

Postpartum hyperglycemia and pregnancy outcomes among women in Arusha Region, Tanzania

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Abstract

Background: Gestational diabetes mellitus is a medical condition that disappears after delivery if early diagnosis and management are done. This study aimed to determine the prevalence of hyperglycemia six weeks postpartum and pregnancy outcomes among women in Arusha City.

Methods: A longitudinal study was conducted between March and December 2018 as part of a large study which involved 468 randomly selected pregnant women and excluded those who were diagnosed with diabetes before pregnancy. Women were screened for hyperglycemia six weeks postpartum where fasting and oral glucose tolerant tests were done by Gluco-Plus™ using World Health Organization criteria. Body fat percentage, mid-upper arm circumference, height and weight were measured using standard procedures. Postpartum information was collected using a structured questionnaire and data was analyzed using the Statistical Package for Social Science version 20 to obtain descriptive and inferential statistics.

Results: Among 468 women who participated in the study at baseline, 392 (83.7%) returned for postpartum assessments. Postpartum hyperglycemia among women was 2.1% (n=8) and majority had normal delivery (92.6%, n=363) while 7.4% (n=29) delivered through caesarean section. About 8.2% (n=32) of the newborn were macrosomia and 4.1% (n=16) low birth weight. Miscarriages or abortions were not identified while stillbirth was observed in 0.5% (n=2) and neonatal death (1.3%, n=5). Postpartum hyperglycemia was significantly associated with body fat percentage (AOR 1.59, 95% CI: 1.14-1.91), mid-upper arm circumference (AOR 1.62, 95% CI: 1.023-1.99), macrosomia (AOR 2.43, 95% CI: 2.2-10.31) and family history of type 2 diabetes (AOR 6.4, 95% CI: 1.93-13.3).

Conclusion: Prevalence of postpartum hyperglycemia was generally low however; it was significantly associated with macrosomia, increased body fat percentage, mid-upper circumference and family history of type 2 diabetes. Also, a low prevalence of poor pregnancy outcomes was reported which may be attributed to actions taken after being referred for further treatments and management which need further exploration.

Keywords: *Postpartum Hyperglycemia, Pregnancy Outcomes, Arusha- Tanzania*

Introduction

Gestational diabetes mellitus (GDM) is a form of hyperglycemia in pregnancy (HIP) with first recognition during pregnancy. This occurs due to several physiological changes during pregnancy (World Health Organization [WHO], 2013; Palani et al., 2014) whereby the body needs additional insulin which forces the pancreas to increase the secretion. If the pancreas cannot cope with the increased insulin demand during pregnancy, blood glucose levels rise too high, resulting in gestational diabetes.

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This occurs as a result of increased maternal adiposity and the effects of placental hormones produced by the placenta including Human chorionic somatomammotropin (HCS), cortisol, estrogen, and progesterone. As pregnancy progresses and the placenta grows, the production of these hormones increases thus leading to increased insulin resistance (Palani et al., 2014).

The estimations show that globally, 21.3 million or 16.2% of live births to women in 2017 had some form of the HIP (International Diabetes Federation [IDF], 2017). About 86.4% of these cases were due to GDM, 6.2% due to diabetes detected before pregnancy, and 7.4% due to other types of diabetes (including type 1 and type 2 diabetes) first detected in pregnancy (IDF, 2017). Furthermore, the majority (88%) of the HIP cases were in low- and middle-income countries with limited maternal care (IDF, 2017). Likewise, Tanzania is one of the countries with limited maternal care and has a prevalence of GDM ranging from 1% in rural to 32% in urban settings (Mwanri et al., 2014; Njete et al., 2018; Msollo et al., 2019; Mghanga et al., 2020; Mdoe et al., 2021). Exceptionally, a higher prevalence of 39% was reported in rural areas of North East Tanzania (Grunnet et al., 2020).

Gestational diabetes mellitus can be due to several predictors including a family history of type 2 diabetes (T2DM), maternal overweight or obesity accompanied by high body fat deposition, dietary factors, cigarette smoking, and extreme pregnancy weight gain (Jensen et al., 2005; Imoh et al., 2016). It may also be due to a history of recurring stillbirth, preterm birth, and macrosomic delivery which implies that the woman experiences high maternal glucose levels that are transferred to the fetus (Jensen et al., 2005; Imoh et al., 2016).

