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EVALUATING THE ASSOCIATION OF MATERNAL ANTHROPOMETRICS AND ALKALINE PHOSPHATASE (ALP) LEVELS FOR GESTATIONAL DIABETES MELLITUS (GDM) AT 24–28 WEEKS: A MULTIVARIABLE ANALYSIS

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Abstract

Background Gestational diabetes mellitus (GDM) is a prevalent metabolic disorder of pregnancy associated with adverse maternal and neonatal outcomes. However, early risk stratification remains limited in many clinical settings. This study aimed to evaluate the association of maternal anthropometric measures and serum alkaline phosphatase (ALP) levels for GDM diagnosed at 24–28 weeks of gestation using a 2-hour oral glucose tolerance test (OGTT) threshold of greater than 140 mg/dL.

Methods A cross-sectional analytical study was conducted among 200 pregnant women between 24 and 28 weeks of gestation recruited through purposive sampling in a city in Bulacan, Philippines. Maternal age, age of gestation (AOG), body mass index (BMI), waist-to-hip ratio (WHR), and serum ALP levels were collected, and binary logistic regression was used to examine their association with GDM status defined by 2-hour OGTT results.

Results Among the participants, 26.5% (n = 53) were diagnosed with GDM. The logistic regression model was statistically significant ($\chi^2(5) = 80.52$, $p < .001$), with ALP emerging as the only significant potential predictor of GDM (B = 0.083, $p < .001$; OR = 1.09; 95% CI [1.06, 1.11]), while maternal age, gestational age, BMI, and WHR were not significantly associated with GDM.

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Conclusion These findings suggest that higher maternal ALP levels at 24–28 weeks of gestation are independently associated with increased odds of GDM. Wherein conventional anthropometric and demographic factors did not significantly predict GDM in this cohort due to a possible effect on the changes in the placenta of a pregnant woman. Incorporating ALP into screening strategies may enhance early risk stratification of pregnant women, particularly in resource-limited settings, and supports further research on enzyme-related biomarkers in GDM risk prediction.

Keywords: *Gestational diabetes mellitus; maternal anthropometrics; alkaline phosphatase; logistic regression; enzyme biomarkers*

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Research Highlights

What is the current knowledge?

- Maternal age is a well-established risk factor for GDM; older pregnant women generally have higher risk, but age alone has only moderate potential predictive value and works best when combined with other factors.
- BMI is the most consistently reported anthropometric predictor of GDM, especially when measured before or early in pregnancy; however, BMI alone has limited accuracy and does not fully capture metabolic risk.
- WHR and other body-shape measures show inconsistent associations with GDM; their association is generally weak to modest and inferior to BMI in most studies.
- AOG and mid-pregnancy anthropometric measures have limited independent potential predictive value, as physiological pregnancy-related changes may mask true metabolic risk.
- Serum ALP is an emerging biomarker for GDM; increasing evidence shows that higher ALP levels are associated with increased GDM risk, potentially reflecting underlying hepatic or metabolic dysfunction. It is not yet part of routine screening and is best used alongside traditional predictors.

What is new in this study?

- Serum ALP outperformed traditional anthropometric predictors (BMI, WHR, age, and gestational age) in a multivariable model, challenging the prevailing assumption that anthropometry remains the strongest potential predictor of GDM at 24–28 weeks.

- Maternal BMI and WHR were not significantly association to GDM in this cohort, suggesting that mid-pregnancy anthropometric measures may lose potential predictive value due to physiological and placental changes—an underexplored explanation in prior studies.
- ALP independently associated to GDM even when conventional risk factors were controlled, supporting the idea that hepatic or placental metabolic markers may capture GDM risk not reflected by body size or fat distribution.
- The study provides population-specific evidence from a Filipino cohort, addressing a major gap in GDM prediction research, which is heavily dominated by Western and East Asian populations.
- By demonstrating that a single specimen collection, low-cost, routinely available laboratory marker (ALP) can identify GDM risk at the standard screening window, the study highlights a practical screening alternative for resource-limited settings, which is rarely emphasized in existing models.

INTRODUCTION

GDM is one of the most common metabolic disorders of pregnancy, with worldwide prevalence continuing to rise in parallel with increasing maternal age and obesity rates (WHO, 2021). GDM is associated with adverse maternal and neonatal outcomes, including hypertensive disorders, cesarean delivery, macrosomia, neonatal metabolic complications, and a higher risk of developing type 2 diabetes later in life for both the mother and child (ADA, 2024). In the Philippine clinical context, the Philippine Obstetrical and Gynecological Society (POGS, 2011) and the Philippine UNITE for Diabetes (2012) have recommended a 2-hour 75-g OGTT cutoff of ≥140 mg/dL, adapted from older WHO (1999) criteria is broadly used in many local clinical settings to identify abnormal glucose tolerance.

