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ORIGINAL RESEARCH

Gestational Diabetes Mellitus Risk Factors in Pregnant Women Attending Public Health Institutions in Ethiopia's Sidama Region: An Unmatched Case-Control Study

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Background: Gestational diabetes mellitus (GDM), a chronic condition leading to glucose intolerance during pregnancy, is common in low- and middle-income countries, posing health risks to both the mother and fetus. Limited studies have been done in Ethiopia, especially using WHO's 2013 universal screening criteria. Therefore, this study aimed to evaluate the risk factors linked to GDM in women attending antenatal (ANC) clinics in Hawassa town public health institutions, located in the Sidama regional state of Ethiopia.

Methods: An Unmatched case-control study was carried out in Ethiopia's Sidama Region from April 1st to June 10th, 2023, involving 510 pregnant women. The Oral Glucose Tolerance Test (OGTT) was utilized for universal screening and diagnosing GDM based on the updated 2013 WHO diagnostic criteria. Data analysis included descriptive and analytical statistics, with variables having p-values below 0.1 deemed suitable for bivariate analysis. Statistical significance was assessed using the adjusted odds ratio (AOR) with a 95% confidence interval and a p-value < 0.05.

Results: The study involved 633 participants (255 cases and 378 controls), resulting in a 100% response rate, with women having an average age of 29.03 years.Variables such as: age at first conception (AOR=0.97, P=0.01, 95% CI (0.95,0.99)), urban residency (AOR=1.66, P<0.01, 95% CI(01.14,2.40)), widowed marital status (AOR=0.30, P=0.02, 95% CI (0.30,0.90)), parity (AOR=1.10, P<0.01, 95% CI (1.03,1.17)), history of stillbirth (AOR=1.15, P=0.03, 95% CI(1.04,2.30)), and previous cesarean section (AOR=1.86, P=0.01, 95% CI (1.13,2.66)) were identified as independent factors associated with GDM.

Conclusion: The study concluded that factors like age at first conception, place of residence, marital status, parity, history of Caesarian section, and stillbirth were independently associated with GDM. Surprisingly, upper arm circumference (MUAC), a proxy for pre-gestational BMI, was not identified as a risk factor for GDM. It is recommended that healthcare providers conduct comprehensive GDM risk assessments in pregnant women to identify and address risk factors, and propose specific screening and intervention strategies.

Keywords: women, WHO, pregnancy, diabetes, DM, factors, screening, OGTT, glucose, SSA, Sub-Saharan Africa, SSA, Ethiopia, Sidama, Hawassa

Introduction

Insufficient synthesis of pancreatic insulin or inappropriate usage of it results in diabetes mellitus (DM).[1,2] DM encompasses Type I and Type II pre-gestational diabetes as well as gestational diabetes (GDM).[1,3] GDM is a prevalent chronic condition that develops during pregnancy, characterized by any level of glucose intolerance typically first identified during pregnancy due to physiological changes in glucose metabolism, placental output, and maternal insulin resistance.[1–5] GDM is diagnosed through specific criteria that cover over 90% of diabetes cases during pregnancy.[1,6] The diagnostic criteria typically involve screening pregnant women for glucose intolerance using tests such as the Oral Glucose Tolerance Test (OGTT) or the Glucose Challenge Test (GCT). These tests assess blood glucose levels at different intervals after an

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overnight fast of 8 to 14 hours, administering 75 gm anhydrous glucose in 250–300 mL water. The WHO 2013 guidelines set diagnostic thresholds for GDM.[7,8]

GDM is a significant global public health issue with both short- and long-term health risks for mothers and fetuses,[3,9–11] including complications like abortion, preterm birth, malformations, cognitive delays, and maternal health issues.[1–5,12–14] This condition also increases the risk of developing diabetes and cardiovascular diseases and results in high healthcare costs and elevated maternal and infant mortality rates.[15] Women with GDM have a higher likelihood of developing type 2 diabetes,[16] with implications for future generations as well.[17]

The prevalence of GDM varies globally depending on demographics, racial/ethnic backgrounds, population characteristics, testing methods, and diagnostic criteria.[1] Notably, GDM is prevalent in low- and middle-income countries, including varying rates across Africa.[12] In Ethiopia, studies show a prevalence ranging from 12.04% to 16.9% among pregnant women,[1,3] with factors such as inadequate dietary variety, high BMI, and family history identified as significant risk factors.[1,4,12,13]

Efforts to address GDM in Ethiopia involve early screening for pregnant women to evaluate risks, diagnose, and start treatment promptly.[18,19] However, challenges persist in implementing universal screening criteria, like the WHO 2013 guidelines, in resource-limited settings.[3,12,20,21] The 2022 Standards of Care protocol stresses the importance of diabetes screening for expectant mothers worldwide, despite these obstacles.[1,14] Initiatives in Ethiopia, such as preconception care programs and revised hospital protocols, strive to enhance maternal and neonatal health outcomes.[22–24] Additionally, the Ethiopian Ministry of Health has endeavored to enhance guidance for healthcare providers on GDM diagnosis, yet there is still insufficient utilization of GDM screening in many healthcare facilities.[9,23]

Limited primary research with WHO 2013 criteria in Sub-Saharan Africa, including Ethiopia, leads to disparities and inconclusive outcomes.[3,12,20,21] Additionally, most GDM studies in Ethiopia use secondary data,[1,25] with few incorporating random blood sugar for diagnosis and focusing on urban hospitals, neglecting rural areas.[4,12,13] Notably, the Sidama Region, a newly emerged Region of Ethiopia, lacks primary research on GDM risk factors using WHO 2013 criteria, highlighting the need for more comprehensive evidence.[18,19] Hence, there is a need for broader evidence, such as this research on GDM risk factors in pregnant women in Ethiopia's Sidama Region, to inform health policies and improve screening, diagnosis, and management protocols. By generating primary data in line with WHO 2013 screening standards, this study adds to the existing literature on GDM in low- and middle-income nations, where the prevalence of the condition is frequently undervalued. The present manuscript was crafted following the Supplementary Materials (STROBE Statement checklist, attached as word document).[26]

Methods and Materials

Study Design

A facility-based unmatched case-controls study was carried out.