Gestational diabetes mellitus normally disappears after delivery, but if no actions are taken for early diagnosis and management, it may cause long-term health risks to the mother such as the development of T2DM five to ten years postpartum. Evidence shows that a third of women who are diagnosed with GDM continue to have diabetes or impaired glucose tolerance six to 12 weeks after delivery which creates a need for postpartum testing (Palani et al., 2014). High glucose levels during pregnancy may also lead to hypertension, miscarriages/abortions, stillbirth and preterm birth in successive pregnancies (Wendland et al., 2012; IDF, 2017). Furthermore, unmanaged GDM may result in a newborn that is large for gestational age (macrosomia) which may increase birth trauma such as shoulder dystocia (Wendland et al., 2012; Hartling et al., 2013). Macrosomic infants are at risk of hypoglycemia soon after birth because their bodies continue producing extra insulin in response to the mothers' excess glucose (Plows et al., 2018). Newborns with excessive fat stores as a result of high maternal sugar levels during pregnancy continue to be overweight in childhood and adulthood which may increase the risk of developing non-communicable diseases (NCDs) such as diabetes later in life (WHO, 2013; Palani et al., 2014).

Hence, postpartum evaluation of glucose status should be done to disclose persistent alterations of glucose metabolism, by performing an oral glucose tolerance test (OGTT) and/or fasting plasma glucose (American Diabetes Association [ADA], 2013). Women with a history of GDM should be followed-up for at least 6 to 12 weeks after delivery to determine their glucose status because 2.6% to 38% of women with GDM can develop T2DM within 12 weeks following delivery (Carson et al., 2013). Although follow-up after GDM diagnosis and/or after delivery is emphasized to prevent adverse health effects, it is not commonly practised in Tanzania. Therefore, timely screening and management of GDM after diagnosis or post-delivery is very important for immediate actions to prevent short and long-term adverse effects on the mother and her newborn. It is recommended that postpartum glucose testing can be timed at 7 days to 6 weeks postpartum ("early" testing window), 6–12 weeks postpartum ("ADA recommended" testing window) and after 12 weeks through 6 months postpartum ("late" testing window) (American College of Obstetricians and Gynecologists (ACOG), 2001). Hence, this study was done to assess the prevalence of postpartum

hyperglycemia, and pregnancy outcomes to provide information to policymakers to include postpartum diabetes testing and follow-up in antenatal care (ANC) to prevent adverse health effects.

Materials and methods

Study area, design and population

It was a longitudinal study that was carried out as part of a large study undertaken in urban areas of Arusha City between March and December 2018 among pregnant women attending ANC at Ngarenaro and Kaloleni Health Centers where data was collected during pregnancy, during delivery and post-delivery. The district was selected purposively due to a known high prevalence of T2DM (16.2%) especially in urban (22.9%) areas (Masaki et al., 2015), which may, in part, reflect undiagnosed and unmanaged GDM.

The study involved women in their second and third trimesters without diabetes before pregnancy and excluded women who were known to have diabetes and under managements (Msollo et al., 2019). A sample size of 468 was obtained using the formula for prevalence studies (Daniel, 1999) where the prevalence (i.e., p) was assumed to be 50% due to limited national data for the prevalence of GDM whereby a non-response rate of 20% was assumed (Macfarlane, 1997). The eligible women were randomly selected using a table of random numbers and resulting in 468 women being involved in the study at baseline of which 392 returned within 6 weeks for postpartum assessments.

Maternal characteristics and pregnancy outcomes assessments

The delivery information was recorded by the birth attendants (nurses) and the researchers using a short questionnaire which was attached to every participant's ANC card at the baseline. Birth outcomes information included; gestational age at delivery, miscarriages, abortions, birth modalities (caesarian section or normal delivery), stillbirth, preterm and neonatal death, child's weight at delivery and fetal abnormalities.

Follow-up was done during and after delivery whereby reminder messages and phone calls were made monthly and weekly as the expected date of delivery approached. In this case, women were reminded of the date for post-delivery assessments and information on reasons for loss to follow up was also collected in the same way.

Laboratory tests for blood glucose six weeks post delivery

Women were required to fast overnight before blood sample collection. Fasting blood glucose level was measured by Gluco-Plus™ (Glucoplus Inc. 2323 Halpern, Ville St. Laurent, Quebec, Canada) and thereafter any woman with a reading of $<7\text{mmol/L}$ participated in an OGTT using anhydrous glucose of 75 g dissolved in 300 ml of water. Women whose fasting blood glucose levels were $\geq 7\text{mmol/L}$ were requested to return the next day for another fasting glucose test. Hyperglycemic status was classified based on the values for non-pregnancy whereby a reading of fasting glucose level $\geq 7\text{mmol/L}$ and/or 11.1mmol/L for OGTT was defined as diabetes (WHO, 2006).

Anthropometric assessments among women during pregnancy, post-delivery and their newborns

Mid-upper arm circumference (MUAC) for the woman was measured using a non-stretchable tape and overweight was classified as MUAC $\geq 28\text{cm}$. Weight was measured with minimum clothing without shoes using a digital bathroom weighing scale (SECA-Germany), placed on a flat surface and recorded to the nearest 0.1 kg. The weight of the newborn was also measured by the care provider using their normal baby weighing scale. The mother's body fat percentage was determined using a

bioelectric impedance analyzer (Tanita TBF 105 Fat Analyzer™) which was adjusted for age, weight and height which was measured during baseline.

