.26, *P* < 0.001); no significant association was found between sleep quality and postpartum hemorrhage. For neonatal outcomes, each 1-point increase in PSQI raised the odds of neonatal hypoglycemia by 16% (AOR 1.16, 95% CI 1.07–1.27, *P* < 0.001).

Conclusion: Poor sleep quality is highly prevalent among Tanzanian women with GDM and is independently associated with poorer glycemic control, hypertensive disorders, maternal infection, and neonatal hypoglycemia. Integrating routine sleep screening and low-cost sleep interventions into antenatal GDM care may improve glycemic control and maternal-neonatal outcomes in resource-limited settings.

Keywords: Gestational diabetes mellitus; Sleep quality; Glycemic control; Maternal outcomes; Neonatal outcomes; Tanzania

Clinical Trial Number: Not applicable

Background

Gestational diabetes mellitus (GDM) is a major global public health problem, with prevalence ranging from 6.07% to 20.4% [1]. GDM is associated with serious adverse outcomes for mothers and neonates, including hypertensive disorders of pregnancy, macrosomia, neonatal hypoglycemia, and increased risk of type 2 diabetes mellitus [1,2]. In low- and middle-income countries (LMICs) such as Tanzania, the burden of GDM is rising rapidly due to urbanization, physical inactivity, and increasing obesity rates [3]. This trend places additional pressure on already overstretched healthcare systems facing resource shortages and competing priorities [4]. Glycemic control is the core component of GDM management and directly determines maternal and neonatal outcomes [5].

Emerging evidence indicates that modifiable non-traditional factors, particularly sleep quality, play a critical role in metabolic health during pregnancy [6]. A bidirectional correlation exists between sleep deprivation and impaired glucose metabolism [7]. In this correlation reduced sleep duration, increased nocturnal awakenings, and poor sleep efficiency leading to glycemic variability, heightened insulin resistance, and significant risks to both mother and newborn [8–10]. These risks translate directly into adverse clinical outcomes, including newborn hypoglycemia, macrosomia, cesarean section, and preeclampsia [11,12].

Studies in high-income countries have confirmed that sleep interventions can improve glycemic control in GDM [8]. Despite growing evidence from high-income countries, data regarding sleep quality and its relationship with GDM, glycemic control, and pregnancy outcomes remain scarce in sub-Saharan Africa (SSA) [13,14]. Cultural, environmental, and healthcare system differences in Tanzania may alter sleep behaviors and their health impacts [15].

Historically, Tanzanian studies have focused on classical risk factors such as obesity, poor diet, hypertension, anemia, with little consideration of sleep patterns [14,16]. GDM prevalence in Tanzania has increased from less than 1% in 1991 to as high as 27.5% in recent studies, with significant urban-rural disparities and obesity rates ranging from 19.5% to 27.5% in certain regions [17,18]. However, there remains a profound knowledge gap regarding the baseline status of sleep quality among Tanzanian women with GDM and how local sleep patterns correlate with GDM complications and management. Therefore, this study aimed to assess sleep quality and its associations with glycemic control and maternal and neonatal outcomes among Tanzanian women with GDM.

Material and methods

Study design

A prospective longitudinal study was conducted from 1 August 2025 to 1 February 2026 across seven regional referral hospitals (RRHs) in mainland Tanzania. This two-point-in-

time data collection design was adopted to establish a temporal sequence between prenatal sleep exposure and subsequent delivery outcomes, which reduces reverse causality bias compared with cross-sectional research. Data were collected at two distinct stages: (1) second-trimester enrollment for baseline sleep, sociodemographic, and glycemic indicators; and (2) within 24 hours post-delivery to abstract maternal and neonatal clinical outcomes from hospital medical records.

Study Setting

The research was carried out at seven public regional referral hospitals geographically distributed across different regions of Tanzania: Dodoma, Morogoro, Singida, Songea, Shinyanga, Kitete (Tabora), and Manyara Regional Referral Hospitals. Each regional referral hospital delivers comprehensive tertiary obstetric care; manages high-risk pregnancies, including women with GDM; and maintains complete standardized maternal-neonatal medical records, which enabled reliable outcome extraction for this study. These facilities receive antenatal and delivery referrals from surrounding rural and peri-urban dispensaries and health centers, capturing a mixed urban-rural patient population representative of Tanzanian women with GDM.

Participants

The study sample consisted of pregnant women with GDM in their second trimester receiving care at selected regional referral hospitals in mainland Tanzania. Eligible participants were (1) aged 18-45 years, in the second trimester of pregnancy; (2) receiving routine antenatal care at one of the selected regional referral hospitals; and (3) diagnosed with GDM according to the criteria of the International Association of Diabetes and Pregnancy Study Groups (IADPSG). Women were excluded (1) if they had serious underlying medical conditions (e.g., chronic hypertension, renal disease, or psychiatric disorders) that may independently affect sleep quality or pregnancy outcomes, or (2) if they were using sleep-altering medications, including sedatives, stimulants, or other drugs known to affect sleep quality significantly.

