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Incidence and risk factors of gestational diabetes mellitus among pregnant women in Southeast Ethiopia: a prospective study

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Abstract

Objective: Gestational diabetes mellitus (GDM) increases the risk of perinatal morbidity. Currently, GDM is becoming a public health concern in low and middle-income countries (LMICs), and it is known to cause severe morbidity for mothers and newborns. Hence, this study aimed to assess the incidence and predictors of gestational diabetes mellitus among antenatal care (ANC) pregnant women in Goba town.

Design: A prospective cohort study.

Setting: Goba town health centers in southeast Ethiopia.

Participants: 480 pregnant women on ANC follow up from April 30th to 30th september 2021.

Primary and secondary outcome: Incidence and risk factors of gestational diabetes mellitus.

Results: The cumulative incidence of GDM in this study was 15.7% [95% CI: (12.3, 19.2)]. Being unemployed [aRR = 2.73, 95% CI: (1.36, 5.47)], having a family history of diabetes [aRR = 3.01; 95% CI: (2.09,4.35)], low physical activity [aRR = 2.43, 95%CI: (1.11, 5.32)], inadequate dietary diversity [aRR = 1.48,95%CI: (1.29,1.92)], anemia [aRR=2.51; 95% CI: (1.32, 3.54)] and antenatal depression [aRR =4.95; 95% CI: (3.35, 7.31)] were significantly associated with GDM.

Conclusion: The cumulative incidence of GDM was relatively high. Having antenatal depression symptoms, low physical activity, inadequate dietary diversity, being unemployed, anemia, and family history of DM were identified as significant risk factors for the occurrence of GDM.

Keywords: Gestational diabetes mellitus, pregnant women, risk factors, Ethiopia

Strength and limitations of the study

- Firist prospective study in the study setting gestational diabetes mellitus
- First, in this study fasting plasma glucose is used to diagnose GDM due to lack of resources for oral glucose tolerance test that might affect the strength of recommendations.

- Second, pre-pregnancy anthropometric measurement and BMI were not determined among pregnant women which may be part of the determinant factors**.**

Background

Gestational diabetes mellitus (GDM) is a glucose intolerance detected during pregnancy for the first time (1). Pregnancy itself induces changes in maternal glucose metabolism and insulin sensitivity, thereby increasing the demand for insulin production (2). Gestational diabetes mellitus diagnosed in pregnancy complicates 3% to 5% of pregnancies, and it is associated with an increased risk for perinatal morbidity (3).

Diabetes mellitus and other non-communicable diseases are becoming more prevalent in developing countries, including Ethiopia (4). Globally, diabetes prevalence is increasing rapidly, estimated 381 million in 2013 to 422 million living with diabetes in 2015. According to the international diabetes federation's (IDF) projection, by 2035, the global burden of diabetes will reach 592 million people, or one in 10, will have diabetes (5). The International Diabetes Federation estimates that 16.2% of live births to women had some form of hyperglycemia in pregnancy (6). In sub-Saharan Africa (SSA), the burden was revealed to be 14.28% (7). In Ethiopia, women are at greater risk of GDM despite having a lower mean body mass index (BMI) (8). In a study conducted in Gondar town, the cumulative incidence was 12.8% (9). Other studies conducted in Wolita and Hadiya zones, the southern part of Ethiopia reported the cumulative incidence of GDM to be 4.2% (10) and 26.2% (11), respectively.

Gestational diabetes mellitus is associated with a greater risk of neonatal macrosomia (12,13), shoulder dystocia, neonatal trauma, respiratory distress, increased admission to neonatal intensive care units (14). Women with hyperglycemia detected during pregnancy are at greater risk of adverse pregnancy outcomes, with an incidence of 30.3% (15). These include high blood pressure and birth difficulties, with the baby more prone to fractures and nerve damage (6). Gestational diabetes mellitus also results in permanent type 2 diabetes in women, with an incidence ranging from 2.6% to 70% (16,17).

High GDM prevalence was observed in mothers with a family history of type 2 diabetes (13,18,19), previous stillbirth, high mid-upper arm circumference (MUAC), and anemia (20,21). Advanced maternal age (22), inactive physical activity, and risky behaviors have also been

shown to increase the magnitude of GDM (19,23). The proportion of gestational diabetes mellitus increases with the number of pregnancies (24).

Adverse outcomes in pregnancies among women with diabetes are, in most cases, preventable by optimizing glycemic control. Early screening and treatment of mothers with GDM can minimize the complications for both mothers and their babies (14). Once diagnosed with GDM, a woman has a substantial chance of developing type 2 diabetes following delivery, with some studies reporting a 5-year cumulative incidence rate of over 50% (25).

Despite all the above facts, there are few studies on the incidence and associated factors of GDM in SSA (26), including Ethiopia, particularly in the study setting. Therefore, we aimed to assess the incidence and predictors of GDM in Southeast Ethiopia.

Methods

Study design and setting

A facility-based prospective follow-up study was conducted among pregnant women in health centers, Goba town from April 30th to September 30th, 2021. The pregnant women were followed from 20 weeks of gestation to 32 weeks. Goba is one of the administrative towns in the Bale zone, located 445km away from Addis Ababa city. According to the 2019 fiscal year, the total population of Goba town was 51,562 and the estimated number of pregnant women was 1789 (27). The town has two health centers and one referral hospital. The health centers found in Goba town serve more than three-fourths of pregnant women for antenatal care (ANC) follow-up.

Source population

All pregnant women who started ANC were followed-up at Harawa Sinja and Oda Baha Health Center, Goba town, southeast Ethiopia.

Study population

Pregnant women with a gestational age of 20 weeks who were on ANC at Harawa Sinja and Oda Baha Health Center, Goba town, Southeast Ethiopia.

Inclusion criteria

Pregnant women who are permanent residents of the study area and without any known pre-existing or overt diabetes mellitus (DM).

Exclusion criteria

Pregnant women who took medications that could affect glucose metabolisms, such as steroids, beta-adrenergic agonists, and anti-psychotic medications, and who have an acute febrile illness were excluded.

Sample size determination and sampling techniques

Sample size estimation was determined using Epi Info version 7 software, taking into account the following statistical assumptions: The proportion of stillbirths in the non-exposed and exposed groups was 5.17% and 14%, respectively, at a confidence level of 95% (2-sided), power of 80%, and exposed to non-exposed ratio of 1:2 (9). Considering the loss to follow-up of 15%, the minimum sample size required for the study was 480 pregnant women.

Table 1: Sample size calculation for different associated factors

Exposure variables	Exposed to non-exposed ratio	Event in the non-exposed vs exposed	Power of the study	Crude odds ratio	Total sample size
Family history of DM (9)	1:2	5.17% vs 14%	80	2.97	417
History of abortion (10)	1:2	16.3% vs 45.5%	80	4.2	101
previous GDM(21)	1:2	1.8% vs 12%	80	7.4	236

All pregnant women on ANC follow-up at two health centers, Goba town and fulfilled our inclusion criteria were included in the study.

Variables of the study

Dependent variable

Gestational diabetes mellitus :- Defined as blood glucose level that fulfills one of the following criteria according to updated world health organization (WHO) diagnostic criteria (Fasting

plasma glucose between 92 to 125 mg/dl or one-hour oral glucose tolerance test ≥ 180mg/dl or two-hour oral glucose tolerance test between 153 to 199 mg/dl) (1)

Exposure variables

Sociodemographic variables such as pregnant women's age, occupation, religion, ethnicity, and educational status; behavioral variables (caffeine, alcohol, dietary diversity and smoking); reproductive related factors; previous history of (GDM, pregnancy-induced hypertension, stillbirth, intrautrine fetal death , and spontaneous abortion); health-related (chronic disease); and family history of type 2 DM and GDM) were considered in this study.

Data collection procedures

An interveiewer-administered, a structured questionnaire was prepared in English and translated into the local language 'Amharic and Afan Oromo.' The questionnaire was back-translated into English to assure consistency. The questionnaire was checked by language experts (MA holders in language). Midwifery with a Bachelor of Science degree was involved in the data collection activity. Three days of training were provided to data collectors aiming to familiarize them with the study's objectives, data collection methods, ethical issues, and the contents of the questionnaire.

Both primary and secondary data (chart review) were collected. The baseline maternal and socio-demographic characteristics, behavioral, dietary diversity, and antenatal depression status were collected using face-to-face interviews. Dietary diversity was assessed using a 24- hour food recall method by the Food and Nutrition Technical Assistance (FANTA) 2016 version of the woman's minimum dietary diversity measurement tool. The four or less minimum dietary diversity score (MDDS) was categorized as inadequate dietary diversity (28).

The Edinburgh Postnatal Depression Scale (EPDS) screening tool was utilized to assess antenatal depression in the past week (29). The short form of the International Physical Activity Questionnaire (IPAQ) was employed to assess the physical activities of the last seven days. Then, using metabolic equivalents (MET-minutes per week) of the IPAQ scoring protocol, pregnant women were categorized into a high, moderate, and low level of physical activity (30).

Fasting blood glucose was performed for all pregnant women by plasma glucose testing, using a standard plasma-calibrated glucometer (Hemo Cue Glucose B-201+ (Sweden)) following new

recommendations by WHO for GDM diagnosis (1) (31). Initially, a blood glucose test (random blood glucose) was performed for all selected pregnant women at 20 weeks of gestation to rule out the presence of preexisting diabetes or overt diabetes. Then screening for GDM using fasting blood glucose was performed at 24-28 weeks of gestational age (Figure 1). A similar measurement was repeated at 32 weeks of gestation to identify the late occurrence of GDM. Participants diagnosed with GDM were referred immediately (linked) to health care providers who are experts in managing GDM. Follow-ups were assured through the public health facilities in close collaboration with experts and data collectors.

Data quality control

The data quality was assured by applying a properly designed and pre-tested questionnaire. The tool was pre-tested on five percent of the sample size at the Baha Biftu health center one week before the actual data collection to establish its ability to elicit relevant information. In addition, the researchers ensured proper categorization and coding of the questions. The investigators and a supervisor conducted regular supervision and follow-up. In addition, a regular check-up for completeness and consistency of the data was undertaken daily. Incomplete questionnaires were completed during the second appointment. All plasma glucose measurements strictly followed the manufacturer's instructions and standard operating procedures.

Data processing and analysis

The questionnaires were coded manually. The data were entered into Epi-data version 3.1 and then exported from Epi-data to Stata 14 for analysis. Data were checked for missing values. Descriptive statistics were presented using frequencies, percentages, mean and standard deviations to describe study subjects. Multicollinearity was checked by looking at values of variance inflation factors (VIF< 7). The final model fitness was assessed using the Hosmer-Lemeshow goodness of fit test. Bivariate log-binomial regression analysis was be employed to examine the relationship between the outcome and independent variables. Those variables with p $\leq$ 0.2 in the bivariate log-binomial regression analyses were entered into a multivariable log-binomial regression model. This helps to identify important associated factors for the dependent variables after controlling possible confounding factors. The crude and adjusted relative risk was used to estimate the strength of the association between predictors and outcome variables. Variables with a p-value < 0.05 were considered statistically significant with the outcome variable.

Patient and public involvement

Patients and the public were not involved in the planning, designing and interpreting of these data analyses.

Ethical considerations

The research protocol was approved by Ethical Review Committee, Madda Walabu University (Reference no: RDD/0097/13). All methods were conducted following the relevant tenets of the Helsinki Declaration. An official letter was obtained from the Goba town health office. Then, the letters were given to the Harawa Sinja Health Center and the Oda Baha Health Center heads. Finally, written consent was obtained from each study participant after explaining the risk and benefit of participating in the study. The privacy of the respondents was protected though out the data collection process, and anonymity and confidentiality of the data were maintained.

Results

Sociodemographic and economic characteristics of pregnant women

The study included a total of 432 pregnant women, making the response rate 90%. The mean age of the pregnant women was 26.58 (SD ± 5.88) years. Most of the participants (97.8%) were married, (88.9%) were from the Oromo ethnic group, and nearly half (47.5%) were Muslim in religion. One hundred thirty-seven (31.7%) women had attended secondary school education, while about 80.5% of pregnant women were unemployed (Table 2).

