

Association Between Glycated Hemoglobin and Breast Cancer Among Women at a Referral Hospital in Meru County, Kenya: A Case-Control Study

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Abstract

The rising dual burden of breast cancer and type 2 diabetes mellitus (T2DM) in Sub-Saharan Africa warrants examining their overlap. This study examined the association between glycated hemoglobin (HbA1c) and breast cancer status at a hospital in Meru County, Kenya. An unmatched case-control study enrolled 285 women: 142 with histologically confirmed breast cancer diagnosis and 143 with benign breast masses. Chi-square, t-tests, ANOVA with Tukey HSD testing, logistic regression, and ROC analysis were used. HbA1c $\geq 6.5\%$ was present in 84.5% of cases (120/142) versus 34.3% of controls (49/143; $\chi^2 = 74.515$, $df = 1$, $p < 0.001$). Mean HbA1c was higher among cases ($6.89\% \pm 0.75$) than controls ($5.82\% \pm 0.71$; $t(283) = 12.445$, $p < 0.001$, mean difference 1.07, 95% CI: 0.90–1.24). In multivariable logistic regression, T2DM (adjusted OR = 5.619, 95% CI: 2.802–11.267), alcohol use (aOR = 4.041, 95% CI: 1.707–9.569), family history of breast cancer (aOR = 2.763, 95% CI: 1.340–5.587), hormonal contraceptive use (aOR = 2.151, 95% CI: 1.140–4.058), and BMI (aOR = 1.389 per unit, 95% CI: 1.268–1.521) were independently associated with case status; age was not (aOR = 1.000, 95% CI: 0.969–1.033). HbA1c $\geq 6.5\%$ discriminated cases from controls with moderate accuracy (AUC = 0.751, 95% CI: 0.693–0.809; sensitivity 84.5%, specificity 65.7%). Mean HbA1c did not differ significantly across stages I–III (ANOVA, $F(3,139) = 2.599$, $p = 0.055$), although Stage IV cases ($n = 8$) recorded a higher mean (7.56%) than Stage II (6.78%; Tukey HSD, $p = 0.031$). Because T2DM status was derived from the HbA1c $\geq 6.5\%$ threshold, and HbA1c was measured post-diagnosis, findings reflect association within this sample rather than validated screening performance. Glycemic status shows a strong association with breast cancer in this Kenyan population; prospective population-based studies are needed before HbA1c can be recommended as a breast cancer screening tool.

Keywords: *Glycated hemoglobin, hyperglycemia, breast cancer, type 2 diabetes, case-control study*

1.0 Introduction

Breast cancer is the most commonly diagnosed cancer among women globally, accounting for an estimated 2.3 million new cases in 2022, while type 2 diabetes mellitus (T2DM) affects over 463 million adults worldwide (Ngwa et al., 2022; Zhang et al., 2023). A growing body of evidence describes a plausible metabolic link between the two conditions: hyperglycemia and its accompanying hyperinsulinemia are proposed to promote tumor proliferation through insulin and insulin-like growth factor-1 (IGF-1) signaling, chronic low-grade inflammation, and a shift toward glycolytic (Warburg) tumor metabolism (Asiri et al., 2024; Giovannucci et al., 2010; Vander Heiden et al., 2009). Epigenetic mechanisms, including hypermethylation of tumor suppressor genes, have also been proposed as a downstream consequence of chronic hyperglycemia (Stan & Paul, 2024).

Epidemiological evidence for a direct HbA1c-breast cancer association, however, remains mixed. Ayoub et al. (2020) linked higher HbA1c to more advanced tumor characteristics among breast cancer patients, and Jousheghany et al. (2016) found HbA1c $\geq 7.0\%$ associated with increased breast cancer incidence, while a Swedish population-based cohort reported higher cancer incidence among women with fasting glucose ≥ 6.9 mmol/L (Stattin et al., 2007). By contrast, a large United States cohort study found no significant prospective association between HbA1c and breast cancer risk (Campbell et al., 2022), a divergence the authors attribute to more consistent glycemic control and screening infrastructure in that setting rather than to the absence of a true biological relationship. This inconsistency across populations, together with the general absence of data from Sub-Saharan Africa, motivates the present study.