Setting

The study conducted at the public hospitals in Hawassa Town, Sidama area, from April 1st, 2023, to June 10th, 2023. The city is divided into eight sub-cities and 32 kebeles, with a population of 455,658 in 2017. Hawassa is home to 83 health facilities, both public and private, including four public hospitals and eleven government-operated health centers. With a population of 394,057, including 190,216 individuals of reproductive age (15–49 years old) and 13,630 pregnant women, these institutions are crucial for providing ANC services. The four public hospitals in Hawassa are dedicated to offering high-quality ANC services to pregnant women with a manageable client volume.

Participants

It appears that the study focused on pregnant women between the ages of 18 and 49 in Hawassa town, selected from public health facilities using a systematic random sampling technique. Two health centers and four hospitals were chosen through an Excel-generated simple random sample method. The anticipated number of pregnant clients for each facility was determined based on the average monthly follow-up rate for antenatal care (ANC). Subsequently, the expected number of pregnant women with and without GDM was estimated monthly for each facility. The sample size for cases

and controls was allocated to each facility using a proportional allocation to sample size (PPS) approach, followed by a month-long screening for GDM.

Out of the total estimated samples (633 in total, with 255 cases and 378 controls), pregnant women were screened for GDM and enrolled systematically based on predetermined eligibility criteria. Only singleton pregnant women aged 18 years or older and at least 12 weeks into gestation were eligible for inclusion in the survey. Pregnant women with pre-existing diabetes mellitus, chronic illnesses, or medications affecting glucose metabolism were excluded from the study. Finally, enumerating and preparing the sampling frame to each health facilities, the Selection and inclusion of cases and corresponding controls occurred during subsequent ANC visits until the entire screened sample was achieved.

Participants were required to provide written consent during their initial visit. Evaluation for pre-existing diabetes was performed following WHO guidelines, and fasting was recommended for accurate screening for GDM during subsequent appointments. Women identified with GDM risk factors were advised to undergo further testing as needed. For more clarity, please see Figure 1 (attached separately in the manuscript).

Methods of Case Ascertainment

Cases for the current investigation were pregnant women attending a public health clinic in Hawassa town who voluntarily participated in the initial screening survey and were diagnosed with GDM. To assess outcomes, expectant mothers were advised to fast for 8–12 hours before undergoing a 75g oral glucose tolerance test (OGTT), lasting 1–2 hours. Utilizing the HemoCue Glucose B-201+ System and five microliters of capillary whole blood, participants' blood glucose levels were measured. Women were instructed to relax before providing a finger prick blood sample for the first time. Following the collection of 2–3 drops of blood, one drop was used to fill a cuvette placed in the cuvette holder. The glucose level was displayed within 40–240 seconds. Subsequently, under supervision, women were given 75 grams of glucose dissolved in 250 mL of water to drink within 5 minutes. One to two hours after glucose intake, capillary blood samples were obtained. Capillary blood values were multiplied by a constant factor of 1.11 to calculate plasma venous values, which were then used to determine glucose levels.[27] Finally, GDM was diagnosed according to the 2013 WHO criteria using a 75g OGTT if specific glucose thresholds were met: fasting plasma glucose of 5.1–6.9 mmol/L, one-hour post-glucose load level of 10 mmol/L, and two-hour post-glucose load level of 8.5–11.0 mmol/L.[7,8,28]

Control Selection

The study's control group consisted of pregnant women from Hawassa town's public health facility who had previously participated in a survey, were not diagnosed with GDM, and were now part of the current research. Control group selection involved choosing women from the earlier survey who did not meet the GDM diagnosis criteria at that time. They were intentionally picked from the sampling frame set up at each health facility post-survey and systematically selected during their subsequent ANC follow-up appointment.

The choice of a case-control study design is driven by the necessity for a strong methodology to pinpoint risk factors and guide preventive measures effectively. This design allows for a thorough comparison between cases and controls, facilitating the assessment of associations and the identification of Region-specific risk factors. Moreover, it plays a crucial role in investigating causality and offering key insights for tailored interventions to enhance maternal and neonatal health outcomes, particularly in the context of GDM in Sub-Saharan Africa (SSA) and specifically in the Sidama Region of Ethiopia.