Table 2:Sociodemographic and economic characteristics of pregnant women attending ANC follow up at health centers of Goba town, southeast Ethiopia: April to September 2021(n=432)

Variables		Non-GDM n (%)	GDM n(%)	Total (%)
Age in years	< 25	159 (43.7)	23 (33.8)	182(42.1)
	25-29	120 (33.0)	21(30.9)	141(32.6)
	30-34	52 (14.3)	13 (19.1)	65 (15.1)
	>34	33 (9.1)	11(16.2)	44(10.2)
Religion	Orthodox	157 (43.1)	28 (41.1)	185(42.8)
	Muslim	173 (47.5)	32 (47.1)	205(47.5)
	Protestant	34 (9.3)	8 (11.8)	42(9.7)
Ethnicity	Oromo	293 (80.5)	55 (80.9)	348(88.9)
	Amhara	61 (16.8)	11(16.2)	72 (16.7)
	Others	10 (2.7)	2(2.9)	12 (2.8)
Educational	No formal education	53 (14.6)	11(16.3)	64 (14.8)

status	Primary school	117 (32.1)	19 (27.9)	136 (31.5)
	Secondary school	118 (32.4)	19 (27.9)	137 (31.7)
	Collage and above	76 (20.9)	19 (27.9)	95 (21.9)
Occupational status	Employed	60 (16.5)	24 (35.3)	84 (19.4)
	Non employed	304 (83.5)	44 (64.7)	348 (80.6)

*Others (Gurage, Wolita)

Clinical characteristics of study participants

The mean systolic blood pressure was 105.9 (SD ± 10.2) mmHg, and diastolic blood pressure was 66.4 (SD ± 7.6) mmHg. The pregnant women's mean hemoglobin and random blood glucose levels were 11.9 (SD ±1.1) and 108 (SD ±16.7), respectively. Nearly one-third (33.8%) of the women were primigravida. Twenty-seven (6.3%) had a family history of diabetes mellitus. Fifty (11.6%) pregnant women were identified to have anemia. The previous history of abortion and stillbirth were reported among 3 and 3.8% of pregnant women, respectively (Table 3).

Table 3: Obstetric history of study participant attending ANC follow up at health centers of Goba town, southeast Ethiopia: April to September 2021 (n=432)

Variables		Non-GDM (n=364)	GDM (n=68)	Total
Gravidity	One	143 (39.3)	23 (33.9)	146 (33.8)
	Two	99 (27.2)	22 (32.4)	121 (28.0)
	Three	68 (18.6)	11(16.2)	79 (18.3)
	Four and above	54 (14.3)	12(17.6)	66(15.3)
History of abortion/ Intrauterine fetal death	Yes	5 (2.3)	3 (6.7)	8 (3.0)
	No	216 (97.7)	42 (93.3)	258 (97.0)
History of Stillbirth	Yes	8 (3.6)	2 (4.4)	10 (3.8)
	No	213 (96.4)	43 (95.6)	256 (96.2)
History of confirmed PIH in a previous pregnancy	Yes	12 (5.4)	2 (4.4)	14 (5.3)
	No	209 (94.6)	43 (95.6)	252(94.8)
History of confirmed GDM in a previous pregnancy	Yes	2 (0.9)	1 (2.2)	3 (1.1)
	No	119 (91.1)	44 (97.8)	263 (99.9)
Family history of Diabetes	Yes	17 (4.7)	10 (14.7)	27 (6.3)
	No	347 (95.3)	58 (85.3)	405 (93.7)
Hemoglobin status	< 11mg/dl	35 (9.6)	15 (22.1)	50 (11.6)
	≥11mg/dl	329 (90.4)	53 (77.9)	372 (88.4)

A slightly higher proportion of diabetes family history was revealed among women with GDM than non-GDM (14.7% vs. 4.7%). When pregnant women were compared in terms of anemia

status, those with GDM were identified to have a higher proportion than non-GDM (22.1% vs. 9.6%) (Table 3).

Behavioral and lifestyle characteristics of pregnant mothers

Out of total participants, alcohol and coffee intake during pregnancy was reported by (17.8%) and (90%), respectively. Out of women who consumed coffee, nearly one-third of them reported consuming two cups of coffee per day. Most pregnant women (45.8%) reported having low physical activity, while about one in ten pregnant women reported having probable antenatal depression symptoms. An inadequate dietary diversity score was reported in 6.3% of pregnant women who participated in this study (Table 4).

Table 4: Behavioral characteristics of study participant attending ANC follow up at health centers of Goba town, southeast Ethiopia 2021(n=432)

Variable		Non-GDM (n=364)	GDM (n=68)	Total
History alcohol intake during this pregnancy	Yes	65 (17.9)	12 (17.6)	77 (17.8)
	No	299 (82.1)	56 (82.4)	355 (82.2)
Type of alcohol	Local	49 (75.4)	8 (66.7)	57 (74.0)
	Bear	16 (24.6)	4 (33.3)	20 (29.0)
History of coffee intake in this pregnancy	Yes	326 (89.6)	63 (92.4)	389 (90.0)
	No	38 (10.4)	5 (7.6)	43 (10.0)
Number cups of coffee per day	One cup	83 (25.5)	10 (15.9)	93 (23.9)
	Two cups	110 (33.7)	16 (25.4)	126 (32.4)
	Three cups	79 (24.2)	16 (25.4)	95 (24.4)
	Four and above cups	54 (16.7)	21 (33.3)	75 (19.3)
Physical activity status during pregnancy	Low	156 (49.7)	42 (61.8)	198 (45.8)
	Moderate	144 (39.6)	20 (29.4)	164 (38.0)
	High	64 (17.6)	6 (8.8)	70 (16.2)
Antenatal depression status	Probable depression	24 (6.6)	20 (29.4)	44 (10.2)
	Possible depression	43 (11.8)	13 (19.1)	56 (12.9)
	No depression	297(81.6)	35 (51.5)	332 (76.9)
Dietary diversity score	< 5 (inadequate)	18 (4.9)	9 (13.2)	27 (6.3)
	≥ 5(adequate)	346 (95.1)	59 (86.8)	405 (93.7)

Low physical activity was reported to be higher among non-GDM than GDM pregnant women (49.7% vs. 61.8%). Pregnant women with GDM were shown to have a higher proportion of antenatal depression when compared with non-GDM (29.4 vs. 6.6 %). Similarly, inadequate dietary diversity was revealed to be higher among GDM when compared to non-GDM pregnant women (4.9-13.2%) (Table 4).

Incidence of GDM

During the study period, 432 pregnant women were followed for 4781 weeks. A total of 68 pregnant women developed GDM. The mean time of diagnosis of GDM is 26.1 (95% CI 25.65 to 26.51) weeks of pregnancy. The overall incidence rate of GDM was 14.22 per 1000 weeks of follow-ups, and the cumulative incidence was 15.7% (95%: (12.3, 19.2%) over 5 months.

Predictors of GDM among pregnant women.

The adjusted log-binomial regression model has indicated that being unemployed [aRR=2.73; 95%CI:(1.36, 5.47)], having family history of diabetes [aRR = 3.01; 95% CI: (2.09– 4.35)], low physical activity [aRR = 2.43; 95% CI: (1.11, 5.32)], inadequate dietary diversity [aRR = 1.48; 95% CI: (1.29, 1.92)], anemia [aRR=2.51; 95% CI: (1.32, 3.54)] and antenatal depression [aRR =4.95; 95% CI: (3.35, 7.31)] were significantly associated with GDM (Table 5).

Table 5: Bivariate and multivariable log-binomial regression analysis and predictors of GDM among pregnant women attending antenatal care at health centers, Goba town, southeast Ethiopia: April to September 2021 (n=432)

Variables		Non-GDM (n=364)	GDM (n=68)	cRR (95% CI)	aRR (95% CI)
Age in years	< 25	159	23	1	1
	25-29	120	21	1.18 (0.68, 2.04)	1.36 (0.80, 2.33)
	30-34	52	13	1.58 (0.85, 2.94)	1.53 (0.84, 2.77)
	>34	33	11	1.98 (1.04, 3.75) +	1.84 (0.96, 3.50)
Occupational status	Employed	91	8	1	1
	Non-employed	273	60	2.23 (1.10, 4.5) ++	2.73 (1.36, 5.47) **
Family history of Diabetes	Yes	17	10	2.59 (1.49, 4.47) +	3.01(2.09, 4.35) **
	No	347	58	1	1
	Total	364	68		
hemoglobin status	< 11mg/dl	35	15	2.16 (1.32, 3.54) +	2.51 (1.70, 3.69) **
	≥ 11mg/dl	329	53	1	1
	Total	364	68		

History of coffee intake in this pregnancy	Yes	326	63	1.39 (0.59, 3.27)	
	No	38	5	1	
	Total	364	68		
Number of cups coffee per day	One cup	83	10	1	1
	Two cups	110	16	1.18 (0.56, 2.48)	1.09 (0.44, 2. 29)
	Three cups	79	16	1.57 (0.75, 3.27)	1.85(0.91, 3. 77)
	Four and above cups	54	21	2.60 (1.30, 5.19) +	2.54 (1.38, 5.06) *
Physical activity status during pregnancy	Low	156	42	2.71 (1.26, 5.82)+	2.43 (1.11, 5.32)*
	Moderate	144	20	0.57(0.35, 0.94) +	1.98 (0.88,4.47)
	High	64	6	1	1
Antenatal depression status	Probable depression	24	20	4.31(2.75, 6.77) ++	4.95 (3.35, 7.31) **
	Possible depression	43	13	2.20 (1.24, 3.89) +	2.12 (1.21, 3.71) *
Dietary diversity score	< 5	18	9	1.57 (1.09, 2.62)+	1.48 (1.29,1.92)**
	≥ 5	346	59	1	1

aRR = **p-value < 0.001 *p-value < 0.05, cRR = ++p-value < 0.001 +p-value < 0.05

Discussion

The objective of this study was to determine the incidence of GDM and associated factors among women attending antenatal care in health centers, Goba town, southeast Ethiopia. In this study, the cumulative incidence of GDM among pregnant women attending ANC in health centers of Goba town was found to be 15.7%. Our finding was almost similar to study conducted in Gondar town, Ethiopia (12.8%) (9) and Qingdao, China (17%)(32). The current finding was higher than the study conducted in Wolita Zone, Ethiopia (4.2%)(10). The possible reason might be the difference in the sample size. Nevertheless, it was lower than a study conducted in Tanzania in which the cumulative incidence was identified to be 19.5% (33). Similarly, the current finding was lower than the study conducted in Nigeria, in which the prevalence of GDM was 21.2% (34). A futher study conducted in Hadiya Zone, Ethiopia, revealed a higher incidence than our finding (26.2%)(11). This shows that the incidence of GDM is increasing as of other chronic medical conditions, which have been increasing with lifestyle modification. The variation might be variation in sample size and other sociodemographic variables.

Unemployment was shown to have a significant statistical association with GDM. As revealed in this study, non-employed pregnant women were 2.73 times as high as the risk of developing

GDM compared with the employed pregnant women. The current finding disagreed with a study conducted in Gondar town (9). The variation might be because of the difference in sociodemographic characteristics. Further, among unemployed women low physical activity was shown to have a difference in non-GDM and GDM pregnant women (46%vs 67%), respectively. This is difference supported by the evidence that employed adults were more likely to be physically active than non-employed (35) (36), similarly employed pregnant women were physically active compared with the non-employed group (37). Physical inactivity, in turn, increases the risk of developing GDM (38). In this finding, pregnant women with low physical activity were 2.43 times at risk of developing GDM than pregnant women who performed high physical activity. This finding is supported by a study conducted in Gondar town (9) and Amhara region, Ethiopia (21). Similarly, a study conducted in Tanzania has identified low physical activities as a risk factor for GDM (39).

The risk of developing GDM was 2.6 times higher in pregnant women with a family history of diabetes than their counterparts. This finding agreed with a prospective cohort study conducted in Florida which revealed that the risk of GDM among women having a family history of diabetes was increased by two-fold (40). Similarly, a study in Poland (Poznan city) identified family history of diabetes as an independent risk factor for GDM (41). This association could be because GDM has a genetic component that may predispose individuals to develop glucose intolerance during pregnancy, and type 2 diabetes shares a common genetic background with GDM (42).

