Adiposity, Disease Duration, and Atherogenic Indices as Predictors of Cardiometabolic Risk in Adults with Type 2 Diabetes

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DOI: https://dx.doi.org/10.51244/IJRSI.2026.1304000248

Received: 16 April 2026; Accepted: 21 April 2026; Published: 19 May 2026

ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is a major driver of cardiovascular disease, with rising burden in Nigeria. Limitations of conventional adiposity measures and inconsistent performance of atherogenic indices necessitate evaluation of more reliable predictors of cardiometabolic risk.

Objective: To evaluate the inter-play between visceral adiposity indices, atherogenic indices, and selected clinical factors in assessing cardiometabolic risk among Nigerian adults with T2DM.

Methods: A cross-sectional analytical study was conducted using routinely collected data from adults attending monthly screenings of the Diabetes Association of Nigeria. Sociodemographic, anthropometric, and biochemical data were obtained. Adiposity (BMI, VAI, LAPi) and atherogenic indices (AIP, Castelli's indices, atherogenic coefficient) were computed. Descriptive statistics and multiple linear regression analyses were performed ($p < 0.05$).

Results: Significant sex differences were observed, with obesity being more prevalent in females and overweight in males. Regression models showed modest explanatory power ($R^2 = 0.07–0.15$). Age and sex were consistently and significantly associated with atherogenic indices, while BMI was significantly associated with AIP only. Duration of diabetes and occupation were not significant predictors.

Conclusion: Cardiometabolic risk is modestly explained by demographic factors, with limited contribution from clinical variables. Improved, context-specific risk markers are needed.

Keywords: Type 2 diabetes mellitus; cardiometabolic risk; visceral adiposity index; atherogenic index of plasma; obesity; Nigeria; risk prediction.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major driver of cardiovascular disease globally, with increasing burden in Nigeria and other low- and middle-income countries. Accurate cardiometabolic risk assessment is essential for early detection and prevention of complications. Emerging evidence suggests that visceral adiposity indices, including visceral adiposity index (VAI) and lipid accumulation product (LAPi), outperform body mass index in capturing metabolic dysfunction (Briggs & Sheudeen, n.d.). Waist-to-hip ratio shows stronger cardiovascular prediction than conventional anthropometry (Azeez, n.d.; Qiao et al., 2022). Atherogenic index of plasma shows inconsistent independent predictive value (Ding et al., 2021). Diabetes duration remains poorly understood.

Despite growing use of adiposity and atherogenic indices for cardiometabolic risk assessment in T2DM, no consensus exists on optimal markers for Nigerian populations. BMI inadequately reflects visceral adiposity, while visceral Adiposity Indices (VAI, LAPi), and atherogenic Index of Plasma (AIP) show inconsistent predictive validity after adjustment (Briggs & Sheudeen, n.d.; Ding et al., 2021) and diabetes duration. This study aimed to evaluate the predictive roles of visceral adiposity indices, atherogenic indices, and selected

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

clinical factors in assessing cardiometabolic risk among individuals with type 2 diabetes mellitus in a Nigerian population.

METHODOLOGY

This study employed a cross-sectional analytical design using routinely collected clinical data to evaluate adiposity, disease duration, and atherogenic indices as predictors of cardiometabolic risk among adults with type 2 diabetes mellitus (T2DM). Data were obtained from monthly screening sessions of the Diabetes Association of Nigeria, where individuals with diabetes undergo routine health assessments. The study population included adults (≥18 years) with confirmed T2DM. Participation in screening was voluntary, and data were collected as part of ongoing clinical monitoring. Individuals with incomplete records or conditions likely to affect lipid metabolism, including pregnancy or acute illness, were excluded.

Data were extracted from standardized clinical records and comprised sociodemographic variables (age, sex, occupation), clinical characteristics (duration of diabetes, treatment history), and anthropometric measurements. Body weight and height were measured to compute body mass index (BMI), while waist and hip circumferences were obtained to assess central adiposity. Biochemical parameters were derived from fasting (8–12 hours) blood samples and included fasting blood glucose (FBG), total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C).