Data management

Data collected were analyzed using the Statistical Package for Social Science (SPSS™) version 20 and descriptive statistics, such as frequency, mean and percentage were obtained. Also, a comparison of continuous variables was done using a T-test. Furthermore, inferential statistics were done to obtain associations among factors. Blood glucose values were dichotomized, for univariate and multiple logistic regression analysis to be done to obtain both crude and adjusted odd ratios (Wynants et al., 2017). Statistical inference was based on 95% confidence intervals (CIs) and significance at $p\text{-value} < 0.05$.

Ethical Considerations

The aim, procedure, benefits and possible negative effects of the study were explained and all women who agreed to participate and met the inclusion criteria were enrolled and signed informed consent before the beginning of the study. The study was approved by the National Institute for Medical Research with a reference number NIMR/HQ/R.8a/ VOL.IX/ 2694. Anonymity was ensured by using specific numbers to represent the names of the women during data handling and confidentiality by having a specific room where research activities were carried out.

Results

Maternal characteristics within six weeks post-delivery

A total of 468 women participated in the study at the baseline and 392 (83.7%) were able to participate in the follow up which was scheduled for the sixth week after delivery. Majority of the women delivered at the gestational age of ≥ 37 weeks, and all women (100%, $n=385$) whose babies survived, practised breastfeeding (Table 1).

Table 1: Maternal characteristics within six weeks postpartum

Variables assessed	Frequency	Per cent	Mean (SD)
Returned for post-delivery assessments ($n=468$)			
Yes	392	83.8	
No	76	16.2	
Gestational age at delivery ($n=392$)			
≥ 37 weeks	386	98.5	
< 37 weeks	6	1.5	38(SD ± 1.7)
Breastfeeding practice ($n=385$)			
Yes	385	100.0	
No	0	0.0	

Note: The number of breastfed infants was 385 because 7 died before and/or after being born. SD means standard deviation,

Hyperglycemia and factors that influenced postpartum follow up

A total of 392 women returned for post-delivery assessments (follow-up). All of the women who returned for the post-delivery assessments completed the fasting glucose test (100%, $n=392$) and 39.8% ($n=156$) completed the OGTT procedure. The mean fasting blood glucose level was 4.7 (SD ± 1.4) mmol/L and OGTT 7.7 (SD ± 1.8) mmol/L after delivery. Generally, the prevalence of hyperglycemia postpartum was 2.1% (95% CI: 1.0-3.8) using WHO (2006) criteria for non-pregnancy.

The majority of the women returned for postpartum assessments (83.7%, n=392) while 16.3% (n=76) did not appear at all. The reasons for loss to follow up were the inconvenience of OGTT procedure (29.5%, n= 23), taking care of their newborns and staying indoors for their better health recoveries (50%, n=39), and 16.7% (n=13) were not allowed by their husbands to go for the test (Table 2).

Table 2: Glucose status and reasons for loss to postpartum follow up

Variables tested	Frequency	Per cent	Mean (SD)
Returned for postpartum glucose testing			
Yes	392	83.7	
No	76	16.3	
General Postpartum hyperglycemia (OGTT or Fasting tests)			
Yes	8	2.1	
No	384	97.9	
Completed OGTT			
Yes	156	39.8	
No	236	60.2	
Mean fasting glucose level (mmol/L)	392	100.0	4.7 (SD±1.4)
Mean OGTT level (mmol/L)	156	39.8	7.7 (SD±1.8)
Reasons for loss to follow up			
Inconveniences of OGTT	22	29.5	
Taking care of the babies and staying indoors for recovery	39	50.0	
Husband refused	12	16.7	
Death of the baby	3	3.8	

Note: SD means standard deviation

Anthropometric parameter changes during pregnancy and after delivery

The results shown that women's mean weight in kg (69 vs 62.5, $P < 0.001$), MUAC in cm (27.5 vs 26, $P < 0.001$), and body fat percentage (33.8 vs 32.5, $P < 0.001$) during pregnancy and postpartum differed significantly (Fig. 1).