Anemia was also shown to have an association with the occurrence of GDM. Our finding indicated that pregnant women with anemia were 1.9 times at risk of developing GDM compared with non-anemic pregnant women. The was finding supported by a study conducted in Tanzania that revealed pregnant women with anemia were at increased risk of developing GDM (20). Even though we do not have data that support anemia management with iron suplementatinon increase risk of GDM, there are some evidence that supports women who have anemia being supplemented with iron, which accumulates more than required, and over accumulated iron stored during pregnancy will elevate the risk of developing GDM (43). Further increased ferritin, hemoglobin, and dietary heme intake were associated with an increased risk of GDM (44).

The probability of developing GDM was 3.1 times in the pregnant women who reported antenatal depression symptoms than those with no depression symptoms. The present result supported a study conducted in Chicago which revealed that women with GDM were 3.79 times more likely to have a history of depression (45). Similarly, a cohort study conducted in Canada has reported a two-fold increased risk of depression among GDM women than in non GDM (46). The possible explanation could be depression results in hypercortisolemia, increasing insulin resistance (47).

In this study, pregnant women with inadequate dietary diversity were 1.5 times at risk of developing GDM than those with adequate dietary diversity. The finding agreed with the study conducted in Gondar town, where pregnant women with inadequate dietary diversity were at risk of developing GDM (9). This observation can be because inadequate dietary diversity will decrease the probability of getting a high-fiber diet that controls blood sugar levels (48). Further, inadequate dietary diversity decreases the chance of getting antioxidants in food consumed, which is important to prevent or delay b-cell dysfunction in diabetes by protecting against glucose toxicity (49).

Limitations of the study

First, in this study fasting plasma glucose is used to diagnose GDM due to lack of resources for oral glucose tolerance test that might affect the strength of recommendations, however different studies reported fasting plasma glucose (FPG) as the most sensitive and specific test (50,51) and recommended to be conducted in resource-limited settings (50). Second, pre-pregnancy anthropometric measurement and BMI were not determined among pregnant women which may be part of the determinant factors.

Conclusion

The cumulative incidence of GDM was relatively higher in Goba town. Having antenatal depression symptoms, anemia, a family history of diabetes, low physical activity, inadequate dietary diversity, and being unemployed, were identified as risk factors for the occurrence of GDM. Therefore, it is important to increase community awareness on the importance of physical exercise, increasing recreational activities, and diversifying food intake during pregnancy. The study's findings would be an input for decision-makers to combat GDM in Ethiopia.

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Patient consent for publication: Not required.

Ethical approval: The research protocol was approved by Ethical Review Committee, Madda Walabu University (Reference no: RDD/0097/13). All methods were conducted following the relevant tenets of the Helsinki Declaration. An official letter was obtained from the Goba town health office. Then, the letters were given to the Harawa Sinja Health Center and the Oda Baha Health Center heads. Finally, written consent was obtained from each study participant after explaining the risk and benefit of participating in the study. The privacy of the respondents was protected though out the data collection process, and anonymity and confidentiality of the data were maintained.

Data availability statement: Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplemental information. Data will be available upon request from the corresponding authors.

Figure legend /caption

Figure 1: Flow diagram of outcome ascertainment for pregnant women on ANC from April 30 to September 30, 2021.

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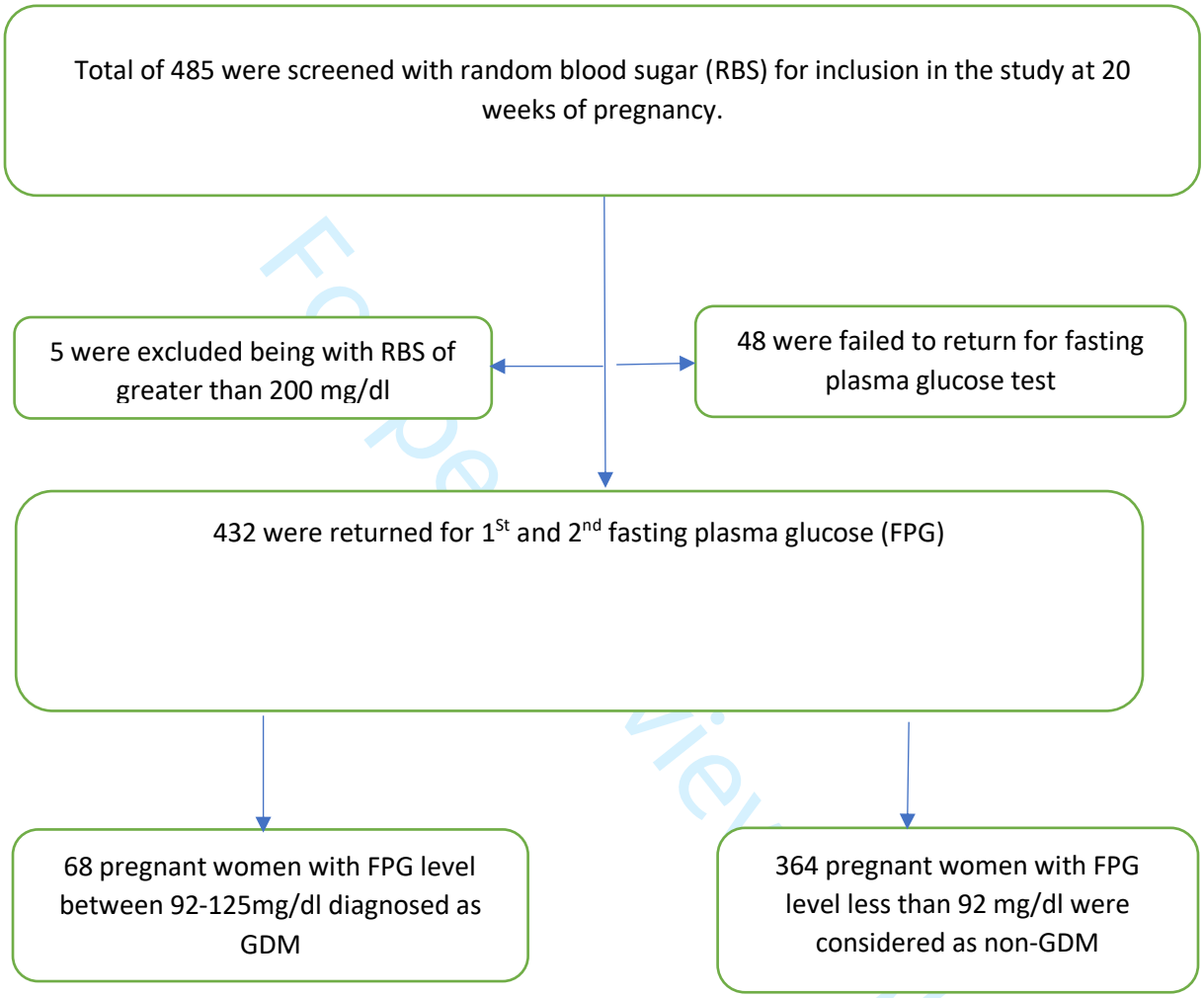
Figure 1: Flow diagram of outcome ascertainment for pregnant women on ANC from April 30th to 30th September 2021.



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3/4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	4/5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	Report numbers of outcome events or summary measures over time	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Incidence and risk factors of gestational diabetes mellitus in Goba town, Southeast Ethiopia: a prospective cohort study

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Incidence and risk factors of gestational diabetes mellitus in Goba town, Southeast Ethiopia: a prospective cohort study

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Abstract

Objective: Gestational diabetes mellitus (GDM) increases the risk of perinatal morbidity. Gestational diabetes mellitus pregnant women receiving is becoming a public health concern in low and middle-income countries (LMICs), and it is known to cause severe morbidity for mothers and newborns. Hence, this study aimed to assess the incidence and predictors of gestational diabetes mellitus among antenatal care (ANC) in Goba town.

Design: A prospective cohort study.

Setting: Goba town health centers in southeast Ethiopia.

Participants: 480 pregnant women on ANC follow-up from 30th April to 30th September 2021.

Primary and secondary outcome: Incidence and risk factors of gestational diabetes mellitus using fasting capillary blood glucose.

Results: The cumulative incidence of GDM in this study was 15.7% [95% CI: (12.3, 19.2)]. Being unemployed [adjusted relative risk (aRR) = 2.73, 95% CI: (1.36, 5.47)], having a family history of diabetes [aRR = 3.01; 95% CI: (2.09,4.35)], low physical activity [aRR = 2.43, 95%CI: (1.11, 5.32)], inadequate dietary diversity [aRR = 1.48,95%CI: (1.29,1.92)], anemia [aRR=2.51; 95% CI: (1.32, 3.54)] and antenatal depression [aRR =4.95; 95% CI: (3.35, 7.31)] were significantly associated with GDM.

Conclusion: The cumulative incidence of GDM was relatively high. Having antenatal depression symptoms, low physical activity, inadequate dietary diversity, being unemployed, anemia, and a family history of DM were identified as significant risk factors GDM.

Keywords: Gestational diabetes mellitus, pregnant women, risk factors, Ethiopia

Strength and limitations of the study

- To our knowledge, this is the first prospective cohort study conducted on GDM in the southeast Ethiopia.
- In this study, fasting capillary blood glucose is used to diagnose GDM.
- Oral glucose tolerance test (OGTT) was not determined due to resource limitation.
- Pre-pregnancy anthropometric measurement and BMI were not determined among pregnant women,which might be part of predictor variables**.**

Background

Gestational diabetes mellitus (GDM) is a glucose intolerance detected during pregnancy for the first time (1). Pregnancy itself induces changes in maternal glucose metabolism and insulin sensitivity, thereby increasing the demand for insulin production (2). The common period for the diagnosis of GDM is between 24 to 28 weeks of gestation (3). However, hyperglycemia during early pregnancy was identified as a risk factor for developing GDM(4). Therefore, determining blood glucose level as early as possible is important to decrease adverse pregnancy outcomes (5,6).

Diabetes mellitus (DM) and other non-communicable diseases are becoming more prevalent in developing countries, including Ethiopia (7). Globally, diabetes prevalence is increasing rapidly, estimated 381 million in 2013 to 422 million living with DM in 2015. According to the international diabetes federation (IDF), by 2035, the global burden of DM is projected to reach 592 million, or one in ten, will have DM (8). The International Diabetes Federation estimates that 16.2% of live births to women had some form of hyperglycemia in pregnancy (9). In sub-Saharan Africa (SSA), the burden of GDM was found to be 14.28% (10). In Ethiopia, women are at greater risk of GDM despite having a lower mean body mass index (BMI) (11). In a study conducted in Gondar town, the cumulative incidence was 12.8% (12). Other studies conducted in Wolita and Hadiya zones, the southern part of Ethiopia reported the cumulative incidence of GDM to be 4.2% (13) and 26.2% (14), respectively.

Gestational diabetes mellitus is associated with a greater risk of neonatal macrosomia (15,16), shoulder dystocia, neonatal trauma, respiratory distress, and increased admission to neonatal intensive care units (17). Women with hyperglycemia detected during early pregnancy are at greater risk of adverse pregnancy outcomes (4), with an incidence of 30.3% (18). These include high blood pressure and birth difficulties, with the baby more prone to fractures and nerve damage (9). Gestational diabetes mellitus also results in permanent type 2 diabetes mellitus (T2DM) in women, with an incidence ranging from 2.6% to 70% (19,20).

A higher prevalence of GDM was observed in mothers with a family history of T2DM (16,21,22). Further, a study conducted on Russian women also identified that a genetic variant in MTNR1B is associated with an increased risk of GDM (23). Previous stillbirth, high mid-upper arm circumference (MUAC), anemia (24,25), advanced maternal age (26), low physical activity,

and a sedentary lifestlyle have also been shown to increase the risk of GDM (22,27). A higher BMI, abdominal circumference and fasting glycemia in the first trimester of pregnancy revealed a 13-fold increased risk of GDM(28). The proportion of gestational diabetes mellitus increases with the number of pregnancies (29).

In most cases, adverse pregnancy outcomes among women with GDM are preventable by optimizing glycemic control. Early screening and treatment of mothers with GDM can minimize the complications for both mothers and their babies (17). Once diagnosed with GDM, a woman has a substantial chance of developing T2DM following delivery, with some studies reporting a 5-year cumulative incidence rate of over 50% (30).