Maternal anthropometric indicators have consistently been implicated as major determinants of GDM risk. Increasing maternal age has long been recognized as a significant factor contributing to impaired glucose metabolism during pregnancy (ACOG, 2020). Measures of body composition, such as BMI and WHR, reflect metabolic load and fat distribution, both of which influence insulin resistance and pancreatic beta-cell function (WHO, 2020). Central adiposity, in particular, is strongly associated with metabolic dysfunction and is a known precursor of hyperglycemia in pregnancy. Additionally, the gestational age at which these parameters are measured may influence their potential predictive accuracy, given the dynamic physiological changes in weight, blood volume, and placental adaptation throughout pregnancy (Catalano & Shankar, 2017).

Beyond physical anthropometrics, biochemical markers have emerged as potential contributors to early prediction models. ALP, an enzyme that physiologically increases during pregnancy due to placental isoenzyme production, has been explored for its potential association with metabolic disturbances. Some findings suggest that alterations in ALP may reflect inflammation, insulin resistance, or placental dysfunction, all of which are implicated in the pathophysiology of GDM (Lain & Catalano, 2007). However, the evidence remains limited, and the association of ALP—especially when assessed alongside maternal anthropometric measures—has not been conclusively

established. Few studies have analyzed ALP in multivariable models combining both biochemical and physical risk indicators.

These gaps underscore the need to evaluate whether maternal age, gestational age at testing, BMI, WHR, and serum ALP levels can collectively be associated with GDM at diagnostic window. Such a multimodal potential predictive value approach may promote earlier risk stratification and targeted intervention, particularly in resource-limited settings. Therefore, this study aims to assess the association of these maternal factors for GDM diagnosed using a 2-hour OGTT > 140 mg/dL at 24–28 weeks of gestation. Through multivariable analysis, this research seeks to advance early identification strategies for women at increased risk of GDM and contribute to the growing literature on prenatal metabolic risk prediction.

METHODOLOGY

Design and Locale

This study aimed to evaluate the association of maternal anthropometric factors which includes maternal age, AOG which refers to the duration of pregnancy measured from the first day of the last normal menstrual period, expressed in completed weeks and days, BMI, WHR, and serum ALP levels for GDM diagnosed between 24 and 28 weeks of pregnancy. A multivariate research design was employed using a cross-sectional analytical framework. The study was conducted within a city in the province of Bulacan, Region III, Philippines, which serves a diverse population of pregnant women receiving routine prenatal care.

Research Sample

A total of 200 pregnant women between 24 and 28 weeks of gestation were recruited through purposive sampling in which the findings may not be fully generalizable to the broader population and may only be specific to the studied cohort. Inclusion criteria were 1) No known history of diabetes mellitus (type 1 or type 2), 2) No prior diagnosis of gestational diabetes in earlier pregnancies, 3) No chronic medical conditions that could affect glucose metabolism, and 4) Ability to provide informed consent. Pregnant women below or beyond 24-28 weeks of gestation, pre-existing metabolic or endocrine disorders, or incomplete laboratory or anthropometric measurements were excluded.

Data Collection

Maternal demographic and physical data were encoded, including maternal age and gestational age. Height was measured to the nearest 0.1 cm using a stadiometer, and weight was recorded to the nearest 0.1 kg using a calibrated digital scale. BMI was computed as weight in kilograms divided by height in meters squared (kg/m^2). Waist circumference and hip circumference were measured using a non-stretchable measuring tape; WHR was subsequently calculated. Venous blood samples were collected to determine serum ALP levels. All samples were processed in the same diagnostic

laboratory using standard enzymatic colorimetric methods with quality-controlled automated analyzers. Moreover, all participants underwent a standard 2-hour OGTT. After an overnight fast (8–12 hours), fasting blood glucose was collected. Participants were then instructed to ingest a 75-g oral glucose solution. The 2-hour post-load blood glucose value was measured; values greater than 140 mg/dL were classified as indicative of GDM for this study. The predictor variables assessed includes maternal age (years), AOG at testing (weeks), BMI (kg/m²), WHR, Serum ALP level (U/L) and the outcome variable is the diagnosis of GDM (binary: GDM vs. non-GDM), defined by 2-hour OGTT > 140 mg/dL.