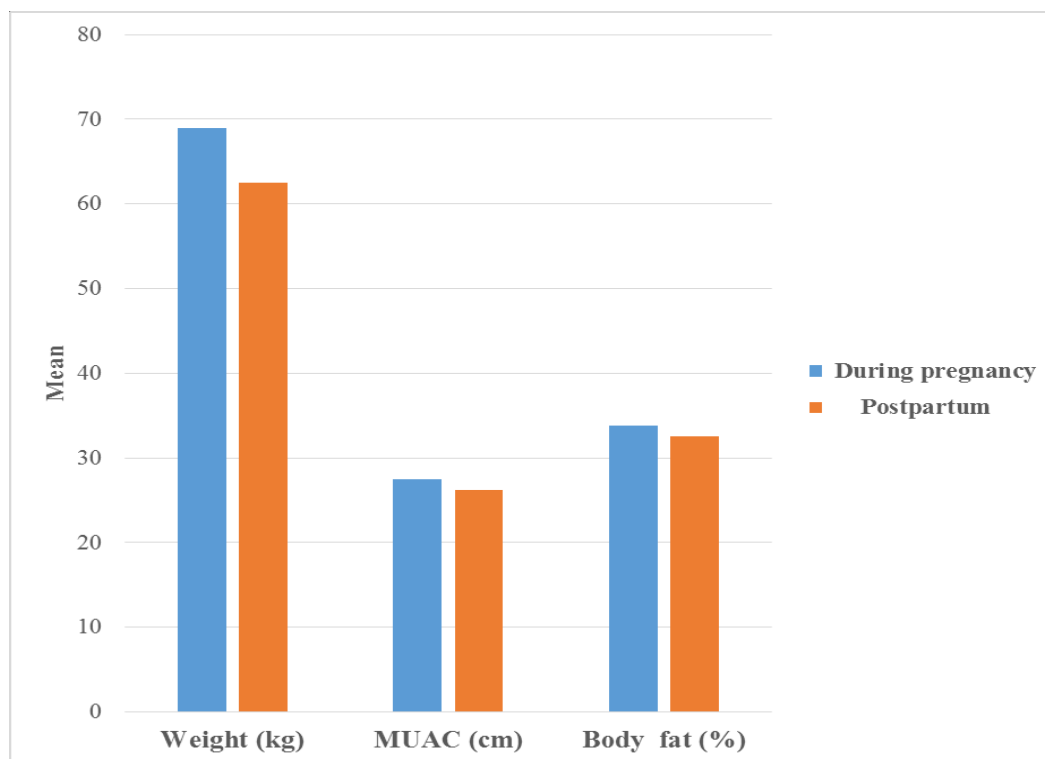


Figure 1: Anthropometric parameter changes during pregnancy and postpartum

Note: kg = kilogram, MUAC=mid-upper arm circumference and cm=centimeter

Pregnancy outcomes

Most of the women delivered through normal vaginal means (92.6%, n=363) and 7.4% (n=29) through caesarean section. Multiple babies were observed in 0.8% (n=3) of the newborns. Miscarriages and abortions were not observed in the study while stillbirth was observed in 0.5% (n=2) of the women, neonatal death (1.3%, n=5), and 8.2% (n=32) had macrosomic babies (≥ 4 kg) at birth. There were no birth injuries, intensive care unit admission and fetal abnormalities identified in the study area (Table 3).

Table 3: Birth outcomes

Variables assessed	Frequency	Percent	Mean (SD)
Birth modality (n=392)			
Caesarean section	29	7.4	
Normal delivery	363	92.6	
Miscarriages/abortions (n=392)			
Yes	0	0.0	
No	392	100.0	
Stillbirth (n=392)			
Yes	2	0.5	
No	390	99.5	
Number of babies delivered n=390)			
Single baby	387	99.2	
Multiple babies	3	0.8	

Neonatal death (n=390)			
Yes	5	1.3	
No	385	98.7	
Child's weight at birth (n=385)			
<2.5kg (Low weight)	16	4.1	
2.5-3.9kg (Normal weight)	337	87.7	3.3 (SD ±0.5)
≥4kg (macrosomic)	32	8.2	
Intensive care unit admission (n=390)			
Yes	0	0.0	
No	390	100.0	
Any injuries at birth (n=390)			
Yes	0	0.0	
No	390	100.0	
Fetal abnormalities (n=390)			
Yes	0	0.0	
No	390	100.0	

Note SD=Standard deviation.

Factors associated with postpartum hyperglycemia

The selected risk factors were analyzed using multiple logistic regression analysis with a stepwise backward selection to find out their association with postpartum hyperglycemia. A significant association was observed with increased body fat percentage (AOR 1.59, 95% CI: 1.14-1.91), MUAC (AOR 1.62, 95% CI: 1.023-1.99), macrosomic delivery (AOR 2.43, 95% CI: 2.2-10.31) and family history of T2DM (AOR 6.4, 95% CI: 1.93-13.3) even after adjusting for preterm and preterm death, maternal age and blood pressure which were not significantly associated with postpartum hyperglycemia (Table 4).