Despite all the above facts, there are only a few studies on the incidence and associated factors of GDM in SSA (31), including in Ethiopia, particularly in the study setting. Therefore, we aimed to assess the incidence and predictors of GDM among pregnant women receiving antenatal care in southeast Ethiopia.

Methods

Study design and setting

A facility-based prospective follow-up study was conducted among pregnant women in health centers of Goba town from April 30th to September 30th, 2021. The pregnant women were followed from 20 weeks of gestation to 32 weeks. Goba is one of the administrative towns in the Bale zone, located 445km from Addis Ababa city. According to the 2019 fiscal year, the total population of Goba town was 51,562 and the estimated number of pregnant women was 1789 (32). The town has two health centers and one referral hospital. The health centers in Goba town serve more than three-fourths of pregnant women for antenatal care (ANC) follow-up.

Source population

All pregnant women who started ANC were followed-up at Harawa Sinja and Oda Baha Health Center, Goba town, southeast Ethiopia.

Study population

Pregnant women with a gestational age of 20 weeks who were on ANC at Harawa Sinja and Oda Baha Health Center, Goba town, Southeast Ethiopia.

Inclusion criteria

Pregnant women who are in their 20 weeks of gestation, singleton pregnancy, permanent residents of the study area, and without any known pre-existing or overt diabetes mellitus (DM).

Exclusion criteria

Pregnant women who took medications that could affect glucose metabolisms, such as steroids, beta-adrenergic agonists, and anti-psychotic medications, and who have an acute febrile illness were excluded.

Sample size determination and sampling techniques

Sample size estimation was determined using Epi Info version 7 software, taking into account the following statistical assumptions: The proportion of the previous history of stillbirths in the non-exposed and exposed groups was 5.17% and 14%, respectively, at a confidence level of 95% (2-sided), power of 80%, and exposed to the non-exposed ratio of 1:2 (12). Considering the loss to follow-up of 15%, the minimum sample size required for the study was 480 pregnant women (Table 1). All pregnant women with a gestational age of 20 weeks were included in this study until the required sample size has reached.

Table 1: Sample size calculation for different associated factors

Exposure variables	Exposed to non-exposed ratio	Event in the non-exposed vs exposed	Power of the study	Crude odds ratio	Total sample size
Family history of DM (12)	1:2	5.17% vs 14%	80	2.97	417
History of abortion (13)	1:2	16.3% vs 45.5%	80	4.2	101
previous GDM(25)	1:2	1.8% vs 12%	80	7.4	236

All pregnant women on ANC follow-up at two health centers in Goba town who fulfilled our inclusion criteria were included in the study.

Variables of the study

Dependent variable

Gestational diabetes mellitus :- Defined as Fasting capillary blood glucose between 92 to 125 mg/dl(1).

Exposure variables

Sociodemographic variables such as pregnant women's age, occupation, religion, ethnicity, and educational status; behavioral variables (caffeine, alcohol, dietary diversity and smoking); reproductive related factors; a previous medical history of (GDM, pregnancy-induced hypertension, stillbirth, intrauterine fetal death, and spontaneous abortion); health-related (chronic disease); and family history of T2DM and GDM were considered in this study.

Data collection procedures

An interviewer-administered, structured questionnaire was prepared in English and translated into the local language 'Amharic and Afan Oromo.' The questionnaire was back-translated into English to assure consistency. The questionnaire was checked by language experts (MA holders in language). Midwifery with a Bachelor of Science degree was involved in the data collection activity. Three days of training were provided to data collectors to familiarize them with the study objectives, data collection methods, ethical issues, and the questionnaire.

Both primary and secondary data (chart review) were collected. The baseline maternal and socio-demographic characteristics, behavioral, dietary diversity, and antenatal depression status were collected using face-to-face interviews. Dietary diversity was assessed using a 24-hour food recall method by the Food and Nutrition Technical Assistance (FANTA) 2016 version of the woman's minimum dietary diversity measurement tool. The four or less minimum dietary diversity score (MDDS) was categorized as inadequate dietary diversity (33).

The Edinburgh Postnatal Depression Scale (EPDS) screening tool was utilized to assess antenatal depression in the past week (34). The short form of the International Physical Activity Questionnaire (IPAQ) was employed to assess the physical activities of the last seven days. Then, using metabolic equivalents (MET-minutes per week) of the IPAQ scoring protocol, pregnant women were categorized into high, moderate, and low levels of physical activity (35).

Fasting capillary blood glucose was performed for all pregnant women by capillary blood glucose, using a standard plasma-calibrated glucometer (Hemo Cue Glucose B-201+ (Sweden)). Even though, the sensitivity of capillary blood glucose is lower than venous blood glucose, the international consensus is that it is acceptable in resource-poor settings for GDM diagnosis (3). Initially, a capillary blood glucose test (random blood glucose) was performed for all pregnant women at 20 weeks of gestation to rule out the presence of pre-existing or overt DM. Then screening for GDM using fasting capillary blood glucose was performed at 24-28 weeks of gestational age (Figure 1). A similar measurement was repeated at 32 weeks of gestation to identify the late occurrence of GDM. Participants diagnosed with GDM were referred immediately (linked) to health care providers who are experts in managing GDM. Follow-ups were assured through the public health facilities in close collaboration with experts and data collectors.

Outcome assertainment

In this study, initially, pregnant women were invited to participate. Then screened for pre-existing DM using rondom capillary blood glucose. Pregnant women who were identified to have rondom capillary blood glucose greater than 200mg/dl, have excluded from the study. Finally, the included pregnant women were undergone fasting capillary blood glucose mesuarment. Pregnant women with fasting capillary blood glucose between 92-125mg/dl were diagnosed as GDM and pregnant women with fasting capillary blood glucose level less than 92 mg/dl declared as non-GDM.

Data quality control

The data quality was assured by applying a properly designed and pre-tested questionnaire. The tool was pre-tested on five percent of the sample size at the Baha Biftu health center one week before the actual data collection to establish its ability to elicit relevant information. In addition, the researchers ensured proper categorization and coding of the questions. The investigators and a supervisor conducted regular supervision and follow-up. In addition, a regular check-up for completeness and consistency of the data was undertaken daily. Incomplete questionnaires were completed during the second appointment. The manufacturer's instructions and standard operating procedures were strictly followed for all blood glucose measurements.

Data processing and analysis

The questionnaires were coded manually. The data were entered into Epi-data version 3.1 and then exported from Epi-data to Stata 14 for analysis. Data were checked for missing values. Descriptive statistics were presented using frequencies, percentages, mean and standard deviations to describe study subjects. Multicollinearity was checked by looking at values of variance inflation factors (VIF< 7). Bivariate log-binomial regression analysis was employed to examine the relationship between the outcome and independent variables. All the variables with $p \leq 0.2$ in the bivariate log-binomial regression analyses were entered into a multivariable log-binomial regression model. This step helps to identify important associated factors for the dependent variables after controlling possible confounding factors. The crude and adjusted relative risk was used to estimate the strength of the association between predictors and outcome variables. Variables with a p-value < 0.05 were considered statistically significant with the outcome variable.

Patient and public involvement

Patients and the public were not involved in the planning, designing, and interpreting of the analysed data.

Ethical considerations

The research protocol was approved by the Ethical Review Committee ofMadda Walabu University (Reference no: RDD/0097/13). All methods were conducted following the relevant tenets of the Helsinki Declaration. An official letter was obtained from the Goba town health office. Then, the letters were given to the Harawa Sinja Health Center and the Oda Baha Health Center heads. Finally, written consent was obtained from each study participant after explaining the study's risks and benefits. The privacy of the respondents was secured throughoutthe data collection process, and anonymity and confidentiality of the data were maintained.

Results

Sociodemographic and economic characteristics of pregnant women

In this study, 500 pregnant women were invited to participate. Of the invited, 485 agreed to participate and were screened for pre-existing DM using random capillary blood glucose. Five

pregnant women were identified to have random capillary blood glucose greater than 200mg/dl, therefore excluded from the study. Of the remaining 480 pregnant women, 48 were lost from follow-up. The remaining 432 pregnant women were undergone fasting capillary blood glucose measurements. Sixty-eight pregnant women were identified to have fasting capillary blood glucose levels between 92-125mg/dl, while 364 pregnant women had capillary blood glucose levels less than 92mg/dl (figure 1).

The study included a total of 432 pregnant women, making the response rate 90%. The mean age of the pregnant women was 26.58 (SD ± 5.88) years. Most of the participants (97.8%) were married, (88.9%) were from the Oromo ethnic group, and nearly half (47.5%) were Muslim in religion. One hundred thirty-seven (31.7%) women had attended secondary school education, while about 80.5% of pregnant women were unemployed (Table 2).

Table 2:Sociodemographic and economic characteristics of pregnant women attending ANC follow-up at health centers of Goba town, southeast Ethiopia: April to September 2021(n=432)

Variables		Non-GDM n (%)	GDM n(%)	p.value
Age in years	< 25	159 (43.7)	23 (33.8)	
	25-29	120 (33.0)	21(30.9)	
	30-34	52 (14.3)	13 (19.1)	
	>34	33 (9.1)	11(16.2)	.027
Religion	Orthodox	157 (43.1)	28 (41.1)	
	Muslim	173 (47.5)	32 (47.1)	
	Protestant	34 (9.3)	8 (11.8)	.733
Ethnicity	Oromo	293 (80.5)	55 (80.9)	
	Amhara	61 (16.8)	11(16.2)	
	Others	10 (2.7)	2(2.9)	.990
Educational status	No formal education	53 (14.6)	11(16.3)	
	Primary school	117 (32.1)	19 (27.9)	
	Secondary school	118 (32.4)	19 (27.9)	
	Collage and above	76 (20.9)	19 (27.9)	.538
Occupational status	Employed	60 (16.5)	24 (35.3)	
	Non employed	304 (83.5)	44 (64.7)	.017

*Others (Gurage, Wolita)

Clinical characteristics of study participants

The mean systolic blood pressure was 105.9 (SD ± 10.2) mmHg, and diastolic blood pressure was 66.4 (SD ± 7.6) mmHg. The pregnant women's mean hemoglobin and random blood glucose levels were 11.9 (SD ±1.1) and 108 (SD ±16.7), respectively. Nearly one-third (33.8%) of the

women were primigravida. Twenty-seven (6.3%) had a family history of diabetes mellitus. Fifty (11.6%) pregnant women were identified to have anemia. The previous history of abortion and stillbirth were reported among 3 and 3.8% of pregnant women, respectively (Table 3).

Table 3: Obstetric history of study participant attending ANC follow-up at health centers of Goba town, southeast Ethiopia: April to September 2021 (n=432)

Variables		Non-GDM (n=364)	GDM (n=68)	P-value
Gravidity	One	143 (39.3)	23 (33.9)	
	Two	99 (27.2)	22 (32.4)	
	Three	68 (18.6)	11(16.2)	
	Four and above	54 (14.3)	12(17.6)	.515
History of abortion/ Intrauterine fetal death	Yes	5 (2.3)	3 (6.7)	
	No	216 (97.7)	42 (93.3)	.115
History of Stillbirth	Yes	8 (3.6)	2 (4.4)	
	No	213 (96.4)	43 (95.6)	.791
History of confirmed PIH(pregnancy-induced hypertension) in a previous pregnancy	Yes	12 (5.4)	2 (4.4)	
	No	209 (94.6)	43 (95.6)	.787
History of confirmed GDM in a previous pregnancy	Yes	2 (0.9)	1 (2.2)	
	No	119 (91.1)	44 (97.8)	.446
Family history of Diabetes	Yes	17 (4.7)	10 (14.7)	
	No	347 (95.3)	58 (85.3)	.002
Hemoglobin status	< 11mg/dl	35 (9.6)	15 (22.1)	
	≥11mg/dl	329 (90.4)	53 (77.9)	.003

A slightly higher proportion of diabetes family history was revealed among women with GDM than non-GDM (14.7% vs. 4.7%). When pregnant women were compared in terms of anemia status, those with GDM hada higher proportion than non-GDM (22.1% vs. 9.6%) (Table 3).