In Kenya, breast cancer constitutes an estimated 23.3% of female malignancies, with the majority of cases presenting at Stage II–IV following diagnostic delays that commonly average 6–12 months (Sayed et al., 2017; Twahir et al., 2021).

T2DM prevalence is concurrently rising nationally (International Diabetes Federation, 2025). In Meru County specifically, these challenges are compounded by low mammography utilization (under 10%) and limited public awareness of breast cancer risk factors and self-examination (Antabe et al., 2020; Wassie et al., 2024). Despite this overlapping burden, context-specific Kenyan data on the association between glycemic status and breast cancer, and on how HbA1c behaves across disease stages, remain scarce.

A prior version of this manuscript attributed a figure of 55.6% hyperglycemia prevalence among Kenyan breast cancer patients to verification, that source concerns curriculum co-design for a breast cancer awareness programme and does not report this statistic. That claim has been removed; the present study's own findings, reported in Section 3.2, provide the locally generated estimate this literature currently lacks.

This study aimed primarily to determine whether glycated hemoglobin is associated with breast cancer status among women presenting to Meru Teaching and Referral Hospital. Secondary objectives were to (1) describe the proportion of breast cancer cases and controls with HbA1c $\geq 6.5\%$; (2) identify factors independently associated with breast cancer status in this sample; and (3) describe HbA1c levels across breast cancer stages.

2.0 Materials and Methods

Study design and setting

This was an unmatched, hospital-based case-control study conducted at Meru Teaching and Referral Hospital (MeTRH), a Level V facility and the principal referral centre for cancer care in Meru County and the neighbouring Tharaka-Nithi and Isiolo regions. Cases and controls were recruited concurrently, over a six-month period, from the same hospital referral pool (the pathology department, where women were referred for histological or cytological evaluation of a breast mass), which we consider to reduce,

though not eliminate, differences in catchment area and referral pathway between the two groups.

"This case-control study found a strong association between glycated hemoglobin and breast cancer status among women at a Kenyan referral hospital"

Controls were broadly age-matched to cases within five years at the point of recruitment; this was an informal matching band applied during recruitment rather than a formal individual or frequency matching design, and the analysis did not condition on this matching.

Study population, sample size, and recruitment

The target sample size was calculated using the Fleiss et al. (2003) formula for unmatched case-control studies, assuming 80% power and a two-sided 5% significance level. Recruitment was consecutive: women referred to the pathology department with a clinically suspicious breast mass underwent biopsy or fine-needle aspiration cytology, and those with a histologically confirmed malignant diagnosis were enrolled as cases, while those with a confirmed benign diagnosis, drawn from the same referral pool, were enrolled as controls.

Inclusion and exclusion criteria

Cases were adult women (≥ 18 years) with a histopathologically confirmed diagnosis of primary breast cancer, at any clinical stage, who had not yet commenced cancer treatment. Controls were adult women (≥ 18 years) with a histologically or cytologically confirmed non-cancerous (benign) breast mass and no personal history of breast cancer. Women who were pregnant or lactating, or who had type 1 diabetes mellitus, a prior or concurrent malignancy other than the index breast cancer, or incomplete

records, were excluded from both groups, as were women who declined informed consent.

Data collection

Structured questionnaires captured sociodemographic characteristics, alcohol use, hormonal contraceptive use, family history of breast cancer, and T2DM status. Body mass index was calculated from measured weight and height using standard clinical procedures. T2DM status and glycated hemoglobin were both derived from HbA1c testing against the American Diabetes Association (ADA, 2023) diagnostic threshold of $\geq 6.5\%$. We flag explicitly that this means T2DM classification and the HbA1c $\geq 6.5\%$ exposure variable are not independent measures in this dataset: a participant classified as having T2DM necessarily also met the HbA1c $\geq 6.5\%$ threshold. Glycated hemoglobin was measured from venous or capillary whole blood using a validated point-of-care immunoturbidimetric analyser, with daily instrument calibration and duplicate testing on a subset of samples for quality assurance (inter-assay variability $< 5\%$). Breast cancer staging followed the American Joint Committee on Cancer (AJCC) TNM 8th edition classification, assigned prior to treatment initiation.