Adiposity and atherogenic indices were calculated using established formulas, including BMI, atherogenic index of plasma (AIP), Castelli's Risk Indices I and II (TC/HDL-C and LDL-C/HDL-C), and atherogenic coefficient (AC). Visceral adiposity index (VAI) and lipid accumulation product index (LAPi) were computed using sex-specific equations. Cardiometabolic risk, assessed via atherogenic indices, served as the primary outcome, while demographic and clinical variables were treated as predictors.

Descriptive and inferential statistics were applied, including graphs, t-tests, ANOVA, and chi-square tests. Multiple linear regression analyses identified independent predictors, with model fit assessed using R^2 and adjusted R^2 ($p < 0.05$). Ethical guidelines were followed, and all data were anonymized prior to analysis.

RESULTS

Figure 1 demonstrates marked sex differences in BMI distribution. Overweight is most prevalent and predominantly observed in males, whereas obesity is disproportionately higher in females. Normal BMI is more common among males, and underweight is rare in both sexes. Overall, the pattern indicates a shift toward higher BMI categories with clear sex-specific disparities.

Table 1 reveals significant sex-based differences across key variables. Age distribution differed markedly, with females predominantly <60 years and males >60 years ($\chi^2 = 54.83$, $p < 0.0001$). Duration of diabetes showed no significant sex variation in either categorization ($p = 0.65$; $p = 0.97$). Vocation varied significantly ($\chi^2 = 91.65$, $p < 0.0001$), with males more frequently pensioners and females' civil servants. BMI was strongly associated with sex ($\chi^2 = 97.42$, $p < 0.0001$), with overweight more common in males and obesity in females. Fasting blood glucose also differed ($\chi^2 = 56.33$, $p < 0.0001$), with poorer glycaemic control more prevalent among females.

Tables 2a–c show that the regression model has modest explanatory power ($R = 0.38$; $R^2 = 0.15$; adjusted $R^2 = 0.14$) with low prediction error (SEE = 0.26). The model is statistically significant ($F = 17.95$, $p < 0.001$), indicating that the predictors jointly influence the atherogenic index of plasma. However, a substantial proportion of variability remains unexplained. Sex and age are strong negative predictors ($\beta = -0.24$ and -0.37, respectively; $p < 0.001$), while BMI is a significant positive predictor ($\beta = 0.13$, $p = 0.001$). Duration of diabetes, occupation, and fasting blood glucose are not significant predictors.

Tables 3a–c indicate that the regression model demonstrated modest explanatory power ($R = 0.29$; $R^2 = 0.08$; adjusted $R^2 = 0.07$) with moderate prediction error (SEE = 4.18). The model is statistically significant ($F = 9.52$, $p < 0.001$), confirming that the predictors jointly influence the atherogenic coefficient, although much of the variability remains unexplained. Age and sex are the only significant independent predictors, both showing

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

negative associations (β = −0.32, p < 0.001; β = −0.11, p = 0.01). Fasting blood glucose shows a non-significant trend, while duration of diabetes, occupation, and BMI are not significant predictors.

The regression model demonstrated a modest association between predictors and Castelli's Risk Index I (R = 0.29), explaining 8.3% of the variance (adjusted $R^2 = 0.07$) with acceptable stability (tables 4a-c). Despite being statistically significant (F = 9.52, p < 0.001), a substantial proportion of variability remained unexplained. Among the predictors, only age (β = −0.316, p < 0.001) and sex (β = −0.108, p = 0.010) were independently associated with the outcome, both showing negative relationships. Other variables, including duration of diabetes, occupation, BMI, and fasting blood glucose were not significant predictors. Overall, demographic factors appeared to exert greater influence on Castelli's Risk Index I than the clinical variables examined.

In tables 5a-c, the regression model demonstrated a modest association with Castelli's Risk Index II (R = 0.27), explaining 7.5% of the variance (adjusted $R^2 = 0.066$), with acceptable model stability and moderate dispersion (SEE = 3.91). Although statistically significant (F = 8.53, p < 0.001), most variability remained unexplained. Age (β = −0.302, p < 0.001), sex (β = −0.114, p = 0.007), and fasting blood glucose (β = −0.091, p = 0.038) were significant independent predictors, all showing negative associations. Duration of diabetes, occupation, and BMI were not significant. Overall, demographic factors and glycaemic status were more influential than other clinical variables.