Behavioral and lifestyle characteristics of pregnant mothers

Out of total participants, alcohol and coffee intake during pregnancy was reported by (17.8%) and (90%), respectively. Nearly one-third of women who consumed coffee, reported consuming two cups of coffee per day. Most pregnant women (45.8%) reported having low physical activity, while about one in ten pregnant women reported having probable antenatal depression

symptoms. An inadequate dietary diversity score was reported in 6.3% of pregnant women participating in this study (Table 4).

Table 4: Behavioral characteristics of study participant attending ANC follow-up at health centers of Goba town, southeast Ethiopia 2021(n=432)

Variable		Non-GDM (n=364)	GDM (n=68)	P-Value
History alcohol intake during this pregnancy	Yes	65 (17.9)	12 (17.6)	.967
	No	299 (82.1)	56 (82.4)	
Type of alcohol	Local	49 (75.4)	8 (66.7)	.527
	Bear	16 (24.6)	4 (33.3)	
History of coffee intake in this pregnancy	Yes	326 (89.6)	63 (92.4)	.435
	No	38 (10.4)	5 (7.6)	
Number cups of coffee per day	One cup	83 (25.5)	10 (15.9)	.002
	Two cups	110 (33.7)	16 (25.4)	
	Three cups	79 (24.2)	16 (25.4)	
	Four and above cups	54 (16.7)	21 (33.3)	
Physical activity status during pregnancy	Low	156 (49.7)	42 (61.8)	.013
	Moderate	144 (39.6)	20 (29.4)	
	High	64 (17.6)	6 (8.8)	
Antenatal depression status	Probable depression	24 (6.6)	20 (29.4)	.000
	Possible depression	43 (11.8)	13 (19.1)	
	No depression	297(81.6)	35 (51.5)	
Dietary diversity score	< 5 (inadequate)	18 (4.9)	9 (13.2)	.010
	≥ 5(adequate)	346 (95.1)	59 (86.8)	

Low physical activity was reported to be higher among GDM than non-GDM pregnant women (61.8% vs. 49.7%). Pregnant women with GDM were shown to have a higher proportion of antenatal depression when compared with non-GDM (29.4 vs. 6.6 %). Similarly, inadequate dietary diversity was revealed to be higher among GDM when compared to non-GDM pregnant women (4.9-13.2%) (Table 4).

Incidence of GDM

During the study period, 432 pregnant women were followed for 4781 weeks. A total of 68 pregnant women developed GDM. The mean time of diagnosis of GDM is 26.1 (95% CI 25.65

to 26.51) weeks of pregnancy. The overall incidence rate of GDM was 14.22 per 1000 weeks of follow-ups, and the cumulative incidence was 15.7% (95%: (12.3, 19.2%) over 5 months.

Predictors of GDM among pregnant women.

After adjustment for maternal age, employment status, family history of diabetes, hemoglobin status, physical activity, antenatal depression, and dietary diversity.The adjusted log-binomial regression model has indicated that being unemployed [adjusted relative risk (aRR) =2.73; 95%CI:(1.36, 5.47)], having family history of diabetes [aRR = 3.01; 95% CI: (2.09– 4.35)], low physical activity [aRR = 2.43; 95% CI: (1.11, 5.32)], inadequate dietary diversity [aRR = 1.48; 95% CI: (1.29, 1.92)], anemia [aRR=2.51; 95% CI: (1.32, 3.54)] and antenatal depression [aRR =4.95; 95% CI: (3.35, 7.31)] were significantly associated with GDM (Table 5).

Table 5: Bivariate and multivariable log-binomial regression analysis and predictors of GDM among pregnant women attending antenatal care at health centers, Goba town, southeast Ethiopia: April to September 2021 (n=432)

Variables		Non-GDM (n=364)	GDM (n=68)	Crude relative risk (cRR) (95% CI)	adjusted relative risk (aRR) (95% CI)
Age in years	< 25	159	23	1	1
	25-29	120	21	1.18 (0.68, 2.04)	1.36 (0.80, 2.33)
	30-34	52	13	1.58 (0.85, 2.94)	1.53 (0.84, 2.77)
	>34	33	11	1.98 (1.04, 3.75) +	1.84 (0.96, 3.50)
Occupational status	Employed	91	8	1	1
	Non-employed	273	60	2.23 (1.10, 4.5) ++	2.73 (1.36, 5.47) **
Family history of Diabetes	Yes	17	10	2.59 (1.49, 4.47) +	3.01(2.09, 4.35) **
	No	347	58	1	1
	Total	364	68		
hemoglobin status	< 11mg/dl	35	15	2.16 (1.32, 3.54) +	2.51 (1.70, 3.69) **
	≥ 11mg/dl	329	53	1	1
	Total	364	68		
History of coffee intake in this pregnancy	Yes	326	63	1.39 (0.59, 3.27)	
	No	38	5	1	
	Total	364	68		
Number of cups of coffee per day	One cup	83	10	1	
	Two cups	110	16	1.18 (0.56, 2.48)	
	Three cups	79	16	1.57 (0.75, 3.27)	
	Four and above cups	54	21	2.60 (1.30, 5.19) +	
Physical activity status	Low	156	42	2.71 (1.26, 5.82)+	2.43 (1.11, 5.32)*
	Moderate	144	20	0.57(0.35, 0.94) +	1.98 (0.88,4.47)

during pregnancy	High	64	6	1	1
Antenatal depression status	Probable depression	24	20	4.31(2.75, 6.77) ++	4.95 (3.35, 7.31) **
	Possible depression	43	13	2.20 (1.24, 3.89) +	2.12 (1.21, 3.71) *
Dietary diversity score	< 5	18	9	1.57 (1.09, 2.62)+	1.48 (1.29,1.92)**
	≥ 5	346	59	1	1

aRR = **p-value < 0.001 *p-value < 0.05, cRR = ++p-value < 0.001 +p-value < 0.05

Discussion

Our study aimed to determine the incidence of GDM and associated factors among women attending antenatal care in health centers Goba town, southeast Ethiopia. In this study, the cumulative incidence of GDM among pregnant women attending ANC in health centers of Goba town was 15.7%. Our finding was almost similar to studies conducted in Gondar town, Ethiopia (12.8%) (12) and Qingdao, China (17%) (36). The current finding was higher than the study conducted in Wolita Zone, Ethiopia (4.2%) (13). The possible reason might be the difference in the sample size. Nevertheless, it was lower than a study conducted in Tanzania in which the cumulative incidence was found to be 19.5% (37). The commulative incidence of GDM in this study was lower than the infindings from a Nigerian study which was reported 21.2% (38). Another study conducted in Hadiya Zone, Ethiopia, revealed a higher incidence than our finding (26.2%) (14). These figures show that the incidence of GDM is increasing as other chronic medical conditions, which have been increasing with lifestyle shifts such as consuming fast food and increasing sedentary lifestyle. The variation might be variation in sample size and other sociodemographic variables.

Unemployment was shown to have a significant statistical association with GDM. As revealed in this study, non-employed pregnant women had a 2.73 times higher risk of developing GDM than employed pregnant women. The current finding disagreed with a study conducted in Gondar town (12). The variation might be because of the difference in sociodemographic characteristics. Further, among unemployed women, low physical activity was shown to have a difference in non-GDM and GDM pregnant women (46%vs 67%), respectively. This difference is supported by the evidence that employed adults were more likely to be physically active than non-employed (39) (40). Similarly, employed pregnant women were physically active compared with

the non-employed group (41). Physical inactivity, in turn, increases the risk of developing GDM (42). In this study, pregnant women with low physical activity were 2.43 times at risk of GDM than pregnant women who performed high physical activity. This finding is supported by a study conducted in Gondar town (12) and Amhara region, Ethiopia (25). Another study from Tanzania has identified low physical activity as a risk factor for GDM (43).

The risk of developing GDM was 2.6 times higher in pregnant women with a family history of diabetes than in their counterparts. This finding agreed with a prospective cohort study conducted in Florida which revealed that the risk of GDM among women with a family history of DM increased two-fold (44). Similarly, a study in Poland (Poznan city) identified family history of diabetes as an independent risk factor for GDM (45). This association could be because GDM has a genetic component that may predispose individuals to glucose intolerance during pregnancy, and T2DM shares a common genetic background with GDM (46).

Anemia was also shown to have an association with the occurrence of GDM. Our finding indicated that pregnant women with anemia were 1.9 times at risk of developing GDM compared with non-anemic pregnant women. The finding is supported by a study conducted in Tanzania that revealed pregnant women with anemia were at increased risk of developing GDM (24). Although there is no evidence to suggest that managing anemia with iron supplementation increases the risk of GDM, some evidence suggests that pregnant women who get iron supplements for anemia have excess iron deposited during pregnancy and are at increased risk of developing GDM (47). Further increased ferritin, hemoglobin, and dietary heme intake were associated with an increased risk of GDM (48).

The probability of developing GDM was 3.1 times in the pregnant women who reported antenatal depression symptoms than those with no depression symptoms. The present result supported a study conducted in Chicago which revealed that women with GDM were 3.79 times more likely to have a history of depression (49). Similarly, a cohort study conducted in Canada has reported a two-fold increased risk of depression among GDM women than in non-GDM (50). The possible explanation could be depression results in hypercortisolemia, increasing insulin resistance (51).

In this study, pregnant women with inadequate dietary diversity were 1.5 times at risk of developing GDM than those with adequate dietary diversity. The finding agreed with the study

conducted in Gondar town, where pregnant women with inadequate dietary diversity were at risk of developing GDM (12). This observation can be because inadequate dietary diversity will decrease the probability of getting a high-fiber diet that controls blood sugar levels (52). Further, inadequate dietary diversity decreases the chance of getting antioxidants in food consumed, which is important to prevent or delay b-cell dysfunction in diabetes by protecting against glucose toxicity (53)**.**

Our study has identified a few limitations. Firstly,we used fasting capillary blood glucose to diagnose GDM due to a lack of resources for oral glucose tolerance tests that might affect the strength of recommendations. However, various studies have reported fasting capillary glucose as the most sensitive and specific test (54,55) and recommended to be conducted in resource-limited settings (54). Secondly, eventhough capillary blood glucose is recommended in resource limited setting it is less sensitive than venous blood glucose. Thirdly, pre-pregnancy anthropometric measurement and BMI were not determined among pregnant women which may be part of the determinant factors.

Conclusion

The cumulative incidence of GDM was relatively high in Goba town. Having antenatal depression symptoms, anemia, a family history of diabetes, low physical activity, inadequate dietary diversity, and being unemployed, were identified as risk factors for GDM. Therefore, increasing community awareness of physical exercise, increasing recreational activities, and diversifying food intake during pregnancy is important. The study's findings would be an input for decision-makers to combat GDM in Ethiopia.

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Data availability statement: the SPSS data used for this study will be available upon request from the corresponding authors.

Figure legend /caption

Figure 1: Flow diagram of outcome ascertainment for pregnant women on ANC from April 30 to September 30, 2021.