Variables

Outcome Variable

In this research, pregnant women were screened for GDM through oral glucose tolerance tests after fasting overnight and completing a 75-gram, two-hour OGTT. Blood glucose levels were monitored using the HemoCue Glucose B-201+ glucometer. Women were advised to relax prior to blood sampling. After collecting the initial blood drops, a drop was allowed to fill a cuvette for glucose measurement, which took 40–240 seconds to display. Following this, the women consumed 75 g of glucose dissolved in 250 mL of water within five minutes. Blood samples were taken at one and two hours, and plasma venous values were calculated by multiplying capillary blood values by a constant factor of 1.11.[27]

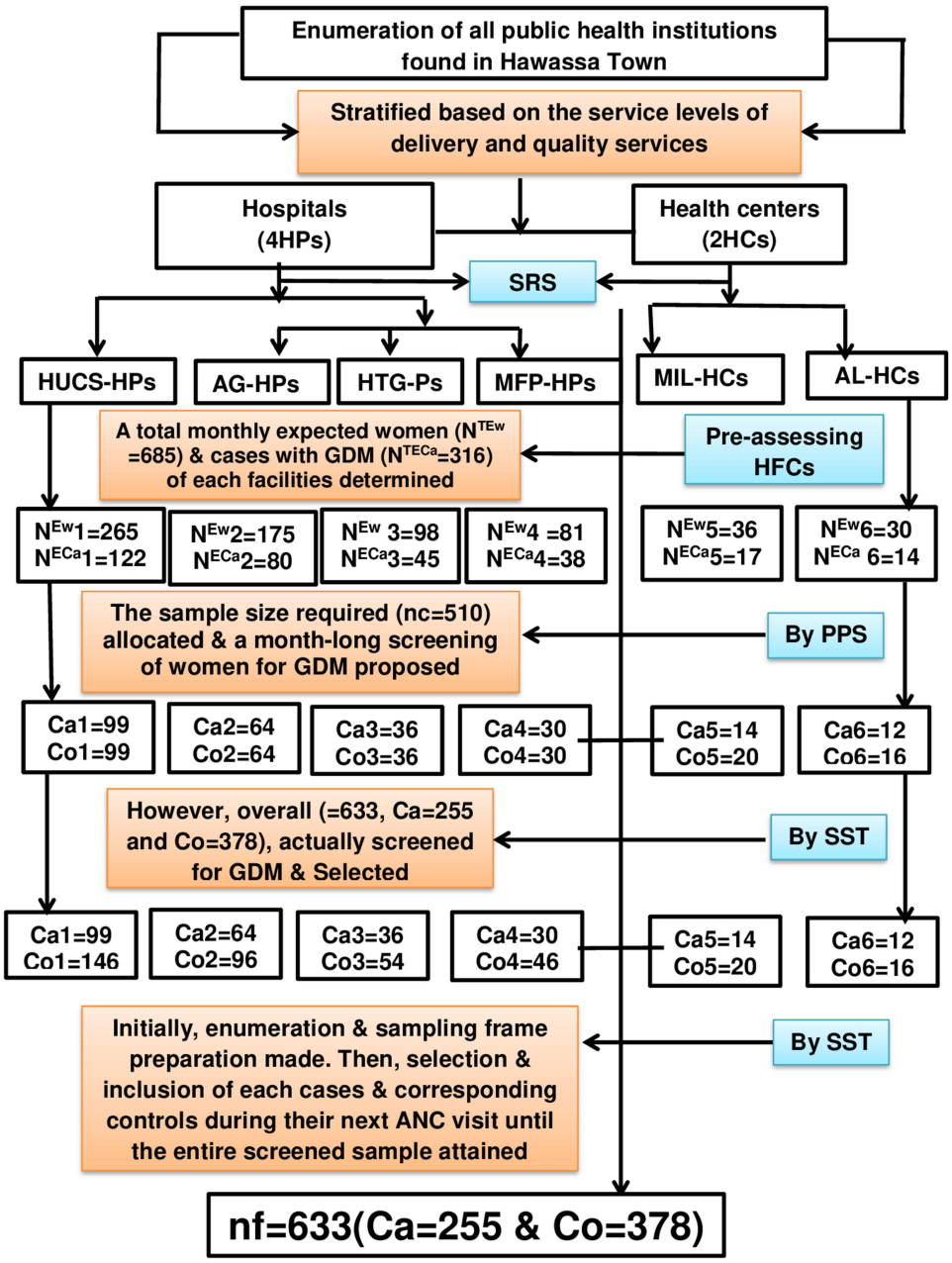

Figure 1 A schematic representation of sampling procedure on GDM case and control study, in pregnant women, Sidama-Region, Ethiopia(n=633), 2023. Millennium Health Center (MIL-HCs), Alito Health Center (AL-HCs), Hawella Tula General Hospital (HTG-HPs), Adare General Hospital (AG-HPs), MotteFurra Primary Hospital (MF-HPs), and Hawassa University Comprehensive Specialized Hospital (HUCS-HPs)).) Simple Random Sampling (SRS), Systematic sampling Techniques (SST), Proportional allocation to size (PPS), Cases(Ca), and Controls (Co), NTEw-Total expected pregnant women visiting the health facilities;NTECa –Total expected cases estimated out of the total women visiting the ANC clinics of the health facilities;NTECo –Total expected controls estimated out of the total women visiting the ANC clinics of the health facilities; HFCs-Health facilities;nc-sample size calculated for the study; nf-The final sample size considered for the study.