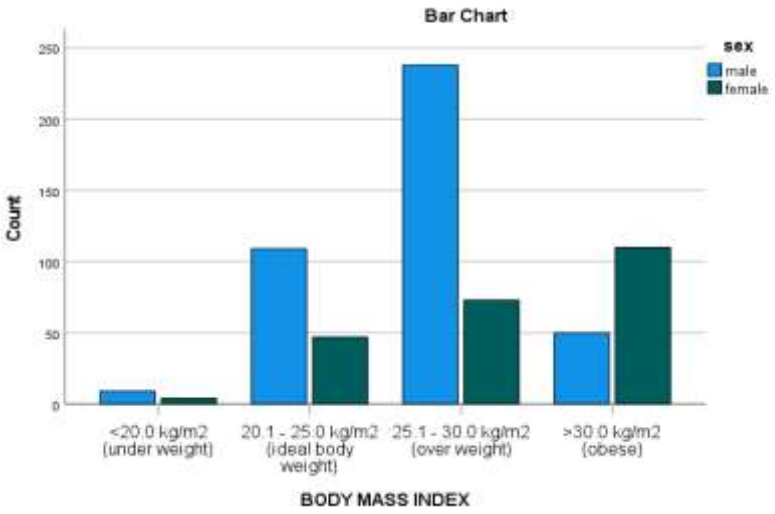

Figure 1. Distribution of body mass index (BMI) categories by sex among study participants.

Table 1. **Socio-demographic and clinical characteristics of study participants by sex.**

	Male	**Female**	**Total**	**χ^2**	**p-value**
Age range				54.83	<0.0001
<60 years	238 (58.6%)	203 (86.8%)	441 (68.9%)		
>60 years	168 (41.4%)	31 (13.2%)	199 (31.1%)		
Duration of Diabetes				1.66	0.65
<5 years	98 (24.1%)	48 (20.5%)	146 (22.8%)		
5-10 years	146 (36.0%)	93 (39.7%)	239 (37.3%)		
11-15 years	87 (21.4%)	47 (20.1%)	134 (20.9%)		
>15 years	75 (18.5%)	46 (19.7%)	121 (18.9%)		

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Duration of Diabetes				0.002	0.97
<10 years	244 (60.1%)	141 (60.3%)	385 (60.2%)		
> 10 years	162 (39.9%)	93 (39.7%)	255 (39.8%)		
VOCATION				91.65	<0.0001
Business	165 (40.6%)	100 (42.7%)	265 (41.4%)		
Clergy + Artisans	29 (7.1%)	19 (8.1%)	48 (7.5%)		
Civil Servant	59 (14.5%)	96 (41.0%)	155 (24.2%)		
Pensioner	153 (37.7%)	19 (8.1%)	172 (26.9%)		
Body Mass Index				97.42	<0.0001
<20.0 kg/m^2	9 (2.2%)	4 (1.7%)	13 (2.0%)		
20.1 - 25.0 kg/m^2	109 (26.8%)	47 (20.1%)	156 (24.4%)		
25.1 - 30.0 kg/m^2	238 (58.6%)	73 (31.2%)	311 (48.6%)		
>30.0 kg/m^2	50 (12.3%)	110 (47.0%)	160 (25.0%)		
Fasting Blood Glucose Levels				56.33	<0.0001
<3.3 mmol/L	7 (1.7%)	0 (0.0%)	7 (1.1%)		
3.3 - 6.0 mmol/L	180 (44.3%)	93 (39.7%)	273 (42.7%)		
6.1 - 6.9 mmol/L	63 (15.5%)	0 (0.0%)	63 (9.8%)		
>7.0 mmol/L	156 (38.4%)	141 (60.3%)	297 (46.4%)		

Table 2a. **Model summary of the multiple linear regression analysis examining predictors of the atherogenic index of plasma.**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.38[a]	0.15	0.14	0.26
a. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age				

Table 2b. **Analysis of variance (ANOVA) for the multiple regression model predicting the atherogenic index of plasma.**

Model		Sum of Squares	df	Mean Square	F	p-value
1	Regression	7.31	6	1.22	17.95	<0.0001[b]
	Residual	42.97	633	0.07		