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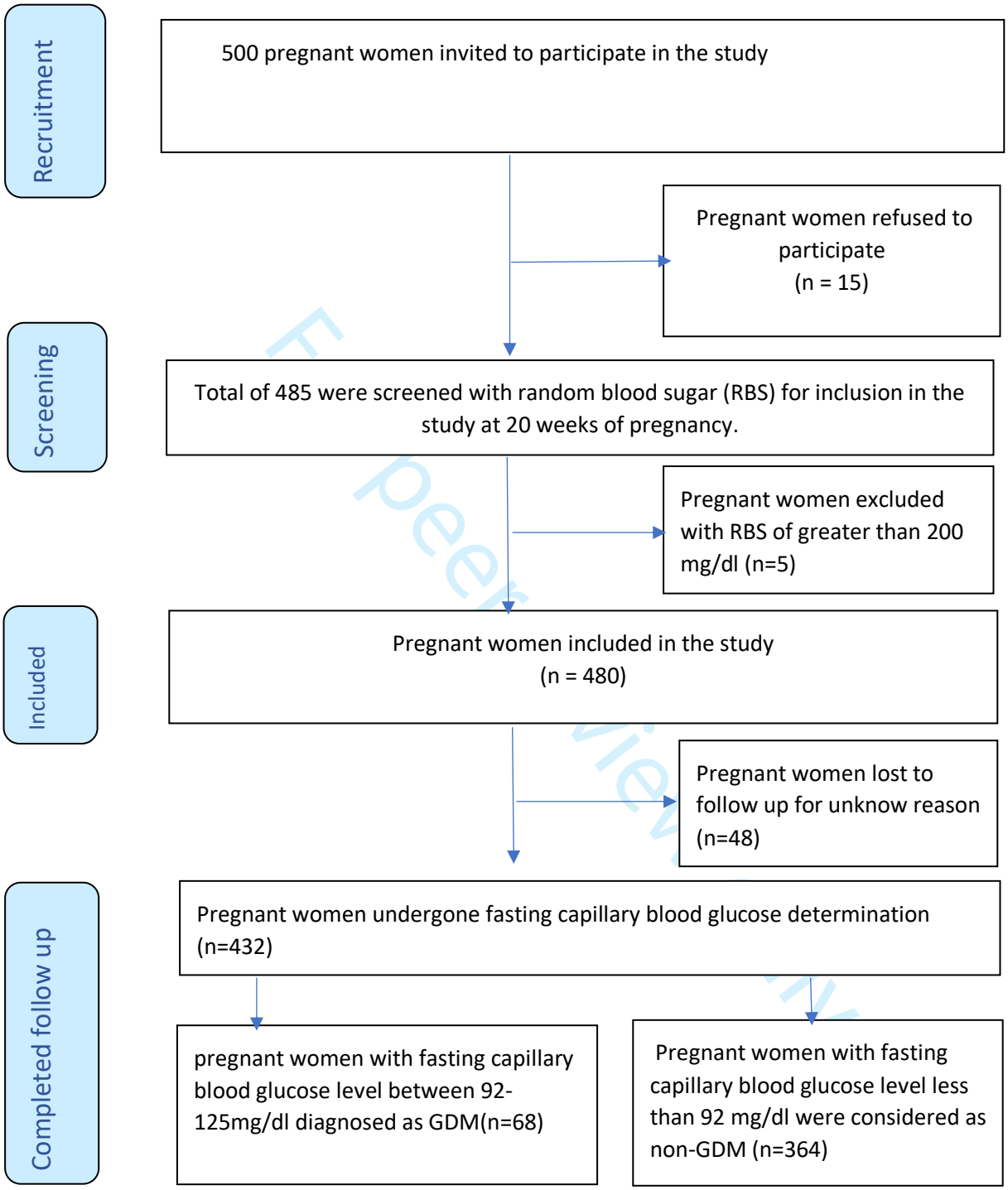
Recruitment
500 pregnant women invited to participate in the study
Pregnant women refused to participate (n = 15)
Screening
Total of 485 were screened with random blood sugar (RBS) for inclusion in the study at 20 weeks of pregnancy.
Pregnant women excluded with RBS of greater than 200 mg/dl (n=5)
Included
Pregnant women included in the study (n = 480)
Pregnant women lost to follow up for unknow reason (n=48)
Completed follow up
Pregnant women undergone fasting capillary blood glucose determination (n=432)
pregnant women with fasting capillary blood glucose level between 92-125mg/dl diagnosed as GDM(n=68)
Pregnant women with fasting capillary blood glucose level less than 92 mg/dl were considered as non-GDM (n=364)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3/4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	4/5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	Report numbers of outcome events or summary measures over time	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Incidence and risk factors of gestational diabetes mellitus in Goba town, Southeast Ethiopia: a prospective cohort study

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Abstract

Objective: Gestational diabetes mellitus (GDM) is becoming a public health concern in low- and middle-income countries (LMICs), and is known to cause severe morbidity for mothers and newborns. However, evidence reported for the incidence and predictors of GDM scant in Ethiopia. We aimed to assess the incidence of, and risk factors for, gestational diabetes mellitus in Goba town, Southeast Ethiopia.

Design: Prospective cohort study.

Setting: Goba town, Southeast Ethiopia.

Participants: Four hundred eighty pregnant women on antenatal care (ANC) follow-up from 30th April to 30th September 2021.

Primary and secondary outcome: Incidence and risk factors of gestational diabetes mellitus using fasting capillary blood glucose. Log-binomial model was used to identify the risk factors of GDM. Adjusted relative risk (aRR), along with 95% confidence intervals (CIs), were calculated to estimate the strength of associations.

Results: The cumulative incidence of GDM in this study was 15.7% [95% CI: (12.3 to 19.2)]. Being unemployed [aRR = 2.73, 95% CI 1.36 to 5.47], having a family history of diabetes mellitus [3.01; 2.09 to 4.35], low physical activity [2.43, 1.11 to 5.32], inadequate dietary diversity [1.48, 1.29 to 1.92], anemia [2.51, 1.32 to 3.54] and antenatal depression [4.95, 3.35 to 7.31] were significantly associated with GDM.

Conclusion: The cumulative incidence of GDM was relatively high among the study participants. Having antenatal depression symptoms, low physical activity, inadequate dietary diversity, being unemployed, anemia, and a family history of DM were significant risk factors for GDM.

Keywords: Gestational diabetes mellitus, pregnant women, risk factors, incidence, Ethiopia

Strength and limitations of this study

- The prospective design is a strength of the study.
- Fasting capillary blood glucose was used to diagnose GDM, which is less sensitive than venous blood glucose.

- The oral glucose tolerance test was not used due to resource limitations.
- Pre-pregnancy anthropometric measurements and BMI were not determined among pregnant women, which might be part of the predictor variables**.**

Introduction

Gestational diabetes mellitus (GDM) is a glucose intolerance detected during pregnancy for the first time (1). It is becoming a public health concern in low and middle-income countries (LMICs), and known to cause severe morbidity for mothers and newborns (2,3). Pregnancy itself induces changes in maternal glucose metabolism and insulin sensitivity, thereby increasing the demand for insulin production (4). The common period for the diagnosis of GDM is between 24 to 28 weeks of gestation (5). However, hyperglycemia during early pregnancy was identified as a risk factor for developing GDM (6). Therefore, determining blood glucose levels as early as possible is important to decrease adverse pregnancy outcomes (7,8).

Diabetes mellitus (DM) and other non-communicable diseases are becoming more prevalent in developing countries, including Ethiopia (9). Globally, diabetes prevalence is increasing rapidly, estimated 381 million in 2013 to 422 million living with DM in 2015. According to the international diabetes federation (IDF), by 2035, the global burden of DM is projected to reach 592 million, or one in ten will have DM (10). The International Diabetes Federation (IDF) estimates that 16.2% of live births to women had some form of hyperglycemia in pregnancy (11). In sub-Saharan Africa (SSA), the burden of GDM was found to be 14.28% (12). In Ethiopia, women are at greater risk of GDM despite having a lower mean body mass index (BMI) (13). In a study conducted in Gondar town, the cumulative incidence was 12.8% (14). Other studies conducted in Wolita and Hadiya zones, the southern part of Ethiopia, reported the cumulative incidence of GDM to be 4.2% (15) and 26.2% (16), respectively.

Gestational diabetes mellitus is associated with a greater risk of neonatal macrosomia (17,18), shoulder dystocia, neonatal trauma, respiratory distress, and increased admission to neonatal intensive care units (19). Women with hyperglycemia detected during early pregnancy are at greater risk of adverse pregnancy outcomes (6), with an incidence of 30.3% (20). These include high blood pressure and birth difficulties, with the baby more prone to fractures and nerve damage (11). Gestational diabetes mellitus also results in permanent type 2 diabetes mellitus (T2DM) in women, with an incidence ranging from 2.6% to 70% (21,22).

A higher prevalence of GDM was observed in mothers with a family history of T2DM (18,23,24). Further, a study on Russian women also identified that a genetic variant in MTNR1B is associated with an increased risk of GDM (25). Previous stillbirth, high mid-upper arm circumference (MUAC), anemia (26,27), advanced maternal age (28), low physical activity, and a sedentary lifestyle have also been shown to increase the risk of GDM (24,29). A higher BMI, abdominal circumference, and fasting glycemia in the first trimester of pregnancy revealed a 13-fold increased risk of GDM(30). The proportion of gestational diabetes mellitus increases with the number of pregnancies (31).

In most cases, adverse pregnancy outcomes among women with GDM are preventable by optimizing glycemic control. Early screening and treatment of mothers with GDM can minimize the complications for both mothers and their babies (19). Once diagnosed with GDM, a woman has a substantial chance of developing T2DM following delivery, with some studies reporting a 5-year cumulative incidence rate of over 50% (32).

Despite all the above facts, there are only a few studies on the incidence and associated factors of GDM in SSA (33), including in Ethiopia, particularly in the study setting. Therefore, we aimed to assess the incidence and risk factors of gestational diabetes mellitus in Goba town, Southeast Ethiopia.

Methods

Study design and setting

A facility-based prospective follow-up study was conducted among pregnant women in health centers of Goba town from April 30th to September 30th, 2021. The pregnant women were followed from 20 weeks of gestation to 32 weeks. Goba is one of the administrative towns in the Bale zone, located 445km from Addis Ababa city. According to the 2019 fiscal year, the total population of Goba town was 51,562, and the estimated number of pregnant women was 1789 (34). The town has two health centers and one referral hospital. The health centers in Goba town serve more than three-fourths of pregnant women for antenatal care (ANC) follow-up.

Source population

All pregnant women who started ANC were followed-up at Harawa Sinja and Oda Baha Health Center, Goba town, southeast Ethiopia.

Study population

Pregnant women with a gestational age of 20 weeks receiving ANC at Harawa Sinja and Oda Baha Health Center, Goba town, Southeast Ethiopia.

Inclusion criteria

Pregnant women who are in their 20 weeks of gestation, singleton pregnancy, permanent residents of the study area, and without any known pre-existing or overt diabetes mellitus (DM).

Exclusion criteria

Pregnant women who took medications that could affect glucose metabolisms, such as steroids, beta-adrenergic agonists, and antipsychotic medications, and who have an acute febrile illness were excluded.

Sample size determination and sampling techniques

The sample size was determined using the following parameters: 95% confidence interval, 5% margin error, 80% power, and the prevalence of GDM from a previous study conducted in the Hadiya zone (26%) (16). For incidence rate, based on the single population formula, the sample size was determined to be 295. For risk factors (stillbirth (14), abortion (15), and family history of DM (27)) of GDM, the double population formula using EPI-info version 7 software was used to determine sample size and considering 15% loss to follow-up, 480 samples were included in this study (Table 1). After the sample size was computed for both objectives, the largest sample size was taken.

All pregnant women with a gestational age of 20 weeks were included in this study until the required sample size has reached.

Table 1: Sample size calculation for risk factors of GDM in Goba town, Southeast Ethiopia, 2021

Exposure variables	Proportion in non-exposed	proportion in the exposed	Power of the study	Crude odds ratio	Sample size	Total sample size after considering 15% loss to follow up
History of stillbirth (14)	5.17%	14%	80	2.97	417	480
History of abortion (15)	16.3%	45.5%	80	4.2	101	116
previous history of GDM(27)	1.8%	12%	80	7.4	236	271

All pregnant women on ANC follow-up at two health centers in Goba town who fulfilled our inclusion criteria were included in the study.

Variables of the study

Dependent variable

Gestational diabetes mellitus:- Defined as Fasting capillary blood glucose between 92 to 125 mg/dl(1).

Exposure variables

Sociodemographic variables such as pregnant women's age, occupation, religion, ethnicity, and educational status; behavioral variables (caffeine, alcohol, dietary diversity, and smoking); reproductive related factors; a previous medical history of (GDM, pregnancy-induced

hypertension, stillbirth, intrauterine fetal death, and spontaneous abortion); health-related (chronic disease); and family history of T2DM and GDM were considered in this study.

Data collection procedures

An interviewer-administered, structured questionnaire was prepared in English and translated into the local language 'Amharic and Afan Oromo.' The questionnaire was back-translated into English to assure consistency. The questionnaire was checked by language experts (MA holders in language). Midwifery with a Bachelor of Science degree was involved in the data collection activity. Three days of training were provided to data collectors to familiarize them with the study objectives, data collection methods, ethical issues, and the questionnaire.

Both primary and secondary data (chart review) were collected. The baseline maternal and socio-demographic characteristics, behavioral, dietary diversity, and antenatal depression status were collected using face-to-face interviews. Dietary diversity was assessed using a 24-hour food recall method by the Food and Nutrition Technical Assistance (FANTA) 2016 version of the woman's minimum dietary diversity measurement tool. The four or less minimum dietary diversity score (MDDS) was categorized as inadequate dietary diversity (35).