Table 4: Odd ratios for postpartum hyperglycemia

Risk factors	Crude OR(95%CI)	P-value
Univariate analysis		
Birth weight		
<4kg	1	
≥4kg	3.9(CI: 3.5-8.24)	<0.001*
Body fat percentage	1.59 (CI:1.24-1.79)	<0.001*
MUAC		
<28cm	1	
≥28cm	1.77 (CI:1.12-1.98)	0.002*
Family history of T2DM		
No	1	
Yes	8.9(CI:2.08- 14.4)	0.003*
Multivariate analysis		
Body fat percentage	1.49(CI:1.14-1.91)	0.004*
MUAC		
<28cm		
≥28cm	1.62(CI: 1.023-1.89)	0.032*
Family history of T2DM		
No	1	
Yes	6.4, 95% CI: 1.93-13.3)	0.005*
Birth weight		
<4kg	1	

≥4kg	2.43(CI:2.2-10.31)	0.003*
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Note: The univariate analysis also included preterm and preterm death, stillbirth maternal age and blood pressure with no significant association with postpartum hyperglycemia. The abbreviation AOR means adjusted Odd Ratio and number 1 indicates reference in categorical variables, CI= confidence interval and *significance at $p < 0.05$.

Discussion

The present study assessed the prevalence of postpartum hyperglycemia and pregnancy outcomes among women in urban areas of Arusha to generate evidence for designing appropriate interventions to prevent adverse pregnancy outcomes.

Generally, the prevalence of postpartum hyperglycemia (six weeks after delivery) was observed to be as low as 2.1% in the current study. In Tanzania, there is limited information on the prevalence of postpartum diabetes however; the study done in South Africa at 6-12 weeks postpartum reported that among 78 participating women 27% had diabetes after delivery (Coetzee et al., 2018). Another study done in Iran reported an overall incidence of early postpartum diabetes at 6-12 weeks to be 4.5% (Nouhjah et al., 2017) which was also higher than the prevalence of postpartum diabetes reported in the current study.

The reported low prevalence in the current study may be attributed to the method used for glucose testing which was mainly a fasting test despite its insensitivity. The fasting glucose test was the dominant test method because more than half of the women who returned for postpartum assessments were not willing to perform the OGTT procedure. After all, it is time-consuming. This was confirmed during the reminder messages and phone calls where most of the women were not willing to participate in OGTT was going to be conducted. Hence, they were allowed to come for the fasting test which may have attributed to the observed low prevalence. Evidence shows that the fasting plasma glucose test lack sensitivity as a screening test in postpartum re-evaluation of GDM compared to the use of OGTT (Bennet et al., 2009). A similar study conducted on 11,825 women with GDM reported that the rate of fasting plasma glucose (FPG) or OGTT postpartum testing was 50.2%, but 79.1% of these patients measured only FPG and 21% performed the OGTT (Lawrence et al., 2010).

In addition, the low prevalence of postpartum hyperglycemia in the current study may be because GDM cleared within six weeks postpartum which may be attributed to the actions taken after diagnosis whereby referrals were provided for a further checkup, counselling, and treatments or management. Another study supports the current findings that GDM stops after delivery if appropriate measures such as medication are used for treatment (Kitzmillier et al., 2007). On the other hand, all women who complied with postpartum testing in the current study were breastfeeding which may have contributed to the significant change in weight, body fat percentage and MUAC hence, reducing their chances of being hyperglycemic which needs further exploration to confirm the findings. Another similar study supports our findings that breastfeeding mothers lose more weight than those who are not breastfeeding hence, they have a decreased risk of developing T2DM (Liu et al., 2010).

Poor pregnancy outcomes were observed to be low in the study area whereby most of the women delivered through normal vaginal means without miscarriages and abortion while stillbirth and neonatal death were reported in very few women. In addition, macrosomic babies ($\geq 4\text{kg}$ at birth) occurred in 8.2% ($n=32$) of the children but there were no birth injuries, intensive care unit admission and fetal abnormalities reported. The present study has a high rate of macrosomia as compared to the national data where the rate of overweight was 2.8% including 0.5% of severe overweight among 0-59 children in Tanzania however, this survey did not specify the weight of infants at birth (Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) et al., 2018).

The low rate of poor pregnancy outcomes in the present study may be attributed to women's understanding of their conditions as unawareness of once blood glucose status can influence self-care practices. A study done by Msollo et al. (2021) insists that among 468 interviewed pregnant women, only 11% were aware of the existence of GDM before the introduction of the study which may negatively influence their health-seeking behaviour. Furthermore, the majority of the pregnant women in Arusha were not aware of the risk factors for GDM, despite this knowledge is very important for self-care as it can facilitate earlier self-identification for immediate actions to prevent adverse pregnancy outcomes and long-life health effects (Msollo et al., 2021).

This implies that awareness obtained from the introduction of the study may have contributed to the lower rate of poor pregnancy outcomes as a result of self-care and management. Also, this low prevalence of poor pregnancy outcomes may be due to the referrals that enabled women to have further checkups and treatments hence, reduced poor pregnancy outcomes. A study done in Dar es Salaam, Tanzania supports these findings that treatment reduces the risk of pregnancy complications hence; untreated hyperglycemic women may have an increased risk of morbidities among women and their newborns (Darling et al., 2014).

