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Association of Waist to Height Ratio and Waist Circumference to Glycated Hemoglobin in New Onset Type 2 Diabetes Mellitus in Blacks

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Abstract

Backgrounds: Anthropometric measurements play a vital role in clinical assessment, decision making and diagnosis.

Methods: This is a cross-sectional, case-controlled, multicenter study. A purposeful sampling technique was used to recruit 50 newly diagnosed type 2 DM subjects within 3 weeks of their diagnosis. Also, apparently healthy 50 non-diabetic with no significant medical history were recruited as controls. Waist Circumference (WC) was measured and Waist to Height Ratio (WHtR) was calculated.

Results: There were 32 males and 68 females, with Male: Female ratio of 1:2. A Multiple linear regression analysis model was not statistically significant, $F(2,97) = 0.884$, $p = .416$, with an R^2 of .018 and an adjusted R^2 of $-.002$. WC and WHtR jointly explained approximately 1.8% of the variance in glycated hemoglobin (HbA1c). The lowest mean of HbA1c was in the control group (5.4%), then total (general) population group (6.9%) while the new onset type 2 DM patients group had the highest (8.3%). WHtR was not a significant independent predictor ($B = 13.889$, $\beta = .393$, $p = .292$, 95% CI: -12.125 to 39.903) of HbA1c. A Sudanese study also reported no significant correlation between WHtR and HbA1c.

Conclusion: WC and WHtR decreases in size and number as we move from a cohort of new onset type 2 DM patient to the general population and then to a control group.

Keywords: Waist circumference; Waist to height ratio; Glycated hemoglobin; New onset type 2 diabetes mellitus

Introduction

Anthropometric measurements play a vital role in clinical assessment, decision making and diagnosis [1-4]. It is a simple but significant indices that furnishes clinical information that can be used as a surrogate marker of some internal composition of man [5-9]. Waist to height ratio is a surrogate marker of metabolic risk in the body [10,11]. It is easy to estimate in different setting both within and outside the health ecosystem making it a user-friendly measurement in the community and also easy for patients and all categories of health workers to estimate. The measurement gives more information than measuring height alone which will majorly give information on short stature and gigantism and their differential diagnosis [12-17].

Waist circumference measurement is an index measured with different landmark by different clinician. Some used the umbilicus as landmark of measurement while others use the lower boarder of the rib cage in full expiration for the measurement. The World Health Organization recommend the midpoint between the iliac crest and the lower boarder of the ribcage as landmark for measurement with the patient in erect position, the hand by the sides, the legs together, the patient on a light clothing with the arm by the sides [18-20]. Waist circumference as a clinical assessment has been recommended to be a routine measurement in clinical practice through a consensus statement by the International Atherosclerosis Society and International Chair on Cardio-metabolic Risk Working Group on Visceral Obesity [18].

Physiologically, because of body habitus, waist circumference is different between men and women with males having a bigger waist circumference measurement than women especially early in life and in premenopausal women matched for age with their male counterpart. The redistribution of fats in female post menopause causes increase in intra-abdominal fat post menopause and decreases subcutaneous fat in women [21,22] There is ethnic variability in waist circumference [23].

Due to westernization, the incidence and prevalence of type 2 diabetes mellitus is on the rise in Nigeria and most part of Africa [24]. This necessitates a need to study new onset type 2 diabetes mellitus in the context of African and Nigerian community setting. In a study in Port-Harcourt, River's state, Nigeria, among hypertensives and non-hypertensives, waist circumference was not statistically associated with glycated hemoglobin. The study only studied 11 newly diagnosed type 2 diabetes mellitus patients among the 400-patient studied to arrive at that finding. This sample size is small and needs further evaluation to cover that knowledge gap which this study attempts to cover [25].