The Edinburgh Postnatal Depression Scale (EPDS) screening tool was utilized to assess antenatal depression in the past week (36). The short form of the International Physical Activity Questionnaire (IPAQ) was employed to assess the physical activities of the last seven days. Then, using metabolic equivalents (MET-minutes per week) of the IPAQ scoring protocol, pregnant women were categorized into high, moderate, and low levels of physical activity (37).

Fasting capillary blood glucose was performed for all pregnant women by capillary blood glucose, using a standard plasma-calibrated glucometer (Hemo Cue Glucose B-201+ (Sweden)). Even though the sensitivity of capillary blood glucose is lower than venous blood glucose, the international consensus is that it is acceptable in resource-poor settings for GDM diagnosis (5). Initially, a capillary blood glucose test (random blood glucose) was performed for all pregnant women at 20 weeks of gestation to rule out the presence of pre-existing or overt DM. Then screening for GDM using fasting capillary blood glucose was performed at 24 to 28 weeks of gestational age (Figure 1). A similar measurement was repeated at 32 weeks of gestation to identify the late occurrence of GDM. Participants diagnosed with GDM were referred immediately (linked) to health care providers who are experts in managing GDM. Follow-ups

were assured through the public health facilities in close collaboration with experts and data collectors.

Outcome ascertainment

In this study, initially, pregnant women were invited to participate. Then screened for pre-existing DM using random capillary blood glucose. Pregnant women identified to have random capillary blood glucose greater than 200mg/dl were excluded from the study. Finally, the included pregnant women underwent fasting capillary blood glucose measurement. Pregnant women with fasting capillary blood glucose between 92 to 125mg/dl were diagnosed as GDM, and pregnant women with fasting capillary blood glucose levels less than 92 mg/dl were declared non-GDM.

Data quality control

The data quality was assured by applying a properly designed and pre-tested questionnaire. The tool was pre-tested on five percent of the sample size at the Baha Biftu health center one week before the actual data collection to establish its ability to elicit relevant information. In addition, the researchers ensured proper categorization and coding of the questions. The investigators and a supervisor conducted regular supervision and follow-up. In addition, a regular check-up for completeness and consistency of the data was undertaken daily. Incomplete questionnaires were completed during the second appointment. The manufacturer's instructions and standard operating procedures were strictly followed for all blood glucose measurements.

Data processing and analysis

The questionnaires were coded manually. The data were entered into Epi-data version 3.1 and then exported from Epi-data to Stata 14 for analysis. Data were checked for missing values. Descriptive statistics were presented using frequencies, percentages, mean and standard deviations to describe study subjects. Multicollinearity was checked by looking at values of variance inflation factors (VIF< 7). Bivariate log-binomial regression analysis was employed to examine the relationship between the outcome and independent variables. All the variables with $p \leq 0.2$ in the bivariate log-binomial regression analyses were entered into a multivariable log-binomial regression model. This step helps to identify important associated factors for the dependent variables after controlling possible confounding factors. The crude and adjusted relative risk was used to estimate the strength of the association between predictors and outcome

variables. Variables with a p-value < 0.05 were considered statistically significant with the outcome variable.

Patient and public involvement

Patients and the public were not involved in the planning, designing, and interpreting the analysed data.

Ethical considerations

The research protocol was approved by the Ethical Review Committee of Madda Walabu University (Reference no: RDD/0097/13). All methods were conducted following the relevant tenets of the Helsinki Declaration. An official letter was obtained from the Goba town health office. Then, the letters were given to the Harawa Sinja Health Center, and the Oda Baha Health Center heads. Finally, written consent was obtained from each study participant after explaining the study's risks and benefits. The privacy of the respondents was secured throughout the data collection process, and anonymity and confidentiality of the data were maintained.

Results

Sociodemographic and economic characteristics of pregnant women

In this study, 500 pregnant women were invited to participate. Of the invited, 485 agreed to participate and were screened for pre-existing DM using random capillary blood glucose. Five pregnant women were identified to have random capillary blood glucose greater than 200mg/dl, therefore excluded from the study. Of the remaining 480 pregnant women, 48 were lost from follow-up. The remaining 432 pregnant women were undergone fasting capillary blood glucose measurements. Sixty-eight pregnant women were identified to have fasting capillary blood glucose levels between 92-125mg/dl, while 364 pregnant women had capillary blood glucose levels less than 92mg/dl (figure 1).

The study included a total of 432 pregnant women, making the response rate 90%. The mean age of the pregnant women was 26.58 (SD ± 5.88) years. Most of the participants (97.8%) were married, (88.9%) were from the Oromo ethnic group, and nearly half (47.5%) were Muslim by religion. One hundred thirty-seven (31.7%) women had attended secondary school education, while about 80.5% of pregnant women were unemployed (Table 2).

Table 2: Socio-demographic and economic characteristics of pregnant women attending ANC follow-up at health centers of Goba town, Southeast Ethiopia, April to September 2021 (n = 432)

Variables		Non-GDM n (%)	GDM n(%)	p-value
Age in years	< 25	159 (43.7)	23 (33.8)	
	25-29	120 (33.0)	21(30.9)	
	30-34	52 (14.3)	13 (19.1)	
	>34	33 (9.1)	11(16.2)	0.027
Religion	Orthodox	157 (43.1)	28 (41.1)	
	Muslim	173 (47.5)	32 (47.1)	
	Protestant	34 (9.3)	8 (11.8)	0.733
Ethnicity	Oromo	293 (80.5)	55 (80.9)	
	Amhara	61 (16.8)	11(16.2)	
	Others	10 (2.7)	2(2.9)	0.990
Educational status	No formal education	53 (14.6)	11(16.3)	
	Primary school	117 (32.1)	19 (27.9)	
	Secondary school	118 (32.4)	19 (27.9)	
	Collage and above	76 (20.9)	19 (27.9)	0.538
Occupational status	Employed	60 (16.5)	24 (35.3)	
	Non employed	304 (83.5)	44 (64.7)	0.017

*Others (Gurage, Wolita)

Clinical characteristics of study participants

The mean systolic blood pressure was 105.9 (SD ± 10.2) mmHg, and diastolic blood pressure was 66.4 (SD ± 7.6) mmHg. The pregnant women's mean hemoglobin and random blood glucose levels were 11.9 (SD ± 1.1) and 108 (SD ± 16.7), respectively. Nearly one-third (33.8%) of the women were primigravida, around twenty-seven (6.3%) had a family history of DM, and fifty (11.6%) pregnant women were identified to have anemia. The previous history of abortion and stillbirth were reported among 3 and 3.8% of pregnant women, respectively (Table 3).

Table 3: Obstetric history of study participant attending ANC follow-up at health centers of Goba town, southeast Ethiopia, April to September 2021 (n = 432)

Variables		Non-GDM (n=364)	GDM (n=68)	p-value
Gravidity	One	143 (39.3)	23 (33.9)	
	Two	99 (27.2)	22 (32.4)	
	Three	68 (18.6)	11(16.2)	
	Four and above	54 (14.3)	12(17.6)	0.515
History of abortion/ Intrauterine fetal death	Yes	5 (2.3)	3 (6.7)	
	No	216 (97.7)	42 (93.3)	0.115

History of stillbirth	Yes	8 (3.6)	2 (4.4)	
	No	213 (96.4)	43 (95.6)	0.791
History of confirmed pregnancy-induced hypertension (PIH) in a previous pregnancy	Yes	12 (5.4)	2 (4.4)	
	No	209 (94.6)	43 (95.6)	0.787
History of confirmed GDM in a previous pregnancy	Yes	2 (0.9)	1 (2.2)	
	No	119 (91.1)	44 (97.8)	0.446
Family history of diabetes	Yes	17 (4.7)	10 (14.7)	
	No	347 (95.3)	58 (85.3)	0.002
Hemoglobin status	< 11mg/dl	35 (9.6)	15 (22.1)	
	≧11mg/dl	329 (90.4)	53 (77.9)	0.003

A slightly higher proportion of diabetes family history was revealed among women with GDM than non-GDM (14.7% vs. 4.7%). When pregnant women were compared in terms of anemia status, those with GDM had a higher proportion than non-GDM (22.1% vs. 9.6%) (Table 3).

Behavioral and lifestyle characteristics of pregnant mothers

Out of total participants, alcohol and coffee intake during pregnancy was reported by (17.8%) and (90%), respectively. Nearly one-third of women who consumed coffee reported consuming two cups of coffee per day. Most pregnant women (45.8%) reported having low physical activity, while about one in ten pregnant women reported having probable antenatal depression symptoms. An inadequate dietary diversity score was reported in 6.3% of pregnant women participating in this study (Table 4).

Table 4: Behavioral characteristics of study participant attending ANC follow-up at health centers of Goba town, southeast Ethiopia 2021 (n = 432)

Variable		Non-GDM (n = 364)	GDM (n = 68)	p-value
History of alcohol intake during this pregnancy	Yes	65 (17.9)	12 (17.6)	
	No	299 (82.1)	56 (82.4)	0.967
Type of alcohol	Local	49 (75.4)	8 (66.7)	
	Bear	16 (24.6)	4 (33.3)	0.527
History of coffee intake in this pregnancy	Yes	326 (89.6)	63 (92.4)	
	No	38 (10.4)	5 (7.6)	0.435
Number of cups of	One cup	83 (25.5)	10 (15.9)	

coffee per day	Two cups	110 (33.7)	16 (25.4)	
	Three cups	79 (24.2)	16 (25.4)	
	Four and above cups	54 (16.7)	21 (33.3)	0.002
Physical activity status during pregnancy	Low	156 (49.7)	42 (61.8)	
	Moderate	144 (39.6)	20 (29.4)	
	High	64 (17.6)	6 (8.8)	0.013
Antenatal depression status	Probable depression	24 (6.6)	20 (29.4)	
	Possible depression	43 (11.8)	13 (19.1)	
	No depression	297(81.6)	35 (51.5)	0.000
Dietary diversity score	< 5 (inadequate)	18 (4.9)	9 (13.2)	
	≥ 5(adequate)	346 (95.1)	59 (86.8)	0.010

Low physical activity was reported to be higher among GDM than non-GDM pregnant women (61.8% vs. 49.7%). Pregnant women with GDM were shown to have a higher proportion of antenatal depression when compared with non-GDM (29.4 vs. 6.6 %). Similarly, inadequate dietary diversity was revealed to be higher among GDM when compared to non-GDM pregnant women (4.9 vs. 13.2%) (Table 4).

Incidence of GDM

During the study period, 432 pregnant women were followed for 4781 weeks. A total of 68 pregnant women developed GDM. The mean time of diagnosis of GDM is 26.1 (95% CI 25.65 to 26.51) weeks of pregnancy. The overall incidence rate of GDM was 14.22 per 1000 weeks of follow-ups, and the cumulative incidence was 15.7% (95%: (12.3 to 19.2%) over 5 months.

Predictors of GDM among pregnant women.

After adjustment for maternal age, employment status, family history of diabetes, hemoglobin status, physical activity, antenatal depression, and dietary diversity.The adjusted log-binomial regression model has indicated that being unemployed [adjusted relative risk (aRR) =2.73; 95%CI:(1.36 to 5.47)], having family history of diabetes [aRR = 3.01; 95% CI: (2.09 to 4.35)], low physical activity [aRR = 2.43; 95% CI: (1.11 to 5.32)], inadequate dietary diversity [aRR = 1.48; 95% CI: (1.29 to 1.92)], anemia [aRR = 2.51; 95% CI: (1.32 to 3.54)] and antenatal depression [aRR = 4.95; 95% CI: (3.35 to 7.31)] were significantly associated with GDM (Table 5).