	Total	50.28	639			

a. Dependent Variable: atherogenic index of plasma

b. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age

Table 2c. **Multiple linear regression coefficients for predictors of the atherogenic index of plasma.**

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
	(Constant)	0.773	0.125		6.21	<0.0001
	Sex	-0.140	0.024	-0.241	5.94	<0.0001
	Age (years)	-0.014	0.002	-0.371	8.27	<0.0001
	Duration of Diabetes (years)	0.001	0.002	0.024	0.59	0.55
	Vocation	0.000	0.009	-0.001	0.02	0.99
	BMI (Kg/m^2)	0.009	0.003	0.129	3.19	0.001
	Fasting blood glucose (mmol/L)	0.001	0.003	0.008	0.18	0.86

a. Dependent Variable: atherogenic index of plasma

Table 3a. Model summary of the multiple linear regression analysis for the specified atherogenic coefficient.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	0.29	0.08	0.07	4.18

a. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age

Table 3b. Analysis of variance (ANOVA) for the multiple regression model predicting the atherogenic coefficient.

Model		Sum of Squares	df	Mean Square	F	p-value
1	Regression	998.921	6	166.487	9.524	0.000[b]
	Residual	11064.751	633	17.480		
	Total	12063.672	639			

a. Dependent Variable: Atherogenic coefficient

b. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age

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Table 3c. **Multiple linear regression coefficients for predictors of the atherogenic coefficient.**

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**p-value**
		B	**Std. Error**	**Beta**		
1	(Constant)	18.620	1.998		9.32	<0.0001
	Sex	-0.974	0.379	-0.108	2.57	0.01
	Age (years)	-0.178	0.026	-0.316	6.80	<0.0001
	Duration of Diabetes (years)	-0.001	0.025	-0.002	0.04	0.97
	Vocation	-0.023	0.141	-0.007	0.16	0.87
	BMI (Kg/m^2)	-0.003	0.046	-0.003	0.07	0.94
	Fasting blood glucose (mmol/L)	-0.084	0.050	-0.074	1.69	0.09
a. Dependent Variable: Atherogenic coefficient						

Table 4a. Model summary of the multiple linear regression analysis for predictors of the Castelli's Risk Index I.

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	0.29[a]	0.08	0.07	4.18
a. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age				

Table 4b. **Analysis of variance (ANOVA) for the multiple regression model predicting Castelli's Risk Index I.**

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**
1	Regression	998.921	6	166.487	9.52	<0.0001[b]
	Residual	11064.751	633	17.480		
	Total	12063.672	639			
a. Dependent Variable: Castelli's risk index 1						
b. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age						

Table 4c. **Multiple linear regression coefficients for predictors of Castelli's Risk Index I.**

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**p-value**
	B	**Std. Error**	**Beta**		

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1	(Constant)	19.620	1.998		9.82	<0.0001
	Sex	-0.974	0.379	-0.108	2.57	0.01
	Age (years)	-0.178	0.026	-0.316	6.80	<0.0001
	Duration of Diabetes (years)	-0.001	0.025	-0.002	0.04	0.97
	Vocation	-0.023	0.141	-0.007	0.16	0.87
	BMI (Kg/m^2)	-0.003	0.046	-0.003	0.07	0.94
	Fasting blood glucose (mmol/L)	-0.084	0.050	-0.074	1.69	0.09
a. Dependent Variable: Castelli's risk index 1						

Table 5a. **Model summary of the multiple linear regression analysis for predictors of Castelli's risk index II**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.274[a]	0.075	0.066	3.91
a. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age				

Table 5b. **Analysis of variance (ANOVA) for the multiple regression model predicting Castelli's Risk Index II.**

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**
1	Regression	782.912	6	130.485	8.53	<0.0001[b]
	Residual	9683.222	633	15.297		
	Total	10466.134	639			
a. Dependent Variable: Castelli's risk index 2						
b. Predictors: (Constant), fasting blood glucose, dm duration, vocation, sex, BMI, age						

Table 5c. Multiple linear regression coefficients for predictors of Castelli's Risk Index II.