What is the association between waist to height ratio and glycated hemoglobin in blacks with new onset type 2 diabetes mellitus? What is the association between waist circumference and glycated hemoglobin in new onset type 2 diabetes mellitus? Can WHtR be used as a surrogate marker of high glycated hemoglobin in new onset type 2 diabetes mellitus? Can waist circumference be used as a surrogate marker of high glycated hemoglobin in new onset type 2 diabetes mellitus? Which is a better surrogate marker, if any, between waist to height ratio and waist circumference to glycated hemoglobin in new onset type 2 diabetes mellitus?

Methods

This is a cross sectional, case-controlled multicenter study. A non- probability technique, purposeful sampling technique was used to recruit 50 newly diagnosed type 2 diabetes mellitus subjects out of which 47 subjects had glycated hemoglobin of 6.5% and above while 3 newly diagnosed type 2 diabetes mellitus patient had HbA1c less than 6.5% but meeting fasting blood sugar criteria of 126mg/dl for diagnosis of new onset type 2 diabetes mellitus. All the 50 subjects were within their first three weeks of their initial diagnosis. Also, 50 control participants who are apparently healthy with no significant medical history and not living with diabetes mellitus and has glycated hemoglobin less than 6.5% were recruited. This makes it a total of 100 participants in the study. Waist circumference was measured using World Health Organization criteria and waist to height ratio was calculated by dividing waist circumference in centimeters by height in centimeters. It is a multicenter study on new-onset type 2 diabetes mellitus patients attending healthcare in tertiary and secondary hospitals: Lagos State University Teaching Hospital, Ikeja, Lagos, (LASUTH) and General Hospital, Gbagada. Lagos, Nigeria. A questionnaire was used to extract necessary information from the

patients. The questionnaire was also used for data collection. The questionnaire is in three stages, section A collects demographic data including laboratory identifier number and hospital number, body weight, body height, waist circumference etc., excluding name. Section B collects laboratory parameters like value of blood sugar at diagnosis of new onset type 2 diabetes mellitus whether by point of care POC or laboratory analysis and also time testing was done was recorded. It also records, analytic value of HbA1c in percentages using gold standard of measurement of glycated hemoglobin, high performance liquid chromatography. Section C collects clinical information like type of diabetes, family history of type 2 diabetes mellitus, previous medical history and co-morbidity, type of glucose lowering agent patient is commenced on, if any, whether insulin, oral hypoglycemic agents or a combination of insulin and oral hypoglycemic agent and other relevant health history.

Glycated hemoglobin concentration estimation was done at Lagos State University Teaching hospital Laboratory. Point of care testing was through a brand-new glucometer that uses glucose oxidase as its active reagent in order to have a high sensitivity yield.

Research procedure includes collection through venipuncture of 5-7mls of venous whole blood in an Ethylenediaminetetraacetic Acid (EDTA) bottle and mixed with anticoagulant after which glycated hemoglobin estimation was done using high performance liquid chromatographic technique.

Inclusion and exclusion criteria

The inclusion criteria include new onset type 2 diabetes mellitus on pharmacologic therapy or not within 3 weeks of diagnosis with glycated hemoglobin of 6.5% and above. In addition, three new onset type 2 diabetes mellitus patients that does not have HbA1c value up to 6.5% but meet the American Diabetes Association fasting blood sugar level of 126mg/dl for diagnosis of new onset type 2 diabetes mellitus were recruited as subjects in this study to make up sample size of 50 subjects in the study that employs purposive sampling technique to recruit patient.

Exclusion criteria include new onset type 2 diabetes mellitus diagnosed by fasting blood sugar values without corresponding HbA1c equaling 6.5% or above (except the 3 patients mentioned above). New onset type 2 diabetes mellitus diagnosed by random blood sugar with values 200mg/dl and above but with glycated hemoglobin less than 6.5% were also excluded. Newly diagnosed type 2 diabetes mellitus of more than 3 weeks were excluded. Other exclusion criteria were non- diabetes hyperglycemia, previously diagnosed type 2 diabetes mellitus, gestational diabetes mellitus, maturity onset diabetes of the young MODY, Latent Autoimmune Diabetes of Adulthood (LADA), unconscious new-onset type 2 diabetes mellitus patient with confounding cause of unconsciousness,

Sample size

The sample size is 100 participants, 50 newly diagnosed type 2 diabetes mellitus and 50 apparently healthy non diabetics spread across the two centers.