The 2013 WHO updated diagnostic criteria were applied to identify GDM.[7] Furthermore, the study categorized individuals as (1=Case, 0=Control), in line with similar research.[8,29]

Exposure variables

Encompass factors such as age, gender, ethnicity, marital status, maternal occupation, education levels of women and spouses, occupation of women and spouses, religion, income, location of residence, and alcohol consumption. Additionally, obstetric and clinical variables including prior child's birth weight, history of GDM, family history of

type II diabetes, previous Caesarian-sections (CS), middle upper arm circumference (MUAC), fasting blood glucose levels, previous cesarean deliveries, and gestational age were considered.[8,29]

Data Sources/ Measurement

The study included six groups of five individuals each, comprising a midwifery nurse and a supervisor. The principal investigator provided a two-day on-site training for 18 data collectors and 12 supervisors. Face-to-face interviews were conducted to gather clinical and sociodemographic data on gestational diabetes mellitus (GDM) using a standardized questionnaire. Data points covered family history of diabetes, birth weight of a prior child, residence, age, marital status, religion, ethnicity, education, employment, and income. Gestational age was determined using reliable methods such as the Last Normal Menstrual Period and dating ultrasounds, with obstetric ultrasounds used when needed. Antenatal Care cards offered socio-demographic, obstetric, and clinical details. Physical activity levels pre-pregnancy were evaluated, and alcohol consumption frequency was noted. Mid-upper arm circumference (MUAC) was measured on the left arm as a proxy for BMI before conception. Pregnant women with a MUAC of 28 cm or more were categorized as overweight or obese.[8]

Bias

The study employed rigorous measures to minimize biases and ensure the credibility of results, by applying WHO 2013 criteria for diagnosing GDM, employing clear participant selection and recruitment methods, utilizing standardized assessment tools, and employing structured data collection techniques. Accurate glucometers were utilized, along with continuous quality control measures. Data collectors and supervisors underwent extensive training, with regular meetings held to uphold data quality. Statistical analyses were carried out to determine GDM predictors, and model adequacy was evaluated using the Hosmer-Lemeshow test. Blinding procedures were instituted for outcome assessors to boost the study's validity and reliability.

Study Size

The sample size for the current study was calculated using OpenEpi version 3, considering a two-sided confidence level of 95%, a power of 80, a control-to-case ratio of 1:1, and a double population proportion exposure difference, as shown in Supplementary Material 1: Table S1. The sample size for the current study was calculated using OpenEpi version 3, considering a two-sided confidence level of 95%, a power of 80, a control-to-case ratio of 1:1, and a double population proportion exposure difference. The hypothetical proportion of controls exposed was 10.4%, based on the major significant predictors of GDM from Ethiopian studies (Supplementary Material 1: Table S1. Sample size determination).[8,29,30] By taking urban residents as the independent predictor exposure variable, the sample size for this study was estimated. The proportion of exposure among cases was 20.19%, while among controls it was 10.4%, with an odds ratio of 2.1.[8] With a control-to-case ratio of 1:1, 80% power at a 95% confidence interval was attained. With 510 pregnant women overall—255 cases and 255 controls—the sample size allowed for a 10% non-response rate for each group. After confirming the power, it was determined to include the 633-person sample from the prior survey in the case-control analysis to increase the effect evaluation's power, since it exceeded the present study's criteria.

Quantitative Variables

The study examined all quantitative variables in their original forms but subjected them to different treatments, such as grouping according to prior research. For example, the outcome variable GDM was assessed using techniques from earlier studies and grouped into either 1 (yes) or 0 (no). Age at first conception was divided into <20, 20–34, and ≥35 years. Other quantitative variables such as gravidity, parity, family size, gestational age, and women's MUAC were categorized for descriptive analysis. The study sought to comprehend how these variables influence women's health.[8,29]

Statistical Methods

The study utilized EPI Data version 3.1 for tasks like data cleaning, coding, error investigation, and analysis. The main investigator oversaw the data entry process. Descriptive stats, including means, standard deviations, tables, and figures, were used for data summarization and presentation. Proportions and 95% confidence intervals assessed the results'

magnitude. Independent variables were checked for multicollinearity via tolerance testing and variance inflation factor analysis. The model's adequacy was gauged using the Hosmer-Lemeshow goodness of fit test. Bivariate and multivariate logistic regressions were conducted to handle confounding variables and identify predictors, with significance levels set at p-values < 0.1 and 0.05 in the initial and subsequent analyses. Findings were reported using crude odds ratios, adjusted odds ratios, and confidence intervals, with statistical significance determined by a P value < 0.05 for significant factors. To address missing data, a comprehensive approach was taken. Initially, missing data patterns were examined to detect potential biases. Techniques like multiple imputation or sensitivity analysis were then applied to effectively manage missing data, ensuring robust analysis of study results while considering and addressing any impact of missing data.

Result

Participants

The study included 633 pregnant women (255 cases and 378 controls) who participated in the screening survey with a 100% response rate overall. The decision to include all pregnant women who underwent screening procedures rather than the predetermined sample size (i.e 510) was made to ensure appropriate case and control samples and to boost the study's ability to detect effect sizes. (Supplementary Materials: Table S1. Sample size determination, attached as word document).

Descriptive Data

Socio-Demographic Characteristics

The study revealed that the average age of cases was 29.03, with controls averaging 30.47. Both groups were primarily in the 20–34 age range, and most cases and controls resided in rural areas. The majority of individuals in both groups had completed secondary education, with a notable proportion having a university/college degree. Furthermore, 31.0% of cases and 29.1% of controls were married, while 55.3% of cases and 49.5% of controls were employed in governmental or non-governmental organizations. The majority of individuals in both groups belonged to the middle-income category. (Refer to Table 1 for details).