Sample size and sampling

The single proportion formula was used to determine the size of the sample to use in this study, and it was calculated using the estimated GDM prevalence of 27.5 in Tanzania, a 95% confidence interval, and a 5% margin of error (z-score of 1.95). The initially used sample was 306 pregnant women. This was estimated with a non-response rate of 15 percent, which resulted in a final sample of 360 participants. The purposive sampling method was used to recruit the participants, with proportional representation of each of the seven sampled centers, with women recruited daily until the required sample size was achieved in each center. Convenience sampling with proportional allocation across the seven hospitals was used to recruit participants (Table 1). The allocation ensured adequate representation from each facility based on the estimated GDM caseload.

Table 1: Proportional allocation across the seven hospitals

Hospital	GDM Caseload	Proportion	Sample (n)
Dodoma RRH	90	0.164	59
Songea RRH	85	0.155	56
Shinyanga RRH	100	0.182	65
Kitete RRH (Tabora)	95	0.173	62
Manyara RRH	80	0.145	52
Morogoro RRH	55	0.100	36
Singida RRH	45	0.082	30
Total	**550**	**1.000**	**360**

RRH = Regional Referral Hospital; GDM = Gestational Diabetes Mellitus

Data collection

Maternal sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a validated 19-item instrument measuring subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction. Scores range from 0 to 21, with scores > 5 indicating poor sleep quality (Cronbach's α = 0.746 in pregnant populations) [19]. Sleep quality was measured retrospectively for the previous month at enrollment. Glycemic control parameters collected at enrollment included fasting blood glucose (mmol/L); HbA1c (where available); frequency and method of blood glucose monitoring (fingerstick, continuous glucose monitoring, or laboratory tests); and GDM treatment modality (diet, oral agents, or insulin). Demographic and clinical data collected included age, education level, marital status, obstetric history (gravidity, parity, miscarriage history), pre-pregnancy BMI, and gestational age at GDM diagnosis.

Glycemic Control Assessment Tools: Objective biochemical markers and self-reported glycemic control behaviors were used to assess glycemic control. Fasting blood glucose (mmol/L) was measured after an 8-hour overnight fast and is a basic metabolic indicator. The frequency with which blood glucose was monitored was grouped into multiple times daily, once daily, a few times a week, or rarely/never. A fingerstick glucose meter, a continuous glucose monitoring (CGM) device, or a laboratory blood test was used to monitor the method. Information on glycemic treatment was documented as diet alone, oral hypoglycemic agents, insulin therapy, or a combination of these.

Maternal outcomes were abstracted from delivery records and included mode of delivery (spontaneous vaginal, vacuum, or cesarean section), estimated blood loss, postpartum hemorrhage (>500 mL), hypertensive disorders of pregnancy, and sepsis/suspected infection. Hypertensive disorders were defined according to standard criteria: gestational hypertension as blood pressure ≥140/90 mmHg on two occasions ≥4 hours apart and preeclampsia as gestational hypertension with proteinuria or end-organ dysfunction.

Neonatal outcomes measured immediately after birth included birth weight (low birth weight <2500 g, normal weight 2500–3999 g, and macrosomia ≥4000 g), gestational age at birth (preterm <37 weeks, term 37–41 weeks, and post-term ≥42 weeks), neonatal hypoglycemia (blood glucose <2.2 mmol/L in first 24–48 hours), NICU admission (>24 hours), and stillbirth. (Supplementary File 1)

Data quality and management

Four research assistants received two days of standardized training on study objectives, ethical considerations, and data-collection instruments to ensure consistent interpretation and uniform questionnaire completion. Interview-administered questionnaires were completed using ODK (Open Data Kit) software. The principal investigator monitored all activities daily, reviewed questionnaires for completeness and errors, and addressed issues on the same day to minimize information loss and recall bias. Data were entered into Stata 19.5 and Excel for cleaning, coding, and categorization. Quality control measures included logic checks to ensure responses fell within expected ranges, independent verification through cross-checking and investigation of suspicious values, and regular validations of completeness and consistency. All data were kept confidential in a secure location accessible only to authorized researchers.

Statistical Analysis

Data were analyzed using Stata version 19.5 (Stata Corp, College Station, Texas, USA) [20]. Descriptive statistics were generated to summarize participants' characteristics. Continuous variables were presented as mean ± standard deviation (SD) for normally distributed data or median with interquartile range (IQR) for non-normally distributed data. Categorical variables were summarized as frequencies and percentages.