Table 5: Bivariate and multivariable log-binomial regression analysis and predictors of GDM among pregnant women attending antenatal care at health centers, Goba town, southeast Ethiopia: April to September 2021 (n = 432)

Variables		Non-GDM (n=364)	GDM (n=68)	Crude relative risk (cRR) (95% CI)	adjusted relative risk (aRR) (95% CI)
Age of women in years	< 25	159	23	1	1
	25-29	120	21	1.18 (0.68 to 2.04)	1.36 (0.80 to 2.33)
	30-34	52	13	1.58 (0.85 to 2.94)	1.53 (0.84 to 2.77)
	>34	33	11	1.98 (1.04 to 3.75) +	1.84 (0.96 to 3.50)
Occupational status	Employed	91	8	1	1
	Non-employed	273	60	2.23 (1.10 to 4.5) ++	2.73 (1.36 to 5.47) **
Family history of DM	Yes	17	10	2.59 (1.49 to 4.47) +	3.01(2.09 to 4.35) **
	No	347	58	1	1
	Total	364	68		
hemoglobin status	< 11mg/dl	35	15	2.16 (1.32 to 3.54) +	2.51 (1.70 to 3.69) **
	≥ 11mg/dl	329	53	1	1
	Total	364	68		
History of coffee intake in this pregnancy	Yes	326	63	1.39 (0.59 to 3.27)	
	No	38	5	1	
	Total	364	68		
Number of cups of coffee per day	One cup	83	10	1	
	Two cups	110	16	1.18 (0.56 to 2.48)	
	Three cups	79	16	1.57 (0.75 to 3.27)	
	Four and above cups	54	21	2.60 (1.30 to 5.19) +	
Physical activity status during this pregnancy	Low	156	42	2.71 (1.26 to 5.82)+	2.43 (1.11 to 5.32)*
	Moderate	144	20	0.57(0.35 to 0.94) +	1.98 (0.88 to 4.47)
	High	64	6	1	1
Antenatal depression status	Probable depression	24	20	4.31(2.75 to 6.77) ++	4.95 (3.35 to 7.31) **
	Possible depression	43	13	2.20 (1.24 to 3.89) +	2.12 (1.21to 3.71) *
Dietary diversity score	< 5	18	9	1.57 (1.09 to 2.62)+	1.48 (1.29 to1.92)**
	≥ 5	346	59	1	1

aRR: **p-value < 0.001, *p-value < 0.05. cRR: ++p-value < 0.001, +p-value < 0.05.

List of variables used to adjust this model: maternal age, employment status, family history of diabetes, hemoglobin status, physical activity, antenatal depression, and dietary diversity

Discussion

Our study aimed to assess the incidence and risk factors of gestational diabetes mellitus in Goba town, Southeast Ethiopia. In this study, the cumulative incidence of GDM among pregnant women attending ANC in health centers of Goba town was 15.7%. Our finding was almost similar to studies conducted in Gondar town, Ethiopia (12.8%) (14) and Qingdao, China (17%) (38). The current finding was higher than the study conducted in Wolita Zone, Ethiopia (4.2%) (13), and the possible reason might be due to the difference in the sample size.

Nevertheless, it was lower than a study conducted in Tanzania in which the cumulative incidence was found to be 19.5% (39). The cumulative incidence of GDM in this study was lower than the findings from a Nigerian study which was reported at 21.2% (40). Another study conducted in Hadiya Zone, Ethiopia, revealed a higher incidence than our finding (26.2%) (16). These figures show that the incidence of GDM is increasing as other chronic medical conditions, which have been increasing with lifestyle shifts such as consuming fast food and increasing sedentary lifestyles. The variation might be variation in sample size and other sociodemographic variables.

Unemployment was shown to have a significant statistical association with GDM. As revealed in this study, non-employed pregnant women had 2.73 times higher risk of developing GDM than employed pregnant women. The current finding disagreed with a study conducted in Gondar town (14). The variation might be because of the difference in sociodemographic characteristics. Further, among unemployed women, low physical activity was shown to have a difference in non-GDM and GDM pregnant women (46%vs 67%), respectively. This difference is supported by the evidence that employed adults were more likely to be physically active than non-employed (41) (42). Similarly, employed pregnant women were physically active compared with the non-employed group (43). Physical inactivity, in turn, increases the risk of developing GDM (44). In this study, pregnant women with low physical activity were 2.43 times more at risk of GDM than pregnant women with high physical activity. This finding is supported by a study conducted in Gondar town (14) and the Amhara region, Ethiopia (27). Another study from Tanzania has identified low physical activity as a risk factor for GDM (45).

The risk of developing GDM was 2.6 times higher in pregnant women with a family history of diabetes than in their counterparts. This finding is in agreement with a prospective cohort study conducted in Florida which revealed that the risk of GDM among women with a family history

of DM increased two-fold (46). Similarly, a study in Poland (Poznan city) identified family history of diabetes as an independent risk factor for GDM (47). This association could be because GDM has a genetic component that may predispose individuals to glucose intolerance during pregnancy, and T2DM shares a common genetic background with GDM (48).

Anemia was also shown to have an association with the occurrence of GDM. Our finding indicated that pregnant women with anemia were 1.9 times at risk of developing GDM compared with non-anemic pregnant women. The finding is supported by a study conducted in Tanzania that revealed pregnant women with anemia were at increased risk of developing GDM (26). Although there is no evidence to suggest that managing anemia with iron supplementation increases the risk of GDM, some evidence suggests that pregnant women who get iron supplements for anemia have excess iron deposited during pregnancy and are at an increased risk of developing GDM (49). Further increased ferritin, hemoglobin, and dietary heme intake was associated with an increased risk of GDM (50).

The probability of developing GDM was 3.1 times in the pregnant women who reported antenatal depression symptoms than those with no depression symptoms. The present result supported a study conducted in Chicago which revealed that women with GDM were 3.79 times more likely to have a history of depression (51). Similarly, a cohort study conducted in Canada has reported a two-fold increased risk of depression among GDM women than in non-GDM (52). The possible explanation could be depression results in hypercortisolemia, increasing insulin resistance (53).

In this study, pregnant women with inadequate dietary diversity were 1.5 times more at risk of developing GDM than those with adequate dietary diversity. The finding agreed with the study conducted in Gondar town, where pregnant women with inadequate dietary diversity were at risk of developing GDM (14). This observation can be because inadequate dietary diversity will decrease the probability of getting a high-fiber diet that controls blood sugar levels (54). Further, inadequate dietary diversity decreases the chance of getting antioxidants in food consumed, which is important to prevent or delay b-cell dysfunction in diabetes by protecting against glucose toxicity (55).

Our study has identified a few limitations. Firstly, we used fasting capillary blood glucose to diagnose GDM due to a lack of resources for oral glucose tolerance tests that might affect the

strength of recommendations. However, various studies have reported fasting capillary glucose as the most sensitive and specific test (56,57) and recommended to be conducted in resource-limited settings (56). Secondly, even though capillary blood glucose is recommended in resource-limited settings, it is less sensitive than venous blood glucose. Thirdly, pre-pregnancy anthropometric measurement and BMI were not determined among pregnant women, which may be part of the determinant factors.

Conclusion

The cumulative incidence of GDM was relatively high in Goba town. Having antenatal depression symptoms, anemia, a family history of diabetes, low physical activity, inadequate dietary diversity, and being unemployed were identified as risk factors for GDM. Therefore, increasing community awareness of physical exercise, increasing recreational activities, and diversifying food intake during pregnancy are important. The study's findings would be an input for decision-makers to combat GDM in Ethiopia.

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Contributors

DA has contributed substantially to the conception and design, acquisition of data, analysis, and interpretation of data. DA has written the draft manuscript and provided final approval of the version to be published. BS, TA, WN, AT, TR, YT, AM, ZT, DS, HG, KB, DZ, AT, FD, FN, GB, ZS, ZF, ZR, and VKC have made substantial contributions to the design, acquisition of data, analysis, and interpretation of data. All revised the article critically for important intellectual content and provided final approval of the version to be published. All authors read and approved the final manuscript.

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Disclaimer

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Competing interests

None declared.

Patient consent for publication

Not required.

Ethical approval

The research protocol was approved by Ethical Review Committee, Madda Walabu University (Reference no: RDD/0097/13). All methods were conducted following the relevant tenets of the Helsinki Declaration. An official letter was obtained from the Goba town health office. Then, the letters were given to the Harawa Sinja Health Center, and the Oda Baha Health Center heads. Finally, written consent was obtained from each study participant after explaining the study's risks and benefits. The privacy of the respondents was protected though out the data collection process, and anonymity and confidentiality of the data were maintained.

Data availability statement

The SPSS data used for this study will be available upon request from the corresponding author.

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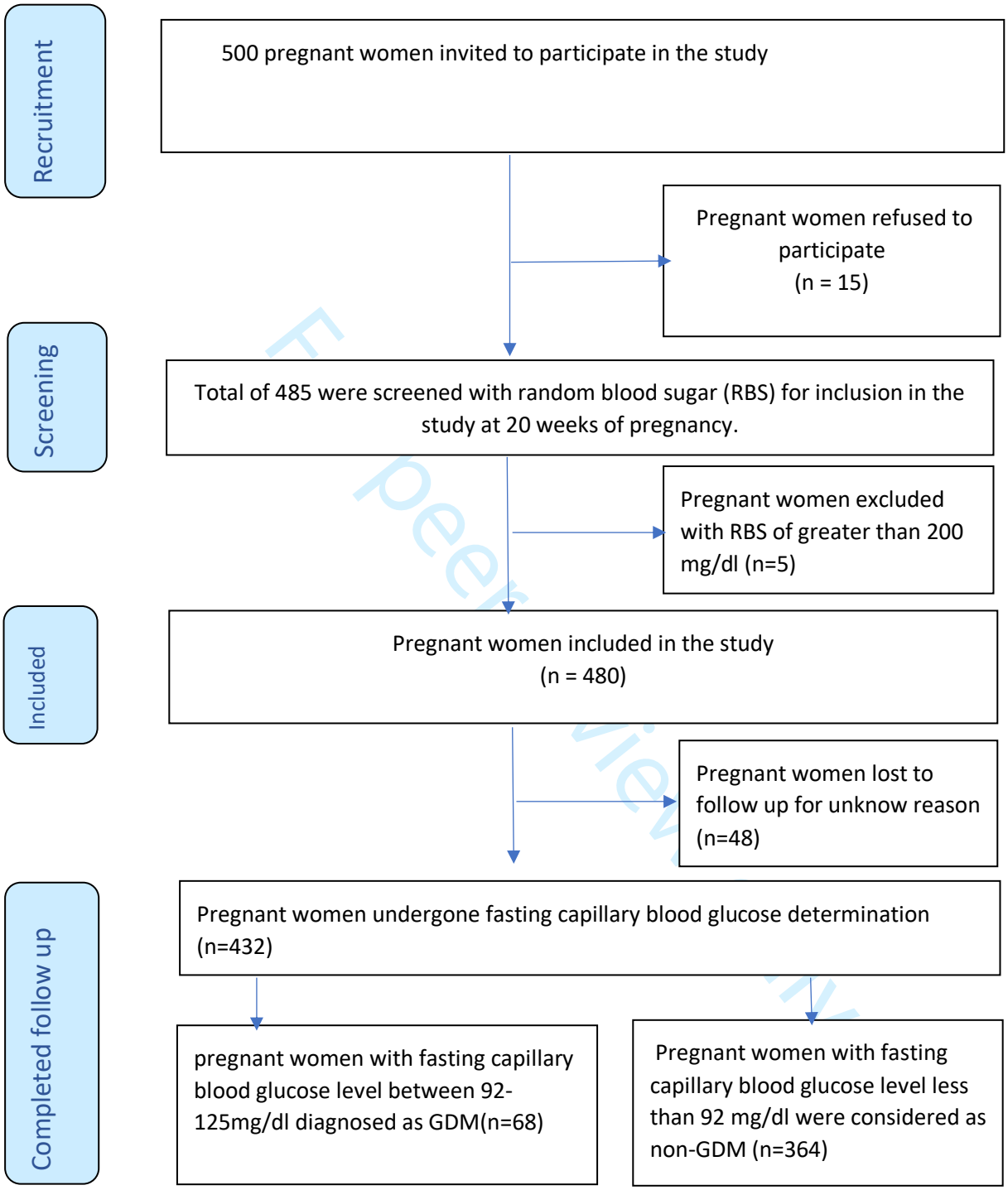
Figure title

Figure 1: Flow diagram of outcome ascertainment for pregnant women on ANC from April 30 to September 30, 2021



STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3/4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	4/5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*5*
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8
		(b) Indicate number of participants with missing data for each variable of interest	8
		(c) Summarise follow-up time (eg, average and total amount)	10
Outcome data	15*	Report numbers of outcome events or summary measures over time	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	10
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.