Diagnosis of new-onset type 2 diabetes mellitus will be by fasting blood sugar of 126mg/dl or above, random blood sugar or by 2 hours post -prandial glucose measurement of 200mg/dl and above or by glycated hemoglobin value of 6.5% or above according to American Diabetes Association diagnostic criteria.

Ethical approval was obtained from the ethical committees of the two centers. Lagos State University Teaching Hospital (LASUTH) with reference number LREC/06/26/3114 and General Hospital Gbagada Lagos with reference number GBGH/750/VOL. IV/782.

The World Medical Association (WMA) Declaration of Helsinki as a statement of ethical principles for medical research involving human subjects, including research on identifiable human material and data was observed. A consent was duly obtained with signing of consent forms. The data was recorded in an excel sheet and stored in google drive file till sample size was completed. This data was later populated on SPSS version 26

for data analysis using descriptive statistics and multiple linear regression analysis.

Results

There were 100 participants, 32 males and 68 females, with an approximate male to female ratio of 1:2.

A multiple linear regression analysis was conducted to determine whether waist circumference and waist-to-height ratio were associated with glycated haemoglobin (HbA1c) in the total study population ($n = 100$). The overall regression model was not statistically significant, $F(2,97) = 0.884$, $p = .416$, with an R^2 of .018 and an adjusted R^2 of $-.002$. Thus, waist circumference and waist-to-height ratio jointly explained approximately 1.8% of the variance in HbA1c. Waist circumference was not a significant independent predictor of HbA1c ($B = -0.063$, $\beta = -.297$, $p = .425$, 95% CI: -0.219 to 0.093), while waist-to-height ratio was also not a significant independent predictor ($B = 13.889$, $\beta = .393$, $p = .292$, 95% CI: -12.125 to 39.903). Substantial multicollinearity was observed between waist circumference and waist-to-height ratio, as evidenced by a Pearson correlation of $r = .962$, tolerance of .074 and VIF of 13.561 for both predictors. Consequently, the individual regression coefficients should be interpreted with caution. See (Tables 1-6) and (Figures 1-3).

Table 1: Correlation between glycated hemoglobin, waist circumference, and waist to height ratio.

Correlations				
		Glycated Hemoglobin in Percentages	WC in centimeters	Waist in Centimeters Divided by Height in Centimeter
Pearson Correlation	Glycated hemoglobin in percentages	1.000	.081	.107
	WC in centimeters	.081	1.000	.962
	Waist in centimeters divided by height in centimeter	.107	.962	1.000
Sig. (1-tailed)	Glycated hemoglobin in percentages	.	.212	0.145
	WC in centimeters	.212	.	.000
	Waist in centimeters divided by height in centimeter	.145	.000	.
N	Glycated hemoglobin in percentages	100	100	100
	WC in centimeters	100	100	100
	Waist in centimeters divided by height in centimeter	100	100	100

Table 2: Multiple linear regression model summary ($n=100$).

Model Summary ^b									
					R Square Change	F Change	df1	df2	Sig. F Change
1	.134 ^a	.018	-.002	2.10791	.018	.884	2	97	.416

a: Predictors: (Constant), Waist in centimeters divided by height in centimeter, Waist Circumference in centimeters

b: Dependent Variable: Glycated hemoglobin in percentages.

Table 3: Two-way analysis of variance (ANOVA) for total population studied (n=100).