Bivariate analyses were performed to examine the relationship between sociodemographic and clinical variables and sleep quality (PSQI score). Independent-samples t-tests or one-way ANOVA were used for continuous outcomes, while chi-square tests were applied for categorical variables.

For multivariable analyses, a linear regression model was fitted to identify factors independently associated with sleep quality (PSQI score as the dependent variable). All potential covariates were entered simultaneously into the model. Model fit was assessed using R-squared, F-statistic, and mean square error (MSE). Multivariable logistic regression analysis was performed to determine the association between sleep quality (PSQI score) and maternal outcomes (e.g., hypertensive disorders of pregnancy), with adjustment for potential confounders including age, marital status, education level, residence, gravidity, parity, pre-pregnancy BMI, miscarriage history, and GDM treatment modalities. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported.

Statistical significance was set at $p < 0.05$ for all analyses. Assumptions for linear regression (linearity, normality of residuals, homoscedasticity, and multicollinearity) were checked and satisfied. No imputation was performed for missing data; complete-case analysis was used where applicable.

Results

Demographic characteristics of pregnant women with GDM

Table 2 summarizes the demographic and baseline clinical characteristics of 360 women diagnosed with GDM. The majority of participants were older than 25 years (59.7%), with a median age of 27.5 years (IQR: 23-33). Most were married (80.6%), housewives (62.8%), and resided in urban areas (62.2%). The mean gravidity was 2.87 ± 2.06 and mean parity was 2.55 ± 1.75; 83.1% were multiparous. Among those with available data (n = 228), 32.5% reported a history of miscarriage, with a median of one previous miscarriage. The mean pre-pregnancy BMI was 22.8 ± 5.82, and 79.2% of women had a normal weight. The median distance to the nearest health facility was 3 km (IQR: 2-5), and the median gestational age at the first antenatal care visit was 18 weeks (IQR: 12-24). Only 9.2% had chronic conditions. GDM was typically diagnosed at a median of 23 weeks' gestation (IQR: 20-28). Regarding treatment, 74.4% managed their condition with diet, 84.7% used oral medication, and 9.2% required insulin therapy (categories not mutually exclusive).

Table 2. Demographic and baseline clinical characteristics of women with GDM (n = 360)

Variable	**GDM Cohort n (%) or mean ± SD or Median (IQR)**
Age group (years)	
18–25	145 (40.3)
>25	215 (59.7)
Age (years), Median (IQR)	27.5 (23–33)
Marital status	
Married	290 (80.6)
Other (single/divorced/widowed)	70 (19.4)
Occupation	
Housewife	226 (62.8)
Other occupations	134 (37.2)
Residence	
Urban	224 (62.2)
Rural	136 (37.8)
Gravidity, Mean ± SD	2.87 ± 2.06
Parity, Mean ± SD	2.55 ± 1.75
Parity status	
Multipara	299 (83.1)
Primipara	61 (16.9)

History of miscarriage (n = 228)	
No	154 (67.5)
Yes	74 (32.5)
Number of miscarriages, Median (IQR)	1 (1–2)
Pre-pregnancy BMI, Mean ± SD	22.8 ± 5.82
BMI category	
Normal weight	285 (79.2)
Underweight/Overweight/Obese	75 (20.8)
Distance to nearest health facility (km), Median (IQR)	3 (2–5)
Gestational age at first ANC visit (weeks), Median (IQR)	18 (12–24)
Chronic conditions	
Yes	33 (9.2)
No	327 (90.8)
Gestational week of GDM diagnosis, Median (IQR)	23 (20–28)
Current GDM treatment †	
Diet-controlled	268 (74.4)
Oral medication	305 (84.7)
Insulin therapy	33 (9.2)

Note: † Categories are not mutually exclusive.

Sleep quality, glycemic control, and maternal-neonatal outcomes in women with GDM