Statistical Analysis

Data were encoded and analyzed using standard statistical software. The primary analysis utilized binary logistic regression to determine the association of the maternal anthropometric factors and ALP levels on the likelihood of developing GDM. Adjusted odds ratios (AOR), 95% confidence intervals (CI), and corresponding p-values were reported. A minimum sample size of 180 was estimated to achieve 80% statistical power to detect medium effect sizes (odds ratio ≈ 1.5) with five predictor variables in a logistic regression model at a significance level of $\alpha = .05$. This is to ensure that the study had sufficient ability to detect meaningful associations between the predictors and the outcome. The final sample of 200 participants exceeded this requirement, ensuring adequate statistical power for multivariable analysis. A significance level of $p < .05$ was used for all inferential statistics.

RESULTS

Table 1.

Descriptive Analysis of GDM and Non-GDM.

	f	%
GDM	53	26.50%
Non-GDM	147	73.50%
Total	200	100%

Out of the 200 pregnant women included in the study, 53 participants (26.5%) were diagnosed with GDM based on the OGTT results. Meanwhile, 147 participants (73.5%) did not develop GDM. This means that approximately 1 in every 4 pregnant women in the sample had GDM. The relatively high proportion suggests that GDM is a significant health concern in the studied population, highlighting the importance of early screening and identification of potential predictive factors.

Table 2.

Binary Logistic Regression Analysis of the Maternal Anthropometrics and ALP Levels in Predicting GDM.

Variable	Coefficient	Standard Error	p-value	Odds Ratio	95% Confidence Interval
Age	-0.0648	0.0445	0.1453	0.9373	(0.8590,1.0227)
AOG	0.0601	0.1579	0.7037	1.0619	(0.7792,1.4471)
BMI	0.0308	0.0704	0.6621	1.0312	(0.8984,1.1838)
WHR	-1.3058	5.0959	0.7978	0.271	(0.0000,5895.3093)
ALP	0.083	0.0128	0	1.0865	(1.0596,1.1141)
Constant	-9.0277	6.0433	0.1352		

Note: Chi-Square = 80.5153, df = 5, p-value = 0.0000

A logistic regression analysis was conducted to examine the effect of maternal age, AOG, BMI, WHR, and serum ALP on the likelihood of developing GDM. The overall model was statistically significant, $\chi^2(5) = 80.52$, $p < .001$, indicating that the set of predictors reliably distinguished between women with and without GDM.

Individually, ALP was the only significant potential predictor of GDM. Specifically, higher ALP levels were associated with increased odds of developing GDM (B = 0.083, SE = 0.013, $p < .001$, OR = 1.09, 95% CI [1.06, 1.11]). This finding suggests that for every one-unit increase in ALP, the odds of developing GDM increase by approximately 9%.

In contrast, maternal age (B = −0.065, SE = 0.045, p = .145, OR = 0.94, 95% CI [0.86, 1.02]), AOG (B = 0.060, SE = 0.158, p = .704, OR = 1.06, 95% CI [0.78, 1.45]), BMI (B = 0.031, SE = 0.070, p = .662, OR = 1.03, 95% CI [0.90, 1.18]), and WHR (B = −1.306, SE = 5.096, p = .798, OR = 0.27, 95% CI [0.00, 5895.31]) were not significant predictors of GDM. The odds ratios for these variables suggest minimal or highly uncertain effects on the likelihood of developing GDM, as reflected in the confidence intervals that include 1.

Overall, these results indicate that among the variables studied, serum ALP is a significant and positive predictor of GDM, while maternal age, gestational age, BMI, and WHR do not significantly contribute to predicting GDM in this cohort.

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DISCUSSION

In the present study, among maternal age, AOG, BMI, WHR, and serum ALP, only ALP emerged as a statistically significant associated to GDM, with higher ALP (>104 U/L) levels associated with increased odds of developing the condition (OR ≈ 1.09 per unit increase). The overall logistic regression model was significant, indicating that the set of predictors reliably distinguished between women who developed GDM and those who did not. These findings suggest that elevated maternal ALP may reflect underlying metabolic processes relevant to the pathogenesis of GDM, rather than traditional anthropometric or demographic risk factors in this cohort.