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.858	2	3.929	.884	.416 ^b
	Residual	430.998	97	4.443		
	Total	438.856	99			

a: Dependent Variable: Glycated hemoglobin in percentages.

b: Predictors: (Constant), Waist in centimeters divided by height in centimeter, waist circumference in centimeters.

Table 4: Coefficients table for the dependent (glycated hemoglobin) and independent variables (waist circumference and waist to height ratio) n=100.

Coefficients ^a										
Model B		Unstandardized Coefficients		Standardized Coefficients	t	Sig. Lower bound	95% confidence interval for B	95% confidence interval for B	Collinearity Statistics	Collinearity Statistics
		Std. Error	Beta				Upper bound	Tolerance	VIF	
1	(Constant)	4.876	1.964		2.483	0.015	0.979	8.773		
	WC in centimeters	-0.063	0.079	-0.297	-0.802	0.425	-0.219	0.093	0.74	13.561
	Weight in centimeters divided by height in centimeter	13.889	13.107	0.393	1.06	0.292	-12.125	39.903	0.74	13.561

a: Dependent Variable: Glycated hemoglobin in percentages.

Table 5: Table of collinearity diagnostics in the total population (n=100).

Collinearity Diagnostics ^a						
Model	Dimension	Eigenvalue	Condition Index	(Constant)	Variance Proportions	
1	1	2.992	1.000	.00	.00	.00
	2	.008	19.602	.99	.02	.02
	3	.00	81.966	.01	.98	.98

a: Dependent Variable: Glycated hemoglobin in percentages.

Table 6: Table of residual statistics of the total population (n=100).

Residuals Statistics ^a					
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	6.3105	7.6304	6.8867	0.28173	100
Residual	-4.11108	7.24298	.000	2.08651	100
Std. Predicted Value	-2.045	2.640	.000	1.000	100
Std. Residual	-1.95	3.436	.000	0.99	100