Obstetric and Clinical Features of Respondents

The study indicated that the average gestational age of women was 25.21 weeks, with 49.9% of cases falling between 25–40 weeks and 49.6% of controls between 13–24 weeks. For cases, the gravidity and parity were 6.88 and 4.45, respectively, with 71.4% and 43.9% having five or more pregnancies and deliveries. Mid upper arm circumference was measured using an inelastic tape meter, with 72.5% and 79.1% of women having measurements below 28 cm. The majority of cases and controls had birth weights ranging from 2.51–3.9 kg and non-anaemic hemoglobin levels, as detailed in Table 2 and Supplementary Materials (Table S2. The mean and standard deviations, attached as word document).

Factors Associated with GDM

The study utilized a binary logistic regression model to investigate factors associated with gestational diabetes mellitus (GDM). Factors with p-values ≤ 0.1 were included in the multivariable logistic regression analysis. Key predictors identified encompassed age at first conception, place of residence, education, marital status, wealth index, history of stillbirth, GDM, cesarean section (C/S), preterm delivery, child birth weight, HIV/AIDS status, parity, and mid upper arm circumference (MUAC) of women in the study. No issues of multicollinearity were observed, and all variables were retained in the model. The model's adequacy was supported by a P-value of 0.778, with a Predictability Percentage of 85.5%, indicating its potential for future interpretation.

Factors Predicting GDM

A binary logistic regression model was utilized to investigate factors associated with gestational diabetes mellitus (GDM). Variables with p-values ≤ 0.1 were included in the multivariable logistic regression analysis. Key predictors identified encompassed age at first conception, place of residence, education, marital status, wealth index, history of stillbirth, GDM, cesarean section (C/S), preterm delivery, child birth weight, HIV/AIDS status, parity, and mid upper arm circumference (MUAC) of women in the study. No multicollinearity concerns were observed, and all variables were retained in the model. The model's adequacy was affirmed by a P-value of 0.778, with a Predictability Percentage of

Table 1 Socio-Demographic Characteristics, and Bivariable Analysis Result, on GDM Case and Control Study, in Pregnant Women, Sidama-Region, Ethiopia(n=633), 2023

Determinants	Gestational Diabetes Mellitus		COR(95% CI)	P value
	Case (n=255) Number	Control (n=378) Number		
Age at first conception (in years)				
<20	69	80	1	
20–34	114	175	0.76(0.51,1.13)	0.17
≥35	72	123	0.68(0.44,1.05)	0.08
Place of residence				
Rural	156	239	1	
Urban	99	139	1.09(0.79,1.51)	0. 06
Education of women				
Non-Educated	68	95	1	
Primary school completed	40	83	0.67(0.41,1.10)	0.10
Secondary school completed	89	122	1.02(0.67,1.54)	0.93
University/College	58	78	1.04(0.66,1.65)	0.87
Education of spouse's				
Non-Educated	32	66	1	
Primary school completed	42	64	1.35(0.76,2.40)	0.30
Secondary school completed	41	69	1.23(0.69,2.17)	0.49
University/College	140	179	1.61(1.00,2.60)	0.05
Marital status				
Single	63	82	1	
Married	79	110	0.94(0.60,1.45)	0.76
Separated	62	73	1.11(0.69,1.77)	0.68
Widowed	51	113	0.59(0.37,0.94)	0.03
Number of family members				
< 5	159	229	1	
>/= 5	96	149	0.93(0.67,1.29)	0.65
Occupational status women				
House Wife	46	65	1	
Employed	141	187	1.07(0.69,1.65)	0.78
Self-employed	68	126	0.76(0.47,1.23)	0.27
Spouse's occupation				
Government employed	66	101	1	
Merchant	43	62	1.06(0.65,1.75)	0.82
NGO employed	115	168	1.05(0.71,1.55)	0.82
Daily laborer	24	29	1.27(0.68,2.36)	0.46
Farmer	7	18	0.60(0.24,1.50)	0.27
Wealth index in quartiles				
Lowest	75	100	1	
middle	130	168	1.03(0.71,1.50)	0.87
Highest	50	110	0.61(0.39,0.950)	0.03

85.5%, indicating its potential for future interpretation. Several factors emerged as independent predictors of GDM risk. The study noted that the likelihood of developing GDM increased by 0.97 for each unit increase in a woman's age at first conception. Urban residence was linked to higher odds of GDM compared to rural areas. Widowed women exhibited a higher likelihood of GDM compared to single women. Women with a history of caesarean sections had a 1.86 times higher risk of developing GDM. Moreover, a history of stillbirth was linked to an increased risk of GDM. Each additional pregnancy (parity) 1.10 times greater likelihood risk of developing GDM. For further details, refer to Table 3 in the Supplementary Data.

Table 2 Obstetric and Clinical Features, Bivariable Analysis GDM Case, and Control Study, in Pregnant Women, Sidama-Region, Ethiopia(n=633), 2023