Table 3 presents sleep quality assessments, glycemic control and monitoring practices, and maternal–neonatal outcomes among women with GDM. Sleep quality was generally poor: the mean PSQI score was 10.8 ± 4.83, and 91.4% of participants had poor sleep quality (PSQI > 5). Common sleep problems included fairly bad subjective sleep quality (50.8%), sleep duration of only 5–6 hours (32.8%), habitual sleep efficiency below 65% (37.2%), and sleep disturbance due to nocturia (83.9%). Glycemic control was suboptimal, with a mean fasting blood glucose of 13.6 ± 5.80 mmol/L and a median HbA1c of 10% (IQR: 5.9-10). Blood glucose monitoring frequency varied, with 38.9% checking a few times a week and only 15.0% monitoring multiple times daily. Most women used a fingerstick blood glucose meter (76.1%). Hypoglycemia occurred in 21.7% of participants (mean 2.36 ± 1.08 episodes among those affected). Nearly all women (93.3%) were on medication for blood sugar, and overall satisfaction with management was moderate (38.9% somewhat satisfied, 18.9% very satisfied). Among 343 women with available delivery data, maternal complications included hypertensive disorders of pregnancy (30.9%), postpartum hemorrhage (12.5%), and sepsis/suspected infection (9.6%). Delivery was by spontaneous vaginal birth in 63.0% and cesarean section in 35.8%. Neonatal outcomes showed a live-birth rate of 93.6% and stillbirth rate of 6.4%. Mean birth weight was 3.5 ± 0.56 kg; macrosomia (≥ 4.0 kg) occurred in 26.5% of infants, while

low birth weight was rare (1.8%). Neonatal hypoglycemia (60.6%) and NICU admission (46.9%) were common.

Table 3. Sleep quality, glycemic control, and maternal–neonatal outcomes in women with GDM

Variable	**GDM Cohort n (%) or mean ± SD or Median (IQR)**
Sleep Quality Assessments (n = 360)	
Mean PSQI score, Mean ± SD	10.8 ± 4.83
Sleep quality category	
Poor sleep quality (PSQI > 5)	329 (91.4)
Good sleep quality (PSQI ≤ 5)	31 (8.6)
Selected PSQI Components	
Subjective sleep quality “Fairly bad”	50.8%
Sleep duration 5–6 hours	32.8%
Habitual sleep efficiency < 65%	37.2%
Sleep disturbance due to nocturia	83.9%
Glycemic Control & Monitoring (n = 360)	
Fasting blood glucose (mmol/L), Mean±SD	13.6 ± 5.80
HbA1c, Median (IQR)	10 (5.9–10)
Frequency of blood glucose monitoring	
Multiple times daily	54 (15.0)
Once daily	121 (33.6)
A few times a week	140 (38.9)
Rarely or never	45 (12.5)
Method to monitor blood sugar †	
Fingerstick blood glucose meter	274 (76.1)
Continuous glucose monitoring (CGM) device	21 (5.8)
Laboratory blood tests only	155 (43.1)
Experienced hypoglycemia during pregnancy	
No	282 (78.3)
Yes	78 (21.7)
Number of episodes, Mean ± SD (n = 78)	2.36 ± 1.08
Currently on medication for blood sugar	
No	24 (6.7)
Yes	336 (93.3)
Satisfaction with blood sugar management	
Very dissatisfied	0 (0.0)
Somewhat dissatisfied	23 (6.4)
Neutral	129 (35.8)
Somewhat satisfied	140 (38.9)
Very satisfied	68 (18.9)
Maternal Outcomes (n = 343)	
Hypertensive disorders of pregnancy	106 (30.9)

Sepsis / suspected infection	33 (9.6)
Postpartum hemorrhage	43 (12.5)
Spontaneous vaginal delivery	216 (63.0)
Cesarean section	123 (35.8)
Neonatal Outcomes (n = 343)	
Live birth	321 (93.6)
Stillbirth	22 (6.4)
Mean birth weight (kg), Mean±SD	3.5 ± 0.56
Macrosomia (≥ 4.0 kg)	91 (26.5)
Low birth weight (< 2.5 kg)	6 (1.8)
Neonatal hypoglycemia	208 (60.6)
NICU admission	161 (46.9)

Note: † Categories are not mutually exclusive. Maternal and neonatal outcomes are reported for n = 343 participants with available delivery data.

Association between glycemic control and other covariates with sleep quality

The multivariable linear regression analysis examined the associations between sleep quality, glycemic status, and clinical management factors. The cohort demonstrated highly suboptimal glycemic control, with a mean fasting blood glucose of 13.6 mmol/L and a median HbA1c of 10%. Blood glucose monitoring quality varied, with 38.9% checking blood sugar several times per week, 33.6% once daily, 15.0% multiple times daily, and 12.5% rarely or never. Fingerstick meters were the dominant monitoring tool (76.1%), followed by laboratory tests (43.1%) and continuous glucose monitoring devices (5.8%). While 93.3% of participants utilized glucose-lowering medication (98.8% via prescription), 21.7% experienced hypoglycemia, averaging 2.36 episodes during pregnancy. Regarding treatment satisfaction, the majority reported favorable or neutral perceptions, with 38.9% somewhat satisfied, 35.8% neutral, and 18.9% very satisfied, while only 6.4% were somewhat dissatisfied and 0.3% were very dissatisfied. (Table 4)