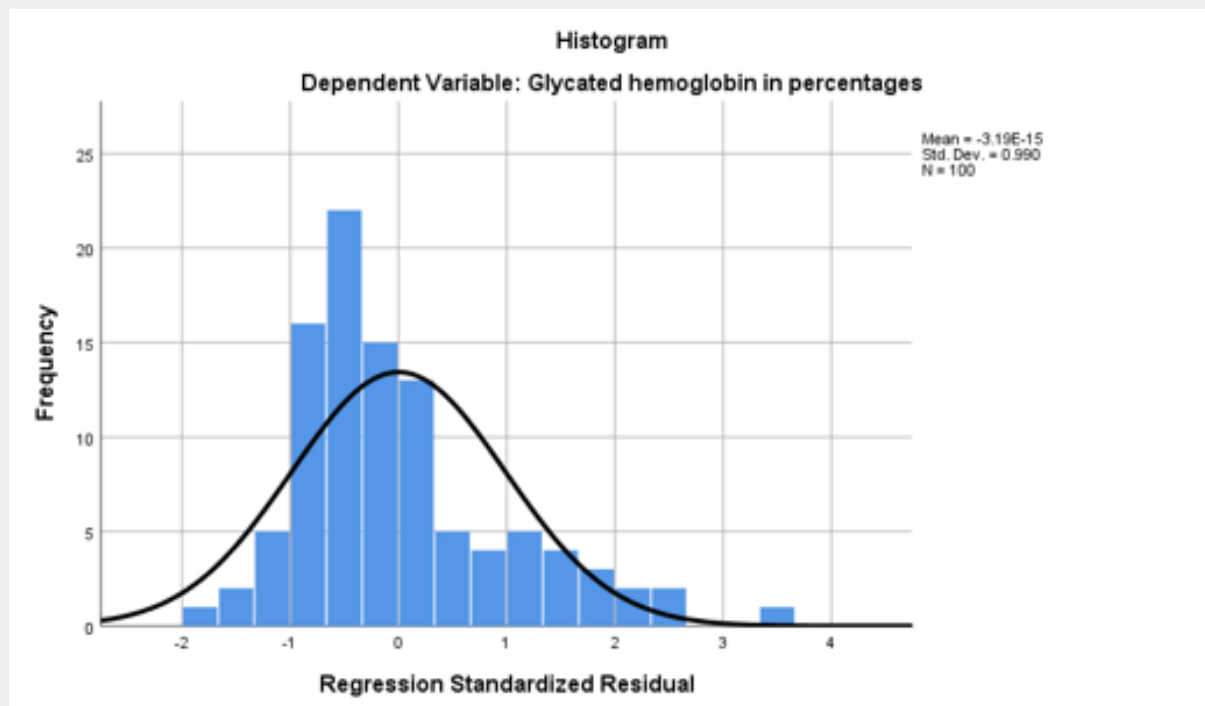


Figure 1: Histogram representation of the frequency of distribution of the dependent variable (Glycated hemoglobin) in the total population (n=100).

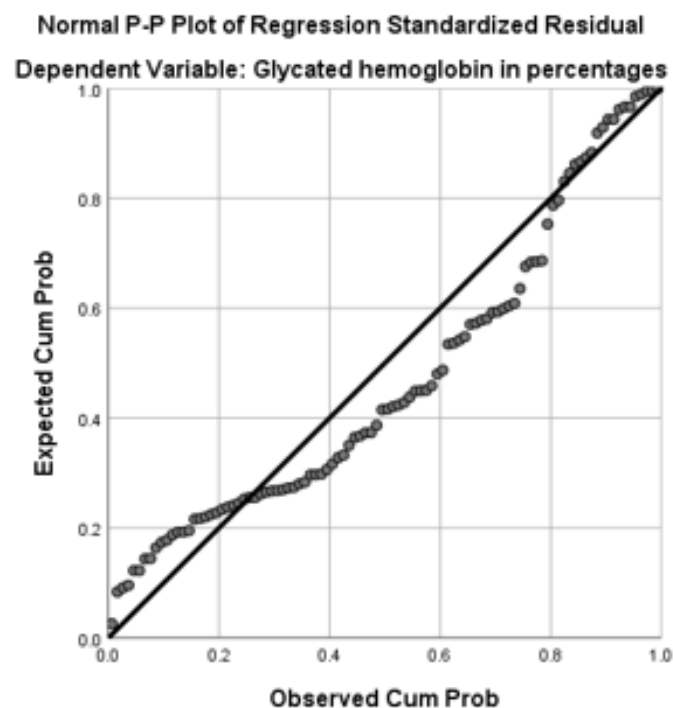


Figure 2: P_P plots of the dependent variable.