Determinants	Gestational Diabetes Mellitus (GDM)		COR(95% CI)	P value
	Case (n=) Number	Control (n=) Number		
Previous history of still birth				
No	161	249	1	
Yes	94	129	1.13(0.81,1.57)	0.08
Previous history C/S[#]				
No	128	215	1	
Yes	127	163	1.31(0.95,1.80)	0.10
Previous GDM history				
No	121	213	1	
Yes	134	165	1.43(1.04,1.97)	0.03
Abortion history				
None	145	226	1	
At least once	110	152	1.13(0.82,1.56)	0.46
Preterm delivery history of women				
No	168	286	1	
Yes	87	92	1.61(1.14,2.28)	0.008
Alcohol consumption history				
No	128	205	1	
Yes	127	173	1.17(0.86,1.62)	0.32
Previous child birth weight in KG[$]				
</=2.50Kg	48	109	1	
2.51–3.9Kg	201	259	1.76(1.20,2.59)	0.004
>/=4 Kg	6	10	1.36(0.47,3.96)	0.57
HIV/AIDS status				
Positive	111	121	1	
Negative	144	257	0.61(0.44,0.85)	0.003
Gestational age in weeks (WKs)[@]				
</= 12 WKs	16	17	1	
13–24 WKs	163	137	1.26(0.62,2.60)	0.52
25–40 WKs	178	122	1.55(0.75,3.19)	0.23
Gravidity				
1	18	20	1	
2–4	55	53	1.15(0.55,2.42)	0.71
≥5	182	305	0.66(0.34,1.29)	0.22
Parity				
1	65	70	1	
2–4	78	80	1.05(0.66,1.66)	0.84
≥5	112	228	0.53(0.35,0.79)	0.002
Measure MUAC[++] of women in CM[!]				
MUAC < 28.00 Cm	185	299	1	
MUAC>/= 28.01 Cm	70	79	1.43(0.99,2.07)	0.06
Pre-ecclampsia state				
No	110	163	1	
Yes	145	215	1.00(0.73,1.38)	0.99
Measured Hemoglobin level of women in mg/dL				
Non-Anaemic (≥11)	120	179	1	
Mild (9.5–10.9)	26	46	0.84(0.49,1.44)	0.53
Moderate (8–9.4)	39	57	1.02(0.6,1.63)	0.93
Severe (6.5–7.9)	70	96	1.090.74,1.60	0.67

Notes: *Significant at P<0.01, [#]C/S, Caesarian Section, [++]MUAC, Mid Upper Arm circumference, [!]CM, Centimeters. [$]Kg, Kilogram, [@]WKs, Weeks.

Table 3 Final Model Formed from Multivariable Analysis Results, on GDM Case and Control Study, Pregnant Women in Sidama-Region, Ethiopia(n=633), 2023

Determinants	Gestational Diabetes Mellitus (GDM)		COR(95% CI)	AOR(95% CI)	P value
	Case (n=255) No	Control (n=378) No			
Age at first conception (in years)	255	378	0.97(0.95,0.99)	0.97(0.95,0.99)	0.01*
Place of residence					
Rural	156	239	1	1	
Urban	99	139	1.09(0.79,1.51)	1.66 (01.14,2.40)	0.01**
Education of women					
Non-Educated	68	95	1	1	
Primary school completed	40	83	0.67(0.41,1.10)	0.70(0.43,1.16)	0.17
Secondary school completed	89	122	1.02(0.67,1.54)	1.15(0.73,1.80)	0.56
University/College	58	78	1.04(0.66,1.65)	1.16(0.67,1.91)	0.57
Education of spouse's					
Non-Educated	32	66	1	1	
Primary school completed	42	64	1.35(0.76,2.40)	1.23(0.68,2.21)	0.48
Secondary school completed	41	69	1.23(0.69,2.17)	1.08(0.60,1.94)	0.80
University/College	140	179	1.61(1.0,02.60)	1.16(0.71,1.90)	0.55
Marital status					
Single	63	82	1	1	
Married	79	110	0.94(0.60,1.45)	0.72(0.44,1.15)	0.17
Separated	62	73	1.11(0.69,1.77)	0.96(0.57,1.60)	0.86
Widowed	51	113	1.52(0.84,2.73)	0.52(0.30,0.90)	0.02*
Wealth index in quartiles					
Lowest	75	100	1	1	
Middle	130	168	1.03(0.71,1.50)	0.87(0.58,1.30)	0.51
Highest	50	110	0.61(0.39,0.950)	0.63(0.39,1.01)	0.06
Previous history of still birth					
No	161	249	1		
Yes	94	129	1.13(0.81,1.57)	1.15(1.04,2.30)	0.03*
Previous C/S[#] history					
No	128	215	1	1	
Yes	127	163	1.31(0.95,1.80)	1.86(1.13,2.66)	0.01*
Previous GDM history					
No	121	213	1	1	
Yes	134	165	1.43(1.04,1.97)	0.73(0.73,1.18)	0.20
Preterm delivery history of women					
No	168	286	1	1	
Yes	87	92	1.61(1.14,2.28)	1.28(0.77,2.12)	0.34
Previous child birth weight	255	378	1.15(0.70,1.90)	0.95(0.55,1.64)	0.85
HIV/AIDS status					
Positive	111	121	1	1	
Negative	144	257	0.61(0.44,0.85)	01.16(0.81,1.65)	0.42
Parity	255	378	1.09(1.02,1.16)	1.10(1.03,1.17)	0.01**
Measure MUAC of women in CM					
MUAC < 28.00 Cm[!]	185	299	1	1	
MUAC>/= 28.01 Cm	70	79	1.43(0.99,2.07)	1.00(0.96,1.04)	0.90

Notes: *Significant at P<0.05, **Significant at P<0.01. [#]C/S, Caesarian-sections, [!]CM, Centimeters. Outcome Variable: Gestational diabetes mellitus (GDM). Exposure Variable(s) entered: age at first conception (in years), Place of residence, education of women, education of spouse's, marital status, wealth index in quartiles, previous history of still birth, previous GDM history, previous C/S history, preterm delivery history of women, Previous child birth weight, HIV/AIDS status, Parity, and measure MUAC of women in CM.