This conclusion aligns with recent evidence demonstrating that maternal liver function, including liver enzyme levels measured early in pregnancy, is associated with subsequent GDM risk. In a large prospective cohort among Chinese pregnant women, elevated ALP levels, even within clinically normal ranges, were associated with increased incidence of GDM (Xiong et al., 2019). Similarly, a prospective study reported that a composite liver function index, which includes ALP among other enzymes, was significantly associated with GDM risk (Zhang et al., 2024). These findings support the hypothesis that hepatic or hepatic-related metabolic alterations in early pregnancy may predispose women to GDM. Mechanistically, perturbed liver function could indicate subclinical hepatic stress, altered lipid metabolism, or early nonalcoholic fatty liver disease, all of which may impair insulin sensitivity or pancreatic β-cell compensation during pregnancy. Evidence also suggests that altered lipid metabolites may mediate a substantial proportion of the association between liver enzyme levels, including ALP, and GDM risk, providing a biologically plausible pathway for these observations (Wang et al., 2023).

However, the finding that anthropometric predictors such as BMI and WHR, as well as maternal age and AOG, were not significantly associated with GDM contrasts with a substantial body of literature that identifies these factors as major predictors. Numerous studies continue to emphasize that elevated pre-pregnancy BMI or maternal overweight/obesity are among the strongest modifiable risk factors for GDM, with central adiposity similarly implicated (ADA, 2023; Buchanan et al., 2020). The discrepancy may reflect several factors, including population characteristics, where limited variation in BMI or WHR reduces the ability to detect associations. Additionally, anthropometric measurements at a single time point may not capture dynamic changes in fat distribution or gestational weight gain, which could be more relevant for GDM risk. Furthermore, it is possible that in the study population, metabolic or hepatic factors, as indicated by ALP, play a more dominant role than adiposity in precipitating GDM, potentially due to genetic, ethnic, lifestyle, or environmental differences affecting liver metabolism. Sample size, measurement variability, and residual confounding may also have contributed to the non-significant associations for BMI, WHR, age, or AOG.

Moreover, the lack of pre-pregnancy or early first-trimester weight data may partially explain why BMI, WHR, and AOG at 24–28 weeks were not significant predictors of 2-hour OGTT values in this study. Most international guidelines, including those from the ADA and the ACOG, emphasize pre-pregnancy or early pregnancy BMI as a key risk stratification variable for GDM, as these

measurements more accurately reflect maternal adiposity and baseline metabolic risk. In contrast, anthropometric measurements obtained during mid-pregnancy are inherently confounded by physiological gestational changes, including fetal growth, placental mass, increased plasma volume, and amniotic fluid accumulation, which may obscure the independent contribution of maternal fat mass to glucose intolerance. As a result, BMI and WHR measured at 24–28 weeks may lack sufficient discriminatory power to predict post-load glucose levels during OGTT. This limitation suggests that the timing of anthropometric assessment is critical when evaluating their association for GDM and underscores the importance of early pregnancy or pre-conception data in metabolic risk assessment. Nonetheless, the present findings remain clinically relevant, as they reflect real-world screening conditions in many low- and middle-income settings where pre-pregnancy weight is often unavailable. Future studies should incorporate pre-pregnancy or first-trimester BMI, track gestational weight gain trajectories, and explore their combined potential predictive value alongside biochemical markers to better delineate maternal metabolic risk across pregnancy.

The recognition of liver biomarkers as predictors of GDM has important clinical implications. Standard GDM screening typically occurs at 24–28 weeks gestation, leaving a relatively narrow window for intervention. Early identification of women at elevated risk based on liver enzyme levels, even when anthropometric risk factors are unremarkable, could allow for earlier monitoring and preventive strategies. ALP measurement is relatively inexpensive and widely available, making it a practical candidate for early risk stratification.

Nevertheless, caution is warranted because ALP is a non-specific enzyme whose levels naturally rise during pregnancy, potentially reflecting placental, hepatic, or bone-derived sources rather than pathological processes alone. Even so, studies have demonstrated that “normal-range” ALP increases can still be association to GDM, although the specific isoenzyme source is often not differentiated (Wang et al., 2023). Additionally, while observational associations are robust, causality has not been definitively established. Mendelian randomization studies have suggested causal links between certain liver enzymes (e.g., ALT) and GDM, but evidence for ALP specifically remains limited (Zhang et al., 2024).