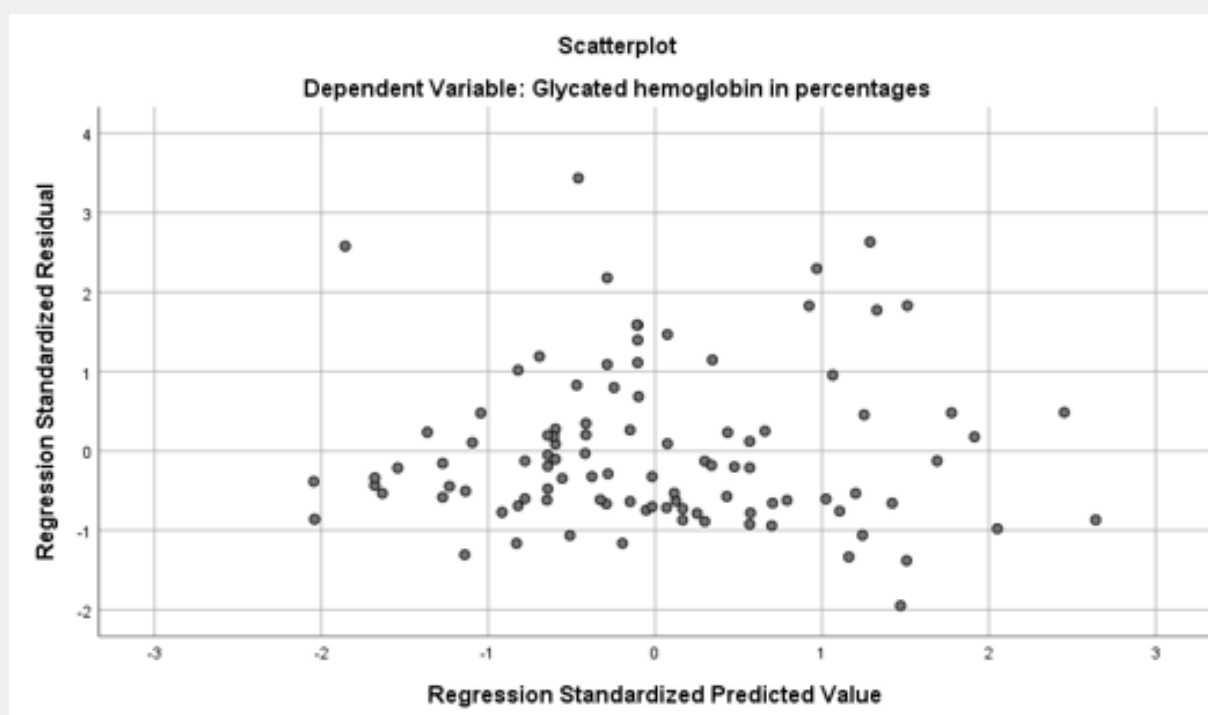


Figure 3: Scatter plots graph of the dependent variable glycated hemoglobin.

Multiple linear regression analysis was performed to determine whether waist circumference and waist-to-height ratio predicted glycated haemoglobin (HbA1c) among the 50 subjects. The overall regression model was not statistically significant, $F(2,47) = 0.679$, $p = .512$, with an R^2 of .028 and an adjusted R^2 of $-.013$. Thus, waist circumference and waist-to-height ratio jointly accounted for 2.8% of the variance in HbA1c. Waist circumference was not a statistically significant independent predictor of HbA1c ($B = -0.089$, $\beta = -.398$, $p = .385$, 95% CI: -0.293 to 0.115), while waist-to-height ratio was also not statistically significant ($B = 10.427$, $\beta = .267$, $p = .559$, 95% CI: -25.215 to 46.070). Substantial multicollinearity was observed between waist circumference and waist-to-height ratio ($r = .949$, $p < .001$; tolerance = .100; VIF = 9.967). Therefore, the individual regression coefficients should be interpreted with caution.

Among the 50 control participants, waist circumference was positively correlated with HbA1c ($r = 0.252$, $p = 0.039$), whereas waist-to-height ratio was not significantly correlated with HbA1c ($r = 0.213$, $p = 0.069$). However, when waist circumference and waist-to-height ratio were entered simultaneously into a multiple linear regression model, the overall model was not statistically significant, $F(2,47) = 2.124$, $p = 0.131$, $R^2 = 0.083$. Neither waist circumference ($\beta = 0.831$, $p = 0.172$) nor waist-to-height ratio ($\beta = -0.595$, $p = 0.325$) was an independent statistically significant

predictor of HbA1c. The interpretation of the individual regression coefficients is limited by severe multicollinearity between waist circumference and waist-to-height ratio ($r = 0.972$, VIF = 18.357, tolerance = 0.054).