Table 4. Association of glycemic control and related factors with sleep quality among women with GDM (n = 360)

Variable	**SE (t-value)**	**95% CI (*p*-value)**
Age category (years)		
18–25	—	—

26–30	0.52 (-0.48)	-1.27 to 0.77 (0.632)
31–35	0.56 (-0.04)	-1.13 to 1.08 (0.966)
≥36	0.57 (-1.84)	-2.18 to 0.07 (0.067)
Marital status		
Single	—	—
Married	0.60 (0.25)	-1.04 to 1.34 (0.803)
Separated/Widowed	**0.95 (2.12)**	**0.15 to 3.89 (0.035)**
Highest education level		
No formal education	—	—
Primary education	**0.65 (2.10)**	**0.08 to 2.63 (0.037)**
Secondary education	**0.75 (2.68)**	**0.53 to 3.48 (0.008)**
College and above	**1.03 (3.22)**	**1.28 to 5.32 (0.001)**
Employment status		
Housewife	—	—
Self-employed	0.81 (0.64)	-1.07 to 2.11 (0.523)
Employed	0.51 (-0.91)	-1.48 to 0.54 (0.364)
Residence		
Urban	—	—
Rural	0.49 (1.46)	-0.25 to 1.67 (0.146)
Fasting blood glucose (mmol/L)	**0.04 (6.72)**	**0.20 to 0.36 (<0.001)**
Frequency of blood glucose monitoring		
Rarely or never	—	—
Once daily	0.74 (1.81)	-0.12 to 2.79 (0.072)
A few times per week	**0.62 (4.77)**	**1.72 to 4.14 (<0.001)**
Multiple times daily	**0.99 (3.99)**	**2.01 to 5.91 (<0.001)**
Method of blood glucose monitoring		

Fingerstick blood glucose meter (Yes vs No)	**0.76 (-3.25)**	**-3.96 to -0.97 (0.001)**
Continuous glucose monitoring (Yes vs No)	**0.84 (-2.59)**	**-3.81 to -0.52 (0.010)**
Laboratory blood test (Yes vs No)	0.62 (0.95)	-0.63 to 1.82 (0.341)
Experienced hypoglycemia during pregnancy		
No	—	—
Yes	0.46 (-0.31)	-1.06 to 0.77 (0.756)
Currently on medication for blood glucose control		
No	—	—
Yes	0.78 (1.83)	-0.10 to 2.95 (0.068)
Satisfaction with blood sugar management		
Somewhat dissatisfied	—	—
Neutral	0.82 (0.87)	-0.90 to 2.33 (0.386)
Somewhat satisfied	0.80 (0.73)	-0.99 to 2.16 (0.464)
Very satisfied	0.87 (-1.24)	-2.80 to 0.64 (0.217)

***Note**: Bold font indicates statistical significance at the $p < 0.05$ level. Blank entries (—) indicate reference categories.*

Association between sleep quality and maternal outcomes

Table 5 presents the adjusted multivariate logistic regression analysis of the association between sleep quality and hypertensive disorders of pregnancy among women with GDM. After adjusting for sociodemographic and clinical confounders, each one-unit increase in PSQI score was significantly associated with an 11% increase in odds of developing hypertensive disorders (AOR = 1.11, SE = 0.05, 95% CI: 1.01–1.22, p = 0.036). Significant predictors in the model included secondary education level (AOR = 7.15, p = 0.048), rural residence (AOR = 0.29, p = 0.023), and underweight pre-pregnancy BMI (AOR = 9.03, p = 0.012).

Table 5. Adjusted association between sleep quality and maternal hypertensive disorders of pregnancy

Variable	N	AOR	95% CI	p-value
PSQI score	-	1.11	1.01 – 1.22	**0.036**
Age category (years)				
18-25	145	1		
26-30	84	1.24	0.32 – 4.87	0.758
31-35	62	2.77	0.63 – 12.13	0.175
36 and above	69	1.73	0.36 – 8.35	0.494
Marital status				
Single	45	1		
Married	290	0.62	0.13 – 3.01	0.552
Separated/Widow	25	-	-	-
Highest education level				
Non-formal	40	1		
Primary level	176	2.63	0.56 – 12.37	0.222
Secondary level	87	7.15	1.02 – 50.23	**0.048**
College and above	57	9.40	0.77 – 114.36	0.079
Employment status				
Housewife	226	1		
Self employed	62	0.22	0.04 – 1.33	0.099
Employed	72	0.74	0.22 – 2.52	0.632
Residence				
Urban	224	1		
Rural	136	0.29	0.10 – 0.85	**0.023**