Overall, the study supports the growing body of evidence indicating that early-pregnancy liver enzyme levels, particularly ALP, may serve as useful predictors of GDM, independent of conventional anthropometric risk factors. These findings suggest that conceptual models of GDM risk should include metabolic and hepatic health alongside traditional obesity and demographic measures. Future research should replicate these findings in larger, more diverse cohorts, include longitudinal ALP measurements across pregnancy, differentiate ALP isoenzymes, integrate lipidomic and other metabolic biomarkers to elucidate underlying mechanisms, and explore the combined use of liver enzyme screening with traditional risk factors to enhance early detection and prevention strategies. Such efforts may refine risk stratification, guide timely interventions, and improve maternal and fetal outcomes in GDM.

This study has several limitations that should be considered when interpreting the findings. The results are based on a single cohort with a relatively modest sample size, which may limit generalizability to broader or more diverse populations. ALP was measured at only one time point during mid-pregnancy; thus, temporal changes in ALP levels across gestation and their relationship with GDM development could not be assessed. In addition, total serum ALP was analyzed without differentiation of specific isoenzymes, precluding determination of whether the observed association reflects placental, hepatic, or bone-derived sources. Other metabolic pathways potentially involved in GDM, such as lipidomic profiles and inflammatory biomarkers, were not evaluated. Consequently, the potential predictive value of ALP in combination with traditional risk factors warrants further investigation in larger, longitudinal studies to clarify underlying mechanisms and to determine its clinical utility for early risk stratification and prevention of adverse maternal and fetal outcomes.

CONCLUSION

In conclusion, although numerous studies have identified maternal anthropometric factors such as BMI, WHR, and age as significant predictors of gestational diabetes mellitus, this study found that these variables were not significantly associated with GDM in the studied cohort. These findings are most applicable to the specific group of pregnant women included in this study and should be interpreted within this context. Given the considerable ethnic, socioeconomic, and regional diversity of the Filipino population, the results may not fully represent all pregnant women nationwide. Lastly, among the predictors associated, only serum alkaline phosphatase demonstrated a significant relationship with GDM, suggesting that traditional anthropometric measures may not always be reliable indicators of risk in certain populations at 24-28 weeks of gestation.

RECOMMENDATIONS AND IMPLICATIONS

Clinical practice: Serum ALP may be considered as an adjunctive marker during routine mid-pregnancy assessments to help identify women at increased risk of GDM at diagnostic window, particularly when traditional anthropometric indicators such as BMI and WHR are inconclusive.

Screening strategies: Reliance solely on maternal anthropometric measures at 24–28 weeks may be insufficient for GDM risk stratification; integrating biochemical markers alongside standard OGTT screening could enhance detection of metabolically at-risk pregnancies.

Health policy: Given its low cost and wide availability, ALP testing could be explored as a feasible component of risk-based GDM screening protocols, especially in resource-limited settings where access to advanced metabolic testing is constrained.

Maternal health programs: The findings support a shift toward metabolic and hepatic health monitoring during pregnancy, encouraging prenatal care programs to move beyond body-size–based risk assessment and adopt more physiology-informed approaches.

Future research: Further large-scale and longitudinal studies are recommended to validate ALP as a potential predictive biomarker for GDM, examine trimester-specific changes, differentiate ALP isoenzymes, and evaluate combined prediction models incorporating liver enzymes with conventional maternal risk factors.

List of Abbreviations

GDM – Gestational Diabetes Mellitus
BMI – Body Mass Index
WHR – Waist-to-Hip Ratio
ALP – Alkaline Phosphatase
OGTT – Oral Glucose Tolerance Test
AOG – Age of Gestation
OR – Odds Ratio
AOR – Adjusted Odds Ratio
CI – Confidence Interval
SE – Standard Error
df – Degrees of Freedom
χ^2 – Chi-square statistic
WHO – World Health Organization
ADA – American Diabetes Association
ACOG – American College of Obstetricians and Gynecologists
IADPSG – International Association of Diabetes and Pregnancy Study Groups
NIH – National Institutes of Health

Declarations

Ethical approval and consent to participate

Ethical clearance was secured from the Institutional Research Ethics Committee of the Angeles University Foundation. Informed consent was obtained from all participants after explaining the purpose, procedures, and voluntary nature of their participation. Data confidentiality was maintained by assigning numerical codes instead of personal identifiers, and all collected data were used solely for academic and research purposes.

Consent for publication

All participants provided consent for the publication of anonymized data and findings derived from this study. No identifiable personal information is included in the manuscript.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. All data presented have been anonymized to ensure participant confidentiality.

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Competing Interests
The authors declare no conflicts of interest or competing interests related to this study. There is no financial relationship present in the study.

Author's contributions
JC drafted the protocol and RB analyzed all the data in this study. All authors read and approved the final manuscript.

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