Discussion

The study on risk factors for gestational diabetes mellitus (GDM) in Ethiopia's Sidama Region using a case-control design identified several key factors associated with GDM. These factors include age at first conception, place of residence, marital status, parity, prior history of Caesarean-Sections (CS), and stillbirth. The study also highlighted that upper arm circumference was not found to be a risk factor for GDM in this population.

As this study revealed that a woman's age at first conception independently predicts GDM, with a likelihood increased risk of 0.97 times. This aligns with findings from previous cross-sectional study in Ethiopia[12] The findings across multiple studies in Ethiopia,[25] Tanzania,[13] Uganda,[20] and Cameroon.[17] Also suggested similar conclusions, possibly influenced by publication bias favoring studies with congruent results. Conversely, a study in Ethiopia by Muche et al 2019,[27] found no association between age and GDM development, highlighting potential differences in study participants, design, criteria, recruitment methods, and sample sizes. Changes in healthcare practices, diagnostic criteria, and population characteristics over time could contribute to discrepancies in study outcomes. The study recommended public health initiatives in Ethiopia and sub-Saharan Africa to focus on raising awareness about GDM, promoting healthy lifestyles, and improving access to prenatal care services. Future research should explore genetic, environmental, and sociocultural factors related to GDM.

Furthermore, the study revealed that widowed women had a 0.52 times likelihood of developing GDM compared to single women, aligning with previous findings in Gondar, Northwest Ethiopia[27] The findings shows the interplay of factors like psychosocial dynamics, behavioral changes, and social support in shaping GDM risk among widowed women. Losing a spouse may lead to heightened stress, anxiety, and depression, disrupting hormonal balance and metabolic processes, increasing vulnerability to conditions like GDM. Coping with partner loss can bring about changes in behavior, eating habits, and lifestyle choices, worsened by unhealthy coping mechanisms, raising GDM risk. This finding underscores the role of psychosocial dynamics and social support in reducing stress and fostering well-being, particularly in widowhood in shaping GDM risk among different marital status groups.

Additionally, urban residents were found to have 1.66 times higher odds of acquiring GDM compared to rural residents, consistent with studies in southern Ethiopia,[13,31] Rwanda,[32] and Tanzania[33] in southern Ethiopia, Rwanda, and Tanzania, attributing this trend to factors like sedentary behavior, unhealthy diets, stress levels, and limited access to nutritious foods in urban settings. In contrast, a cross-sectional study in Northwest Ethiopia indicated a higher GDM occurrence among rural women.[34] The variations in GDM definition and classification between studies could also affect comparability, as diagnostic criteria greatly impact GDM measurement.[1–4] On top of that the changes in healthcare services, public health interventions, urbanization patterns, and data collection timing over time may also contribute to varying results among studies. Despite these discrepancies, the study recommends that urban areas prioritize screening and management of GDM, focusing on lifestyle changes and early prenatal care. Longitudinal studies are essential for monitoring trends in GDM prevalence and understanding how urbanization influences GDM, leading to a comprehensive understanding of GDM disparities.

Moreover, the study showed that with each unit increase in parity, the odds of GDM occurrence increased by 1.10 times, which was supported by findings from other studies in South Western Uganda[20] and Pakistan,[35] possibly influenced by lifestyle factors like reduced physical activity during pregnancy.[1,4,13] Nevertheless, the results of this current study conflict with a study conducted in Ethiopia's Northern Amhara Region.[34] These discrepancies could stem from variations in healthcare practices, access to antenatal care, or the prevalence of other GDM risk factors among the populations of Gonder town in the Amhara Region and Hawassa town. The study suggests that parity should be recognized as a GDM risk factor, and healthcare providers should deliver appropriate care to pregnant women with these risk factors. Subsequent research should investigate the link between parity and GDM in different populations and environments to validate these findings.

Additionally, women with a history of Caesarean section were shown to have a 1.86 times higher likelihood of developing GDM. Similarly, a cross-sectional study in Ethiopia reported similar findings.[31] The consistency observed in the feeding patterns of the study populations in Woliyita zone, southern region of Ethiopia, and Sidama regional state, both known for their unique dietary habits, may explain the similarities in results.[1,4,33] Additionally, a systematic review and meta-analysis

indicated a higher likelihood of caesarean section among women with gestational diabetes mellitus (GDM), suggesting a correlation between C/S history and GDM occurrence.[11] Publication bias could also contribute to the perceived result consistency by selectively displaying conflicting findings from unpublished studies. This association underscores the importance of enhanced monitoring and screening for GDM in these populations and the need for further research to establish causality and explore the mechanisms linking C/S and GDM, along with interventions to reduce the risk.

Furthermore, a history of stillbirth emerged as an independent predictor of GDM, with women having a 1.15 times higher likelihood of GDM if they had a history of stillbirth. A systematic review and meta-analysis conducted in Ethiopia by Belay DM, B. (2020) also support these findings, highlighting an association between adverse pregnancy outcomes, particularly prior stillbirth history, and GDM occurrences.[25] Similarly, a study from Wolaita Zone, Southern Ethiopia, identified a link between previous stillbirth history and GDM incidences.[29] The similarities observed in these studies may be attributed to similarities in sample characteristics, such as demographic profiles and healthcare access. Furthermore, a consistent trend was noted between this study and research from Cameroon, indicating that women with a history of stillbirth had significantly higher odds of developing GDM[17] This similarity may stem from robust statistical analyses in both studies, adjusting for confounding factors affecting the link between past stillbirth and GDM. This finding underscores healthcare provider should prioritize early identification and management of GDM, especially for clients with a history of stillbirth. They should offer support, counseling, and lifestyle changes to decrease GDM risk. Public health campaigns should increase awareness and ensure sufficient resources for diagnosis, treatment, and screening. Future research should investigate the mechanisms connecting GDM risk to stillbirth, and validation studies are necessary to enhance the current data.