Data analysis

Descriptive statistics summarised participant characteristics. Chi-square tests assessed associations between categorical variables; independent-samples t-tests compared mean HbA1c between cases and controls; one-way ANOVA with Tukey HSD post-hoc testing examined HbA1c across breast cancer stages; binary logistic regression, adjusting for T2DM status, alcohol use, family history, hormonal contraceptive use, age, and BMI, estimated adjusted odds ratios (aOR) with 95% confidence intervals for factors associated with case status; and receiver operating characteristic (ROC) curve analysis described the within-sample discriminatory performance of HbA1c. Statistical significance was set at two-tailed $p < 0.05$. Missing data, affecting under 5% of the dataset,

were handled by listwise deletion. Analyses were conducted in IBM SPSS Statistics version 27.0.

Ethical considerations

Ethical clearance was obtained from the Kenya Methodist University Institutional Scientific Ethics Research Committee (KeMU/ISERC/INT/01/2023), with a research permit from the National Commission for Science, Technology and Innovation (NACOSTI/P/23/30930) and authorisation from the Meru County Government Department of Health. All participants provided written informed consent. Data were anonymised, stored in password-protected files, and accessible only to the research team. Participants received no

financial incentive for participation but received free testing, and those with newly identified hyperglycemia or breast pathology were referred for appropriate clinical follow-up.

3.0 Results and Discussion

Participant characteristics

A total of 285 participants were enrolled (143 cases, 142 controls). Mean age was 50.0 ± 10.0 years for cases and 49.0 ± 9.0 years for controls. Among breast cancer cases, 32 (22.5%) were Stage I, 52 (36.6%) Stage II, 51 (35.9%) Stage III, and 8 (5.6%) Stage IV. Table 1 presents baseline characteristics by group.

Table 1

Baseline characteristics and key variables by group

Variable	Cases n (%) (N = 142)	Controls n (%) (N = 143)	p-value
Age (years), mean $\pm$ SD	50.0 ± 10.0	49.0 ± 9.0	-
T2DM — Yes	64 (45.1%)	21 (14.7%)	< 0.001*
Alcohol use — Yes	32 (22.5%)	13 (9.1%)	0.002*
Hormonal contraceptive — Yes	57 (40.1%)	38 (26.6%)	0.013*
Family history — Yes	42 (29.6%)	26 (18.2%)	0.020*
HbA1c (%), mean $\pm$ SD	6.89 ± 0.75	5.82 ± 0.71	< 0.001*
BMI (kg/m ²), mean $\pm$ SD	28.0 ± 3.66	24.3 ± 3.40	< 0.001*

Note. * $p < 0.05$, statistically significant. T2DM = type 2 diabetes mellitus (see Section 2.4 regarding its overlap with the HbA1c threshold variable); HbA1c = glycated haemoglobin; BMI = body mass index. Percentages recalculated against the stated group denominators. p-values are from chi-square tests for categorical variables and independent-samples t-tests for continuous variables.

HbA1c differences between cases and controls

Mean HbA1c was significantly higher among cases ($6.89\% \pm 0.75$) than controls ($5.82\% \pm 0.71$; $t(283) = 12.445$, $p < 0.001$; mean difference 1.07 percentage points, 95% CI: 0.90–1.24). Using the ADA diagnostic threshold of $\geq 6.5\%$, HbA1c above this level was present in 120/142 cases (84.5%) compared with 49/143 controls (34.3%), a difference confirmed by chi-square testing ($\chi^2 = 74.515$, $df = 1$, $p < 0.001$). We describe this as the

proportion of *sampled* cases and controls with $HbA1c \geq 6.5\%$; because cases and controls were both drawn from a single hospital's referral population rather than a population-based sample, this proportion should not be interpreted as the prevalence of hyperglycemia among all breast cancer patients in Meru County, and direct comparison with community- or population-level prevalence estimates elsewhere is not appropriate.