Category of gravidity				
Primigravida	133	1		
Multigravida (2-4)	156	0.41	0.13 – 1.27	0.122
Grand multigravida	71	-	-	-
Category of parity				
Nullipara	27	1		
Primipara	34	1.67	0.31 – 9.04	0.549
Multipara	299	1.14	0.27 – 4.82	0.856
Ever experienced miscarriage				
No	154	1		
Yes	74	1.83	0.74 – 4.57	0.193
Pre-pregnancy BMI				
Normal	285	1		
Underweight	12	9.03	1.61 – 50.57	**0.012**
Overweight	37	1.32	0.33 – 5.26	0.692
Obesity	26	-	-	-
History of chronic conditions				
No	327	1		
Yes	33	0.83	0.19 – 3.55	0.801
Diet-controlled				
No	92	1		
Yes	268	2.37	0.74 – 7.51	0.147
Oral medication				
No	55	1		
Yes	305	0.87	0.20 – 3.85	0.851

Insulin therapy				
No	327	1		
Yes	33	0.79	0.16 – 3.94	0.770

Abbreviations: n=frequency; SE=Standard error; Min=Minimum; Max=Maximum; CI=Confidence interval; p-value=Probability value; OR=Odds Ratio

Association between sleep quality and neonatal hypoglycemia

Table 6 presents the adjusted multivariable logistic regression analysis for the association between sleep quality and neonatal hypoglycemia among women with gestational diabetes mellitus. After adjusting for sociodemographic and clinical confounders, each one-unit increase in PSQI score was significantly associated with a 16% increase in the odds of neonatal hypoglycemia (AOR = 1.16, SE = 0.05, 95% CI: 1.07–1.27, p < 0.001). Insulin therapy during pregnancy was also significantly associated with a strong protective effect (AOR = 0.19, 95% CI: 0.05–0.74, p = 0.017). The crude OR for PSQI score was 1.13 (95% CI: 1.08–1.19, p < 0.001).

Table 6. Adjusted association between sleep quality and neonatal hypoglycemia among women with gestational diabetes mellitus

Variable	**N**	**AOR**	**95% CI**	**p-value**
PSQI score	-	1.16	1.07 – 1.27	**<0.001**
Age category (years)				
18-25	145	1		
26-30	84	0.97	0.38 – 2.47	0.941
31-35	62	1.94	0.66 – 5.68	0.228

36 and above	69	0.68	0.21 – 2.21	0.527
Marital status				
Single	45	1		
Married	290	4.17	0.74 – 23.64	0.107
Separated/Widow	25	3.53	0.45 – 27.51	0.228
Highest education level				
Non-formal	40	1		
Primary level	176	0.55	0.18 – 1.74	0.310
Secondary level	87	0.72	0.17 – 2.98	0.649
College and above	57	0.41	0.06 – 3.03	0.384
Employment status				
Housewife	226	1		
Self employed	62	1.24	0.26 – 5.84	0.783
Employed	72	0.58	0.23 – 1.43	0.236
Residence				
Urban	224	1		
Rural	136	2.00	0.89 – 4.50	0.092
Category of gravidity				
Primigravida	133	1		
Multigravida (2-4)	156	0.71	0.27 – 1.82	0.473
Grand multigravida	71	-	-	-
Category of parity				
Nullipara	27	1		
Primipara	34	2.54	0.70 – 9.18	0.154
Multipara	299	1.96	0.68 – 5.61	0.210

Ever experienced miscarriage				
No	154	1		
Yes	74	1.40	0.63 – 3.08	0.409
Pre-pregnancy BMI				
Normal	285	1		
Underweight	12	3.37	0.69 – 16.55	0.135
Overweight	37	1.26	0.40 – 3.98	0.699
Obesity	26	0.53	0.13 – 2.19	0.382
History of chronic conditions				
No	327	1		
Yes	33	1.42	0.44 – 4.64	0.560
Diet-controlled				
No	92	1		
Yes	268	0.91	0.42 – 1.99	0.821
Oral medication				
No	55	1		
Yes	305	0.39	0.12 – 1.30	0.126
Insulin therapy				
No	327	1		
Yes	33	0.19	0.05 – 0.74	**0.017**

Abbreviations: n=frequency; SE=Standard error; Min=Minimum; Max=Maximum; CI=Confidence interval; p-value=Probability value; OR=Odds Ratio

Discussion

This study demonstrates that poor sleep quality is a highly prevalent and independently modifiable factor associated with adverse maternal and neonatal

outcomes. Each unit increase in PSQI score was independently associated with 11% higher odds of hypertensive disorders of pregnancy, 14% higher odds of maternal infection, and 16% higher odds of neonatal hypoglycemia. Additionally, fasting blood glucose was significantly higher in women with poor sleep quality, suggesting that sleep disturbance mediates dysglycemia in the GDM population.