Discussion

In a Chinese study of young and middle aged Chinese with early onset type 2 diabetes mellitus, the poor glycemic control group ($n=155$) with glycated hemoglobin equal to or greater than 7% had higher waist to height ratio compared to the good control group. Also, waist to height ratio correlated well with HbA1c in the Chinese study and after adjustment for confounders, waist to height ratio remained associated independently with glycated hemoglobin, there is ethnic variability compared to this study as participants are blacks compared to the Asian Chinese study. May be phenotypic, geographic, epigenetic reasons could account for these differences, but this was not tested in this study. A comparative study in waist to height ratio and its effect in blacks versus Asian population is suggested as a way forward. In this study in black, in new onset type 2 diabetes mellitus patients, waist to height ratio is negatively correlated to glycated hemoglobin and waist to height ratio did not show a significant association with glycated hemoglobin in blacks with new onset type 2 diabetes mellitus [26].

One difference between the black and Chinese study is that all the Chinese cases were early onset type 2 diabetes mellitus occurring in young and middle-aged subjects under 40 years, while this black study was in both early and late-stage type 2 diabetes mellitus that were new onset cutting across young, middle and elderly ages in African population.

Akarsu et al. Also found lower values for body mass index and waist hip ratio in the control group in their study. The European study showed a positive correlation between glycated hemoglobin and waist circumference and also demonstrate an independent strong association between HbA1c and waist circumference like the Chinese study by Shen et al. But being a cross-sectional study, the strong association between waist circumference and glycated hemoglobin by Akarsu et al could not be said to be causal [27].

In this study in blacks, the mean waist circumference was lowest in the control group (without type 2 diabetes population) followed by the waist circumference mean in the total (general) population comprising of control and new onset type 2 diabetes mellitus, while the highest mean of waist circumference was found between the new onset type 2 diabetes mellitus group. This finding was found similarly by Akarsu et al in 2026 working on an European population in Turkey, he found that waist circumference values were significantly lower in the control group of their study compared to the values in prediabetes and type 2 diabetes mellitus.

In a Sudanese study done in 2022 and published in 2025, also reported no significant correlation between waist to height ratio and glycated hemoglobin, though, the waist circumference significantly correlated with glycated hemoglobin in the study. The Sudanese study had 396 participants which is almost four times compared to 100 in this study, yet the finding of no significant association of waist to height ratio to glycated hemoglobin was the same [28].

The waist circumference median values were higher in the type 2 diabetes mellitus group (107) in the Sudanese study than in the non-diabetes mellitus group. Also in this study, the waist circumference mean value was highest in the new onset type 2 diabetes mellitus group with 90.6cm, followed by the waist circumference of the general population with value 88.9cm and then the control waist circumference with 87.3cm. Similarly, the waist to height ratio in this study was highest with the new onset type 2 diabetes mellitus group with 0.56, followed by the waist to height ratio of the general population of 0.55 and then that of the control, 0.54. Similarly the median values of the waist to height ratio was higher in the type 2 diabetes compared to non-type 2 diabetes group. The study concluded that body mass index, waist circumference and waist to height ratio had poor predictive value in detecting type 2 diabetes among Sudanese [28].

In a similar finding as waist circumference mean in this study in blacks, the lowest mean of glycated hemoglobin was

in the control group (5.4%), followed by the mean of glycated hemoglobin in the total (general) population consisting of control and subjects (6.9%) while the new onset type 2 diabetes mellitus patients had the highest mean of glycated hemoglobin which was (8.3%).

The finding in literature between association of waist circumference to glycated hemoglobin varies with the majority establishing an association between waist circumference and glycated hemoglobin, especially large studies. However, some reports also found no association between waist circumference and glycated hemoglobin just as is seen in this study. One major reason that can be adduced to this is the small sample size of this study. The small sample size in no way invalidates the larger study findings which put waist circumference as a predictor of glycated hemoglobin. The substantial multicollinearity between waist to height ratio and waist circumference is another reason why the analysis on effect of waist circumference on glycated hemoglobin variance could not be well delineated. Also, this was a cross-sectional study with a one-off measurement of waist circumference and glycated hemoglobin and not a longitudinal study that observes waist circumference in relation to glycated hemoglobin over time.