In addition, the noted low prevalence of postpartum hyperglycemia may contribute significantly to the low rate of poor pregnancy outcomes as postpartum hyperglycemia is reported to be significantly associated with pregnancy outcomes including macrosomia. Another similar study supports these findings by reporting that sometimes glucose levels may not be high enough to cause congenital malformations in the studied population (Sugiyama et al., 2014).

Although the prevalence of postpartum hyperglycemia in the current study was low, it was significantly associated with increased body fat percentage, MUAC ≥ 28 cm, family history of T2DM, and delivery to macrocosmic babies. Increased body fat percentage and MUAC may be reflective of overweight and obesity which is associated with hyperglycemia postpartum. These parametric indices may also affect the weight of the baby, causing macrosomic delivery which is associated with hyperglycemia as well. Similar studies have reported that there is a significant correlation between birth weight and maternal body weight and total body fat (TBF) before pregnancy (Butte et al., 2003; Forsum et al., 2006). In addition, long-term sequelae in offspring with utero exposure to maternal hyperglycemia may include higher risks for obesity and diabetes later in life (Hod et al., 2015). Other similar studies reported that persistent hyperglycemia is associated with a positive family history of diabetes (Weiner et al., 2014; Coetzee et al., 2018).

The rate of postpartum follow-up was found to be high in the current study which may be attributed to efforts taken to make women understand the importance of knowing their pregnancy glucose status. Moreover, the high rate of postpartum return may be attributed to allowing women to be tested for glucose using fasting tests as the majority complained about the inconveniences and long procedure for OGTT. This is because the procedure consumes much of their time for taking care of the newborn and for their health recovery. It may also be due to reminder calls and messages which were performed frequently as well as integration of the follow-up with other regular postpartum services such as immunization. Another similar study reported that a follow-up program linked to the infant's vaccination and regular health check-up visits provides an opportunity for continued engagement with the high-risk mother-child pair (Hod et al., 2015).

Loss to follow-up in the current study may also be attributed to a normal practice that, women stay indoors for at least 12 weeks (3 months) postpartum without doing heavy activities to take care of the newborn and for their health recovery. Hence, postpartum testing can be effective after 12 weeks (3 months) when women have almost completed their maternity leave or it can be integrated with regular postpartum services. Another study done in Kilimanjaro reported that it is a normal practice for women to take a leave of a minimum of three months from household chores

and any other heavy work after delivery to recover their health and become fat as a sign of care (Msollo et al., 2016). Similarly, another study reported that a fasting plasma glucose test would be more feasible and comfortable for the women, and increase return rates compared to OGTT which requires women to stay in the ANC for more than 2 hours and need several blood samples at a time (Weiner et al., 2014). The study by Nielsen et al. (2014), also reported that the low rate of return for postpartum assessment may be influenced by patient subjective barriers, such as newborn care, travel and socioeconomic difficulties, lack of family support, lack of understanding about the T2DM risk factors, and test discomfort.

Limitations of the study

The blood glucose test for postpartum hyperglycemia was assessed using a fasting glucose test as more than half of the women did not accept to conduct the OGTT procedure. However, the results are useful in providing some highlights for better planning of future research and a convenient way for follow-up of the women after delivery.

Conclusion and recommendations

Postpartum hyperglycemia was present in a small proportion of the women which may be influenced by the type of test and time for the testing to be done after delivery, calling for future large longitudinal studies to confirm the effects of timing and type of the test on postpartum hyperglycemia. Furthermore, awareness creation on GDM should be given priority to enhance self-care and develop a mechanism that can be used to increase compliance to postpartum follow-up. As the postpartum period provides an important platform to initiate beneficial health practices for both mother and child, to reduce the future burden of several NCDs, health stakeholders should support postpartum follow-up of mothers and their children while insisting on the recommended tests to be performed.