Our findings reveal that 91.4% of women with GDM experience poor sleep quality, which substantially exceeds population-based estimates for non-pregnant populations [21,22]. While studies generally agree that hyperglycemia in pregnancy is associated with worse sleep, the reported prevalence for GDM cohorts has traditionally ranged from approximately 46% to 69% [23,24]. One study found that 69.2% of GDM patients experienced poor sleep quality with a mean score of 7.7, while another recorded a prevalence of 63.9% [25,26]. Furthermore, the mean PSQI of 10.8 in this study is notably higher than the global estimate for pregnant women, which meta-analyses have reported as approximately 6.07 to 7.54 [26,27]. This disparity may be attributed to specific factors such as advanced maternal age, higher parity, or the use of medications like metformin, which have been independently linked to increased sleep fragmentation and higher PSQI scores in diabetic pregnancies [24]. Consequently, while our findings align with the established trend that GDM exacerbates sleep disturbances through mechanisms such as increased nocturia and sympathetic nervous system activity, the magnitude suggests an exceptionally high level of daytime dysfunction and nocturnal awakenings in this specific population [25].

The robust association between poor sleep quality and elevated fasting blood glucose in our cohort aligns with established mechanistic pathways in pregnant populations [21,22,28]. Sleep deprivation reduces insulin secretion, impairs glucose

utilization, and increases hepatic glucose production through activation of the sympathetic nervous system and elevation of counter-regulatory hormones, including cortisol and catecholamines [24]. In pregnancy, these mechanisms are amplified by physiological insulin resistance that progressively increases across trimesters, particularly in women with GDM [29]. Our finding that frequent blood glucose monitoring was associated with worse sleep, while fingerstick meters and continuous glucose monitoring devices were associated with better sleep, suggests a bidirectional relationship. Previous studies showed women with poor glycemic control require more intensive monitoring. Yet, the cognitive burden and anxiety associated with frequent monitoring itself may further disrupt sleep and worsen glucose control, creating a vicious cycle [28,29]. This finding has important clinical implications, whereby implementing user-friendly glucose monitoring technologies with minimal cognitive burden may improve sleep quality and potentially enhance glycemic control.

Our findings showed poor sleep quality conferred 11% increased odds of hypertensive disorders of pregnancy, consistent with emerging evidence linking sleep dysfunction to preeclampsia in both general and high-risk pregnant populations [30]. The mechanistic pathway involves sleep deprivation activating the renin-angiotensin-aldosterone system (RAAS), increasing systemic vascular resistance and endothelial dysfunction, and exacerbating insulin resistance, all of which are implicated in the pathogenesis of preeclampsia [31,32]. Additionally, sleep fragmentation impairs vascular endothelial function and reduces nitric oxide bioavailability, compromising vasodilatory capacity and placental perfusion [33]. In our model, secondary education and underweight pre-pregnancy BMI were independently associated with hypertensive disorders, while rural residence appeared protective [34–36]. These sociodemographic

associations likely reflect complex interactions between healthcare access, awareness of hypertension, and health-seeking behavior, warranting further investigation in future studies.

Another finding showed that poor sleep quality raised the odds of neonatal hypoglycemia by 16%, which is supported by previous studies [37]. The most likely mechanistic pathway involves maternal hyperglycemia driving fetal hyperinsulinemia, as evidenced by our documented association between maternal sleep quality and elevated fasting glucose [38]. The fetal pancreas responds to maternal hyperglycemia by increasing insulin secretion, and excessive fetal insulinemia suppresses neonatal gluconeogenesis and glycogenolysis immediately post-delivery, precipitating neonatal hypoglycemia [38,39]. Sleep deprivation may independently alter placental function, reduce transplacental amino acid transfer, and impair fetal metabolic programming [39]. Notably, insulin therapy during pregnancy was strongly protective against neonatal hypoglycemia, suggesting that insulin use achieves superior glycemic stability compared to diet-controlled or oral medication approaches, thereby reducing glucose oscillations that trigger fetal hyperinsulinemia [37].

In SSA, the relationship between socioeconomic status and sleep health among women is complex, as evidenced by findings where widowed or separated status often correlates with poor sleep due to social isolation and grief, as seen in other studies as well in communicable and non-communicable diseases [40,41]. While socioeconomic disadvantage generally predicts higher odds of insomnia across many African populations, some research indicates a counterintuitive trend where higher education levels are linked to restless sleep [42]. This association may be driven by increased health awareness leading to more accurate symptom reporting, alongside the intense occupational and

household stress faced by formally employed women [42,43]. Consequently, educated women in regions like Tanzania often navigate competing demands from work, pregnancy management, and domestic responsibilities, which serve as a significant driver of sleep deprivation in these contexts [42,44].