Despite the absence of pre-gestational weight data in this study, the results surprisingly showed no significant association between MUAC and GDM. This contrasts with the common belief that obesity is a major risk factor for GDM across different ethnic groups. Recent studies in Ethiopia, including a systematic meta-analysis,[1] and research at St. Paul's Hospital Millennium Medical College in Addis Ababa,[12] have demonstrated a similar pattern.A consistent report was also seen in the institution based cross sectional study conducted at St.Paul's Hospital Millennium Medical College, Addis Ababa, Ethiopia.[12] Furthermore, in southern Tanzania,[36] Brazilan[37] Turkey,[38] Asia,[39] Saudi Arabia,[40] and Libreville[41] has reported similar outcomes. Discrepancies in study design and methods of measuring obesity between previous and current studies may account for these differing results. While a study in Gondar town in Northwest Ethiopia employed similar methods to evaluate overweight/obesity and GDM,[27] it produced conflicting findings. This unexpected result could be linked to the unique characteristics of the study population in the Sidama Region of Ethiopia, particularly their dietary patterns. The consumption of fiber-rich foods like "Kocho" in this region may contribute to this variance. The study emphasizes the importance of personalized prevention and management strategies, along with targeted screening methods and interventions. It suggests more research on the relationship between upper arm circumference, obesity, and gestational diabetes risk in the Sidama Region, incorporating comprehensive obesity measures such as waist circumference, body fat percentage, or visceral fat assessments for a deeper understanding of obesity's impact on GDM risk.

The study exhibited strengths by utilizing a contemporary and broadly applicable screening tool to detect gestational diabetes mellitus (GDM) in pregnant women beyond 12 weeks gestation. Employing a two-hour 75g oral glucose tolerance test (OGTT) with updated standard reference cutoff values, along with retesting pregnant women with GDM risk factors despite negative initial OGTT results, enhanced the depth of the research. However, there were notable limitations to consider: The World Health Organization's (WHO) caution against utilizing point-of-care diagnostics in resource-constrained settings such as Ethiopia due to challenges related to laboratory access and blood sample handling may impede the practical application of the findings. The study's inclusion of solely pregnant women from public health institutions could restrict the generalizability of the results to the broader population.

Conclusion

The study concluded that factors such as age at first conception, place of residence, marital status, parity, history of Caesarian section, and stillbirth were independently linked to GDM. Interestingly, upper arm circumference (MUAC), a proxy for pre-gestational BMI, was not identified as a GDM risk factor. It is advised that healthcare providers perform thorough GDM risk assessments in pregnant women to detect and address risk factors, and suggest specific screening and

intervention measures. Future research should investigate the connection between risk factors and GDM to create effective interventions and prevention strategies. Further exploration of the relationship between MUAC, obesity, and GDM risk in the Sidama Region is necessary. Longitudinal studies could offer valuable insights into post-pregnancy GDM risk factors. Collaboration among Ethiopia, other Sub-Saharan African countries, and global partners is encouraged to incorporate recognized risk factors into maternal health guidelines for GDM prevention and promote international research collaborations.

Abbreviation

AOR, adjusted odds ratio; ANC, Antenatal care; BMI, body mass index; BP, blood pressure, while CI is for confidence interval; CM, centimeter; DBP, diastolic blood pressure; DM, Diabetes mellitus; EDPS, Edinburgh Postnatal Depression Scale; FANTA, Food and Nutrition Technical Assistance; FPG, fasting plasma glucose; GDM, gestational diabetes mellitus; HPPO, Hyperglycemia with poor pregnancy outcome; IDF, International Diabetes Federation; IGT, impaired glucose tolerance; LMIC, low and middle-income nations; LNMP, last normal menstrual period; MCH, Maternal and child health; MDDS, Minimum Dietary Diversity Score; MET, Metabolic Equivalent of Task; MUAC, mid-upper arm circumference; NCDs, Noncommunicable diseases; OR, Odds ratio; OGTT, Oral glucose tolerance test; SBP, systolic blood pressure; SD, standard deviation; SPSS, statistical package for the social sciences; WHO, World Health Organization.

Data Sharing Statement

The datasets used and/or analyzed during the current study are available in this published article (and its Supplementary Information Files).

Ethics Approval and Consent to Participate

The study adhered to the ethical principles outlined in the Helsinki Declaration for human research ethics. Approval for the study proposal was obtained from the Institutional Review Board (IRB-RVU) at Rift Valley University's Hawassa Campus (HC). Formal authorization letters were issued to the Hawassa town administration Health Bureau and approved healthcare facilities. Participants were fully informed about the study objectives, outcomes, and screening procedures before data collection, and their informed consent was obtained. Trained data collectors facilitated written consent from each participant before data collection. Detailed history taking, clinical examinations, and laboratory tests were conducted on the participants. Interviews were conducted in private to ensure confidentiality, with data anonymized and participants identified by numbers. Data was used solely for the study's purposes. Participants diagnosed with GDM were referred to healthcare specialists and provided with treatment options at local public hospitals.

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Disclosure

The author reports no conflicts of interest in this work.

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