References

- American College of Obstetricians and Gynecologists Committee on Practice Bulletins–Obstetrics. (2001). ACOG practice bulletin. Clinical management guidelines for obstetrician-gynaecologists. Number 30, September 2001 (replaces technical bulletin number 200, December 1994). Gestational diabetes. *Obstetric Gynecology* 98:525–538.
- American Diabetes Association. (2013). Standards of medical care in diabetes. *Diabetes Care* 36 (Suppl 1): S11-66.
- Bennett, W.L., Bolen, S., Wilson, L.M., Bass, E.B., Nicholson, W.K. (2009). Performance characteristics of postpartum screening tests for type 2 diabetes mellitus in women with a history of gestational diabetes mellitus: a systematic review. *Journal of Women's Health* 18 (7):979-87.
- Butte, N.F., Ellis, K.J, Wong, W.W., Hopkinson, J.M. and O'Brian-Smith, E. (2003). The composition of gestational weight gain impacts maternal fat retention and infant birth weight. *American Journal of Obstetrics and Gynecology*. 189: 1423–1432.
- Carson, M.P., Frank, M.I., Keely, E. (2013). Postpartum testing rates among women with a history of gestational diabetes- Systematic review. *Primary Care Diabetes* 7(3):177-86.
- Daniel W. (1999). Biostatistics: a Foundation for analysis in the health sciences. 7th ed. New York: R Wiley.
- Coetzee A, Mason D, Hall DR, Conradie M. Prevalence and predictive factors of early postpartum diabetes among women with gestational diabetes in a single-centre cohort. *International Journal of Gynaecology and Obstetrics*. 142(1):54-60.

- Darling, A.M., Liu, E., Aboud, S., Urassa, W., Spiegelman, D. and Fawzi, W. (2014). Maternal hyperglycemia and adverse pregnancy outcomes in Dar es Salaam, Tanzania. *International Journal of Gynaecology and Obstetrics*. 2014; 125(1): 22–27.
- Forsum E., Lof M., Olausson, H. and Olhager, E. (2006). Maternal body composition about infant birth weight and subcutaneous adipose tissue. *British Journal of Nutrition*. 96:408–414.
- Grunnet, L.G., Hjort, L., Minja, D. T., Msemo, O.A., Møller, S.L., Prasad R.B., Groop, L. et al. (2020). High Prevalence of Gestational Diabetes Mellitus in Rural Tanzania—Diagnosis Mainly Based on Fasting Blood Glucose from Oral Glucose Tolerance Test. *International Journal of Environmental Research. Public Health* 17, 3109; DOI: 10.3390/ijerph17093109.
- Hartling, L., Dryden, D. M., Guthrie, A., Muise, M., Vandermeer, B., & Donovan, L. (2013). Benefits and harms of treating gestational diabetes mellitus: A systematic review and meta-analysis for the U.S. Preventive Services Task Force and the National Institutes of Health Office of Medical Applications. *Annals of Internal Medicine*. 159(2), 123–129.
- Hod, M., Kapur, A., Sacks, D.A., Hadar, E., Agarwal, M., Di Renzo, C., et al. (2015). The International Federation of Gynecology and Obstetrics (FIGO) Initiative on gestational diabetes mellitus: A pragmatic guide for diagnosis, management, and care. *International Journal of Gynecology and Obstetrics* 131(Suppl. 3): S173–S211.
- Imoh, L. C., Ogunkeye, O. O., Isichei, C. O., Gadzama, A. A., Ekwempu, C. C. (2016). Combining the IADPSG criteria with the WHO diagnostic criteria for gestational diabetes mellitus optimizes the predictability of adverse pregnancy outcomes. *Tropical Journal of Obstetrics and Gynaecology* 33: 185–189.
- International Diabetes Federation. (2017). IDF Diabetes Atlas 8th edition. Brussels, Belgium.
- Jensen, D.M., Ovesen, P., Beck-Nielsen, H., Mølsted-Pedersen, L., Sørensen, B., Vinter, C, et al. (2005). Gestational weight gain and pregnancy outcomes in 481 obese glucose-tolerant women in Denmark. *Diabetes Care* 28: 2118–22.
- Kitzmiller, J. L., Dang-Kilduff L., Taslimi, M. M. (2007). Gestational diabetes after delivery: short-term management and long-term risks. *Diabetes care* 30 (Suppl 2): S225-S235.
- Lawrence, J.M., Black, M.H., Hsu, J.W., Chen, W., Sacks, D.A. (2010). Prevalence and timing of postpartum glucose testing and sustained glucose dysregulation after gestational diabetes mellitus. *Diabetes Care* 33(3):569-76.
- Liu, B., Jorm, L., Banks, E. (2010). Parity, breastfeeding, and the subsequent risk of maternal type 2 diabetes. *Diabetes Care* 33:1239–41.
- Macfarlane SB. (1997). Conducting a descriptive survey: 2. Choosing a sampling strategy. *Tropical Doctor*. 27(1):14–21.
- Masaki S, Ngoye A, Petrucka P, Buza J. (2015). Type 2 diabetes prevalence and risk factors of urban Maasai in Arusha municipality and rural Maasai in Ngorongoro crater. *Journal of Applied Life Sciences International* 3(4): 157-168.
- Mdoe MB, Kibusi SM, Munyogwa MJ, Alex Ibolinga Ernest, A.I. (2021). Prevalence and predictors of gestational diabetes mellitus among pregnant women attending antenatal clinic in Dodoma region, Tanzania: an analytical cross-sectional study. *BMJ Nutrition, Prevention & Health* 2021;4:e000149. doi:10.1136/2020-000149.
- Mghanga, F. P., Elia A. Maduhu, E.A., and Helmut A. Nyawale, H.A. (2020). Prevalence and associated factors of gestational diabetes mellitus among rural pregnant women in southern Tanzania. *Ghana Medical Journal* 2020; 54(2): 82-87.
- Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], Tanzania Food and Nutrition Centre (TFNC), National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS)