Implications

By addressing an important evidence gap in SSA, this study highlights sleep quality as a potentially modifiable factor associated with maternal and neonatal health among women with GDM. These findings provide a foundation for developing cost-effective and sustainable strategies to improve pregnancy outcomes in Tanzania and other resource-limited settings.

From a clinical perspective, routine sleep assessment may facilitate the early identification of women at increased risk of adverse maternal and neonatal outcomes. Incorporating sleep screening and sleep hygiene education into existing antenatal care services may represent a feasible and scalable strategy to improve maternal metabolic health and pregnancy outcomes, particularly in resource-constrained settings. In addition, promoting effective self-management strategies, including appropriate glucose monitoring, may provide further benefits for both sleep quality and glycemic control.

At the health system level, the findings support the integration of sleep health into current GDM management guidelines and antenatal care programs. Greater awareness among healthcare professionals regarding the role of sleep-in metabolic regulation and pregnancy outcomes may contribute to more holistic and patient-centered care. Policymakers should consider the inclusion of sleep assessment and behavioral sleep interventions within routine maternal healthcare services. Future research should focus on establishing causal relationships between sleep quality and adverse outcomes through

larger longitudinal studies and randomized controlled trials. The use of objective sleep assessment methods and investigations into the biological mechanisms linking sleep disturbance, glycemic dysregulation, and pregnancy complications may further strengthen the evidence base. In addition, implementation research is needed to identify effective and the culturally appropriate approaches for integrating sleep assessment and intervention into routine antenatal care in low-resource settings.

Limitations

Important limitations should be considered when interpreting findings. Convenience sampling of women attending antenatal care at referral hospitals introduces potential selection bias. Women with severe sleep deprivation or those in rural areas with limited healthcare access may be underrepresented. The PSQI is a self-reported measure that is vulnerable to recall and social desirability biases; women may over- or underreport sleep disturbance based on perceived expectations. The cross-sectional analysis of sleep-glycemic control associations cannot establish temporality; bidirectional causal relationships likely exist, with poor sleep worsening glucose control and hyperglycemia-induced osmotic diuresis disrupting sleep. Critical unmeasured confounders include maternal mental health (depression, anxiety, pregnancy-related distress), obstructive sleep apnea, and environmental factors (housing quality, noise, temperature, food insecurity) that may independently influence both sleep and outcomes.

The study was conducted in secondary and tertiary care settings; generalizability to primary care settings, populations using alternative GDM diagnostic criteria, or different seasonal periods may be limited. Finally, reverse causation cannot be entirely excluded; women who developed acute pregnancy complications (preeclampsia, infection) may

have experienced acute sleep disruption from illness symptoms, which could be misattributed to chronic poor sleep.

Conclusion

Poor sleep quality was highly prevalent among women with gestational diabetes mellitus in Tanzania and was independently associated with poorer glycemic control, hypertensive disorders of pregnancy, and neonatal hypoglycemia. These findings identify sleep quality as a potentially modifiable factor linked to adverse maternal and neonatal outcomes. Integrating sleep assessment and management into routine antenatal care may help improve pregnancy outcomes in resource-limited settings. Further longitudinal and interventional studies are needed to clarify causal relationships and evaluate the effectiveness of sleep-focused interventions.

Declaration

Abbreviation

ANOVA	Analysis of variance
CBT-I	Cognitive behavioral therapy for insomnia
IADPSG	International Association of Diabetes and Pregnancy Study Groups
GDM	Gestational diabetes mellitus
LMIC	Low- and middle-income countries
PSQI	Pittsburgh Sleep Quality Index
SSA	Sub-Saharan Africa
SD	Standard deviations

Ethical Approval and consent to participate

Ethical approval was obtained from the Central South University Xiangya School of Nursing Institutional Review Board (protocol number: 2025WJ030) and the United Republic of Tanzania Ministry of Health (Ref No: GA.314/604/01A/10). This study confirms that all methods were performed in accordance with Tanzania Medical Research guideline and adhering to the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Participants were assured of confidentiality, anonymity, and data protection. Data collection procedures complied with ethical standards of non-maleficence, autonomy, and privacy.

Consent for publication
Not available.

Availability of data and material
De-identified individual participant data will be made available, along with the statistical analysis plan and the analytic code (STATA do-file).

Competing interests
No competing interests.

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Author contributions
FK and GJ conceptualized the idea and study design. FK, GJ, and PAS participated in project execution, data collection, data analysis, and results interpretation. EES, SJM, CES, and YZ participated in manuscript writing and subsequent version revision. All authors reviewed and approved the final manuscript.

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