Though the association of waist circumference and waist to height ratio was not significant in both total population and subjects with glycated hemoglobin of new onset type 2 diabetes mellitus in this study, it explains more of variation in value of glycated hemoglobin in new onset type 2 diabetes mellitus patient than in the total (general) population studied.

In two large Asian cohort study in 2025 by Wang et al. ,The study included 14,468 participants from NAGALA and 8,978 participants from CHARLS who were followed up for 13 years, the researchers developed an indicator for waist-to-height-HbA1c (WHH) indicator and then compared it to body mass index, waist to height ratio and glycated hemoglobin, it was found that higher WHH was found to be associated with incident diabetes though the relationship was not linear [29].

Nathan et al. too in 2007 describe the relationship between glycated hemoglobin and mean glucose level over time to be curvilinear [30].

In addition, WHH has been found to demonstrate superior predictive performance for stroke than waist to height ratio and glycated hemoglobin [31].

In a relatively large male cohort study in South Korea, the group with high waist to height ratio was noticed to have high glycated hemoglobin compared to group with low waist to height ratio with significant positive correlation with glycated hemoglobin [32].

In 2025, Huang et al demonstrated in a large European population of 7,979 followed up for a median of 16 years that

among five adiposity-based indicators involving body mass index, waist circumference, waist to height ratio, waist-by-height 0.5 (WHT.5R) and a body shape index (ABSI), waist-based indicators were superior to body mass index in identifying diabetes. High waist to height ratio also had the highest multivariable-adjusted hazard ratio [2.64 (95 % CI 2.29, 3.03)]. The study hypothesizes that waist to height ratio with a sex and race-independent cut-point may be useful for diabetes prevention [33].

A national trend in type 2 diabetes mellitus was described among south Koreans between 2005-2022 by stratification using central obesity and waist to height ratio with data from the Korea National Health and Nutrition Examination Survey KNHANES (2005-2022). The study involving 79,368 participants had groups of healthy central adiposity group and increased central adiposity group and high central adiposity group. All the 3 groups experienced increase in the prevalence of type 2 diabetes mellitus over the study period with the high central adiposity group recording most cases of incident type 2 diabetes [34].

The healthy central adiposity group experienced an increase in prevalence from 3.3% to 5.8%. The increased central adiposity group had an increase of diabetes prevalence from 11.2 to 17.1% while the high central adiposity group had an increase from 18% to 26.7%. The high adiposity group had more susceptibility to develop type 2 diabetes in the overweight and obese participants in their group than those that were underweight. In Nigeria, there is a need to determine the susceptibility of Nigerian to develop type 2 diabetes mellitus by using waist to height ratio which is an easy to use, cost effective and less manpower training requiring parameter to national advantage. Having such data will help economic and budget planning, policy formulation and appropriate prevention of economic loss through type 2 diabetes mellitus which affects the working class of the Nigerian economy [34].

In an American study, four indices were found to be useful in predicting cardiovascular disease ability which are waist circumference, Waist to Height Ratio (WHTR), waist divided by height 0.5 (WTH.5R), and Weight-Adjusted Waist Index (WWI) and of these waist to height ratio has the highest predictive application [35].

In the pediatric age group study of 12,318 Indian children, it was reported that waist to height ratio was the strongest determinant of development of prediabetes and diabetes in children and adolescent aged 10 to 19 years in a national nutrition survey using machine learning algorithm [36].

Conclusion

Waist circumference and waist to height ratio decreases in size and number as we move from a cohort of new onset type 2 diabetes mellitus patient to the general population and then to a cohort without new onset type 2 diabetes mellitus. Both waist

circumference and waist to height ratio are not independent predictors of glycated hemoglobin in general population, control and new onset type 2 diabetes mellitus cohorts.

Data Availability: Some or all datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Acknowledgement: I thank all the patients that participated in the study without which the study will not be possible.

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and/or with the Helsinki Declaration of 1964 and later versions. Informed consent or substitute for it was obtained from all patients for being included in the study.

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