T2DM, metabolic factors, and other factors associated with breast cancer status

Binary logistic regression identified five factors independently associated with breast cancer status after mutual adjustment: T2DM (aOR = 5.619, 95% CI: 2.802–11.267, $p < 0.001$), alcohol use (aOR = 4.041, 95% CI: 1.707–9.569, $p = 0.001$), family history of breast cancer (aOR = 2.763, 95% CI: 1.340–5.587, $p = 0.006$), hormonal contraceptive use (aOR = 2.151, 95% CI: 1.140–

4.058, $p = 0.018$), and BMI per unit increase (aOR = 1.389, 95% CI: 1.268–1.521, $p < 0.001$). Age was not independently associated with case status (aOR = 1.000, 95% CI: 0.969–1.033, $p = 0.980$). As noted in Section 2.4, T2DM status in this model reflects the same HbA1c $\geq 6.5\%$ threshold

used elsewhere as the primary exposure of interest, and its inclusion alongside the continuous and dichotomised HbA1c variables discussed below should be interpreted with this overlap in mind rather than as fully independent evidence. Results are presented in Table 2.

Table 2

Logistic regression: factors associated with breast cancer status (N = 285)

Factor	Adjusted OR (95% CI)	<i>p</i> -value	Sig.
T2DM	5.619 (2.802–11.267)	< 0.001	***
Alcohol use	4.041 (1.707–9.569)	0.001	***
Family history	2.763 (1.340–5.587)	0.006	**
Hormonal contraceptive use	2.151 (1.140–4.058)	0.018	*
BMI (per unit)	1.389 (1.268–1.521)	< 0.001	***
Age	1.000 (0.969–1.033)	0.980	NS

Note. Dependent variable: breast cancer status (cases = 1, controls = 0). *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, NS = not significant.

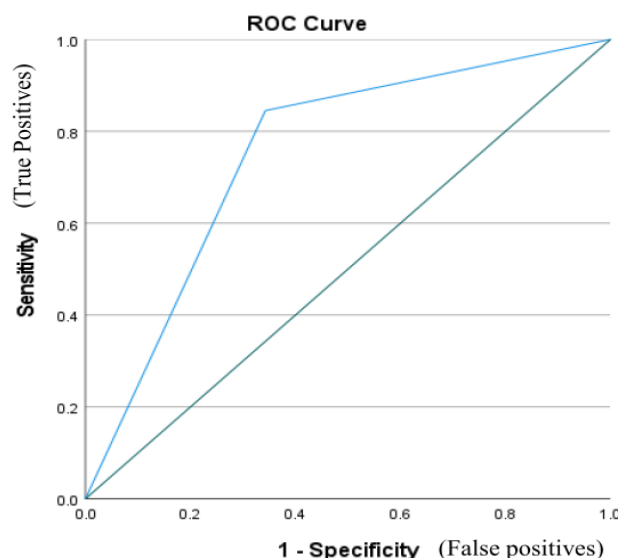
Discriminatory performance of HbA1c

ROC curve analysis of the dichotomised HbA1c threshold ($\geq 6.5\%$ vs. $< 6.5\%$) yielded an area under the curve (AUC) of 0.751 (95% CI: 0.693–0.809, $p < 0.001$), which we characterise as moderate discrimination between cases and controls within this sample, with sensitivity of 84.5% and specificity of 65.7%. We do not describe 6.5% as an “optimal” threshold in the sense of having been empirically derived from this dataset; rather, it corresponds to the established ADA diagnostic threshold for diabetes, applied here to breast cancer case-control status. At a specificity of 65.7%, approximately one-third of controls in this sample would be classified as HbA1c-positive, a false-positive rate that would carry material implications if this threshold were applied as a population screening rule. Because a case-control design fixes the proportion of cases and controls by design rather than reflecting true population disease prevalence, this study cannot estimate positive or negative predictive value, cost-effectiveness, or real-world screening performance; these require prospective, population-based evaluation. Separately, in the

logistic regression model, each one-percentage-point increase in continuous HbA1c was associated with a 7.864-fold increase in the adjusted odds of breast cancer case status (95% CI: 4.845–12.761, $p < 0.001$). We emphasise that this continuous-exposure model and the dichotomised $\geq 6.5\%$ threshold model described above are distinct analyses answering different questions, and neither figure should be read as interchangeable with the other or as an estimate of absolute risk.