- [Zanzibar] and UNICEF. (2018). Tanzania National Nutrition Survey using SMART Methodology (TNNS) 2018. Dar es Salaam, Tanzania.
- Msollo, S.S., Chivaghula, T.J., Muhimbula, H.S., Krawinkel, M. and Kinabo, J. (2016). Overweight and obesity among adults in Same District, Tanzania. *Tanzania Journal of Agricultural Sciences* 15(2): 81-92.
- Msollo, S.S., Martin, H.D., Mwanri, A.W. and Petrucka, P. (2019). "Prevalence of Hyperglycemia in Pregnancy and Influence of Body Fat on Development of Hyperglycemia in Pregnancy among Pregnant Women in Urban Areas of Arusha Region, Tanzania." *BMC Pregnancy and Childbirth* 17 (315).
- Msollo, S.S., Martin, H.D., Mwanri, A.W. and Petrucka, P. (2021). Awareness and Screening Practices for Gestational Diabetes Mellitus among Pregnant Women in Arusha Urban, Tanzania. *Tanzania Journal of Agricultural Sciences* (2021) Vol. 20 No. 1, 1-11.
- Mwanri, A. W., Kinabo, J., Ramaiya, K. and Feskens, E. J. M. (2014). Prevalence of gestational diabetes mellitus in urban and rural Tanzania. *Diabetes Research and Clinical Practice*. 103(1):71–78.
- Nielsen, K.K., Kapur, A., Damm P., de Courten, M. and Bygbjerg, I.C. (2014). From screening to postpartum follow-up. The determinants and barriers for gestational diabetes mellitus (GDM) services, a systematic review. *BMC Pregnancy Childbirth* 14: 41.
- Njete, H. I., John, B., Mlay, P., Mahande, M. J. and Msuya, S. E. (2018). Prevalence, predictors and challenges of gestational diabetes mellitus screening among pregnant women in northern Tanzania. *Tropical Medicine and International Health*. 23(2): 236–242.
- Nouhjah, S., Shahbazian, H., Shahbazian, N., Jahanshahi, A., Jahanfar, S., Cheraghian, B. (2017). Incidence and Contributing Factors of Persistent Hyperglycemia at 6-12 Weeks Postpartum in Iranian Women with Gestational Diabetes: Results from LAGA Cohort Study. *Journal of Diabetes Research*. 2017:9786436. DOI: 10.1155/2017/9786436.
- Palani, S., Joseph, N. M., Tegene, Y., & Zacharia, A. M. T. (2014). Gestational diabetes. A review. *Journal of Global Trends in Pharmaceutical Sciences*, 5(2), 1673–1683.
- Sugiyama, T., Saito, M., Nishigori, H. Nagase, S., Yaegashi, N., Sagawa, N., Kawano, R. et al. (2014). Comparison of Pregnancy Outcomes between Women with Gestational Diabetes and Overt Diabetes First Diagnosed in Pregnancy: A retrospective multi-institutional study in Japan. *Diabetes Research and Clinical Practice*. 103: 20-25.
- Weinert, L. S., Mastella, L. S., Oppermann, M. L. R., Silveiro, S. P., Guimarães, L. S. P. and Reichelt, A. J. (2014). Postpartum glucose tolerance status 6 to 12 weeks after gestational diabetes mellitus: a Brazilian cohort. *Arquivos Brasileiros de Endocrinologia & Metabologia*. 58(2):197-204.
- Wendland, E. M., Torloni, M., Falavigna, M., Trujillo, J., Dode, M., Campos, M., et al. (2012). Gestational diabetes and pregnancy outcomes - a systematic review of the World Health Organization (WHO) and the International Association of Diabetes in Pregnancy Study Groups (IADPSG) diagnostic criteria. *BMC Pregnancy and Childbirth*. 12: 23pp.
- World Health Organization (2013). Diagnostic criteria and classification of hyperglycemia first detected in pregnancy. Geneva: WHO; 2013.
- World Health Organization. (2006). Definition and diagnosis of diabetes mellitus and intermediate hyperglycemia: report of a WHO/IDF consultation. *World Health Organization*, Geneva. p 50. <https://doi.org/ISBN 92 4 159493 4>. Accessed 15 May 2017.
- Wynants, L., Collons, G., & Van Calster, B. (2017). Key steps and common pitfalls in developing and validating risk models. *International Journal of Obstetrics and Gynaecology*. 124(3), 423–432.