Figure 1

Receiver Operating Curve (ROC) for HbA1c



HbA1c across breast cancer stages

Mean HbA1c across the four breast cancer stages is presented in Table 3. One-way ANOVA did not reach conventional statistical significance ($F(3, 139) = 2.599$, $p = 0.055$), though a directional trend was observed, with Stage IV recording the highest mean HbA1c (7.56%, 95% CI: 6.84–8.29) against a comparatively narrow range of 6.78–6.91% across Stages I–III. Tukey HSD post-hoc testing found a statistically significant difference only between Stage II and Stage IV (mean difference = 0.782 percentage points, 95% CI: 0.05–1.51, $p = 0.031$); the Stage III versus Stage IV comparison approached but did not reach significance (mean difference = 0.680, 95% CI: –0.05–1.41, $p = 0.078$), and all other pairwise comparisons among Stages I–III were non-significant ($p = 0.866$ – 0.998). Given that only eight Stage IV cases were available, this comparison is statistically unstable and should be interpreted cautiously; we discuss this further as a limitation below.

Table 3

Mean HbA1c (%) by breast cancer stage among cases

Stage	n	Mean HbA1c (%)	SD	95% CI
I	32	6.91	0.62	6.69–7.13
II	52	6.78	0.67	6.59–6.97
III	51	6.88	0.84	6.65–7.12
IV	8	7.56	0.87	6.84–8.29

Note. One-way ANOVA: $F(3, 139) = 2.599$, $p = 0.055$. Tukey HSD post-hoc: Stage II vs. IV, $p = 0.031$; Stage III vs. IV, $p = 0.078$; all other pairwise comparisons $p > 0.05$.

This study found a markedly higher proportion of sampled breast cancer cases than controls with HbA1c $\geq 6.5\%$, and a correspondingly higher mean HbA1c among cases, in a Kenyan referral-hospital population. Because HbA1c was measured after breast cancer diagnosis, and because both T2DM status and the HbA1c threshold variable in this dataset derive from the same measurement, these findings demonstrate a strong cross-sectional association between

glycemic status and breast cancer case status rather than establishing that hyperglycemia preceded, or caused, breast cancer in this sample. Reverse causation is biologically plausible: tumour-related metabolic and inflammatory effects, and illness-related changes in diet, activity, or treatment-seeking behaviour prior to diagnosis, could each independently elevate HbA1c in newly diagnosed cases. Disentangling these possibilities requires prospective data collected before diagnosis, which this design cannot provide.

T2DM, as defined by the same HbA1c $\geq 6.5\%$ threshold, showed the strongest association with case status among the factors examined, consistent with proposed mechanisms involving hyperinsulinemia, IGF-1 signalling, and chronic inflammation (Asiri et al., 2024; Giovannucci et al., 2010). Alcohol use showed the second-strongest association, consistent with its established role in altering oestrogen metabolism and inducing DNA damage (Lam et al., 2021). Family history was associated with roughly a threefold increase in odds, consistent with the recognised hereditary component of breast cancer and, in the Kenyan context, with the elevated prevalence of BRCA1/2 mutations reported among triple-negative breast cancer patients (Rioki et al., 2023). Hormonal contraceptive use and BMI showed associations broadly consistent with hormonal and adiposity-mediated pathways described elsewhere (Fitzpatrick et al., 2023; Glassman et al., 2023). We compared each of these findings against studies reporting both consistent and null associations; the null finding reported by Campbell et al. (2022) in a high-income cohort, for example, may plausibly reflect differences in population glycemic control, study design, measurement timing, or statistical power relative to the present sample, rather than a true absence of biological relationship, and we present this as one of several possible explanations rather than a settled interpretation.

The absence of a statistically significant omnibus difference in HbA1c across Stages I–III, alongside a distinctly higher mean confined to the

small Stage IV subgroup, is consistent with a pattern in which hyperglycemia may be more closely associated with breast cancer status generally than with a graded progression across earlier disease stages; whether it also contributes to progression toward metastatic disease cannot be determined from this dataset given the limited Stage IV sample.

Limitations

Several limitations should be considered when interpreting these findings. First, the case-control design and post-diagnosis timing of HbA1c measurement mean that temporality, and therefore causality, cannot be established; hyperglycemia may have preceded, coincided with, or followed breast cancer development. Second, the hospital-based selection of both groups, and the use of women with benign breast disease as controls rather than a population-based sample, limits generalisability to the broader population of women in Meru County and may introduce selection effects related to healthcare-seeking behaviour, body mass index, and hormonal exposure. Third, T2DM status and the HbA1c $\geq 6.5\%$ exposure variable were derived from the same measurement, limiting the extent to which they can be treated as independent predictors within the regression model; this should be clarified and, where necessary, re-analysed. Fourth, alcohol use, hormonal contraceptive use, and family history were captured through self-report as binary variables without detail on amount, duration, formulation, or degree of relatedness, raising the possibility of recall bias and residual confounding, and did not account for other established or plausible breast cancer determinants, including menopausal status, parity, age at first birth, breastfeeding history, physical activity, dietary pattern, and duration of diabetes, which were not measured or adjusted for in this analysis. Fifth, factors that can independently affect HbA1c validity, including anaemia, haemoglobin variants, recent blood transfusion, and renal disease, were not systematically assessed, a particularly relevant consideration in African populations. Sixth, the

Stage IV subgroup ($n = 8$) was too small to support stable stage-level comparisons. Finally, because a case-control design does not reproduce population disease prevalence, this study cannot estimate positive or negative predictive value, cost-effectiveness, or real-world screening performance, and the ROC-derived sensitivity and specificity reported here have not been externally validated in an independent or population-based sample.

Clinical and public health implications

Within the scope of these limitations, glycemic status shows a robust, biologically plausible cross-sectional association with breast cancer case status in this Kenyan referral-hospital sample. This supports strengthening coordination between diabetes and oncology services, for example through routine diabetes assessment for women receiving breast cancer care and reciprocal awareness of breast health among women attending diabetes clinics, and continued counselling on modifiable factors such as alcohol use, obesity, and hormonal contraceptive use, alongside prospective, multi-centre research to test whether HbA1c has a legitimate role in breast cancer risk stratification. We do not consider the present evidence sufficient to recommend HbA1c $\geq 6.5\%$ as a breast cancer screening threshold, to justify referring women for breast evaluation on the basis of an elevated HbA1c alone, or to support claims of cost-effectiveness or national screening policy; these would require prospective validation in a population-based sample, as outlined below.

4.0 Conclusion

This case-control study found a strong association between glycated hemoglobin and breast cancer status among women at a Kenyan referral hospital (AUC = 0.751, sensitivity 84.5%, specificity 65.7%), alongside independent associations with T2DM, alcohol use, family history, hormonal contraceptive use, and BMI. Given the study's hospital-based, cross-sectional design and the overlap between the T2DM and HbA1c variables described above, these findings should be

understood as evidence of association within this sample rather than as a validated predictive or screening biomarker.

5.0 Recommendations

The findings support: routine diabetes assessment and management among women receiving breast cancer care; strengthened coordination between oncology and diabetes services, leveraging existing diabetes-clinic infrastructure; community health education on modifiable risk factors including alcohol use, obesity, and hormonal contraceptive use; and prospective, multi-centre research using population-based

sampling to establish temporality, validate the HbA1c $\geq 6.5\%$ threshold across Sub-Saharan African populations, resolve the T2DM-HbA1c collinearity issue described above, and, with an adequately powered Stage IV subgroup, clarify whether hyperglycemia contributes to breast cancer progression as well as initiation. The findings do not yet support using HbA1c $\geq 6.5\%$ as a breast cancer screening threshold, referring women for breast evaluation on the basis of an elevated HbA1c alone, claims of cost-effectiveness, or a national screening policy; each of these would require prospective, population-based validation.

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