Model		Unstandardized Coefficients		Standardized Coefficients	t	p-value
		B	Std. Error	Beta		
1	(Constant)	17.048	1.869		9.12	<0.0001
	sex	-0.956	0.355	-0.114	2.69	0.007
	Age (years)	-0.159	0.025	-0.302	6.48	<0.0001
	Duration of Diabetes (years)	0.002	0.023	0.004	0.09	0.93

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	Vocation	0.003	0.132	0.001	0.02	0.98
	BMI (Kg/m^2)	-0.012	0.043	-0.012	0.27	0.79
	Fasting blood glucose (mmol/L)	-0.096	0.046	-0.091	2.08	0.04
a. Dependent Variable: Castelli's risk index 2						

DISCUSSION

Sex-related differences in cardiometabolic risk among individuals with diabetes are well documented, with adiposity emerging as a consistent distinguishing factor. Across diverse populations, females with diabetes tend to exhibit higher body mass index (BMI) and greater prevalence of obesity compared to males. This pattern is evident from adolescence through adulthood; for example, adolescent females with type 1 diabetes demonstrate higher rates of overweight/obesity and more adverse lipid profiles, alongside greater clustering of cardiovascular risk factors (Vuralli et al., 2023). Similarly, adult cohorts with type 2 diabetes report higher mean BMI among women despite comparable glycaemic indices, although women are often less likely to achieve recommended glycaemic and lipid targets (Du et al., 2016). However, sex differences in glycaemic control remain inconsistent, with some studies reporting poorer control among females and others showing worse indices in males, underscoring the influence of contextual and population-specific factors (Licata et al., 2023; Rentsch et al., 2023).

Sex and age also contribute to variability in atherogenic risk, although their roles are not uniformly defined. Evidence suggests that men may exhibit more adverse lipid and atherogenic profiles, including elevated triglycerides, LDL cholesterol, and composite indices such as the triglyceride–glucose (TyG) index and visceral adiposity index (VAI), indicating sex-specific metabolic risk patterns (Rentzeperi et al., 2022). Conversely, women with dysglycaemia are frequently older and present with a higher burden of comorbidities, complicating the interpretation of age-related trends in atherogenic indices (de Jong et al., 2020; Clair et al., 2023). Notably, there is no consistent evidence supporting a uniform inverse relationship between age and atherogenic markers across populations.

Although direct associations between BMI and the atherogenic index of plasma (AIP) are not consistently reported, substantial evidence links increased adiposity to adverse lipid profiles and insulin resistance. Higher BMI is associated with elevated LDL cholesterol, triglycerides, and surrogate indices of metabolic dysfunction, supporting the role of adiposity in promoting atherogenic states (Vuralli et al., 2023; Rentzeperi et al., 2022; Du et al., 2016). Furthermore, obesity appears to partially mediate sex differences in cardiovascular risk, reinforcing its importance as a modifiable determinant (Clair et al., 2023).

The relative contributions of demographic and clinical factors to cardiovascular risk remain an area of ongoing debate. While demographic variables such as sex and age often identify high-risk groups, their apparent effects are frequently attenuated after adjustment for modifiable clinical and lifestyle factors, including obesity, treatment patterns, and risk-factor control (Vuralli et al., 2023; Clair et al., 2023). Differences in management and therapeutic outcomes between sexes further contribute to observed disparities (de Jong et al., 2020; Du et al., 2016). Thus, demographic characteristics may serve as markers of risk, whereas clinical variables play a central mediating role in determining cardiometabolic outcomes.

Evidence from Nigerian cohorts aligns with global patterns, particularly regarding sex differences in adiposity. Multiple studies consistently report higher prevalence of overweight, generalized obesity, and central adiposity among females with type 2 diabetes, often accompanied by higher levels of physical inactivity (Ayodele et al., 2024; Balogun et al., 2018; Kasimu & Rahman, 2019; Ikoyo et al., 2025). However, as observed globally, sex differences in glycaemic control are heterogeneous, with some studies identifying female sex as being associated with poor control and others reporting worse outcomes among males or no significant differences (Abonyi et al., 2026; Gezawa et al., 2019).

Sociodemographic variables such as age and occupation show some sex-based variation but limited consistent associations with metabolic outcomes in Nigerian populations. Women are often represented in middle-aged and self-employed groups and may exhibit higher adiposity and blood pressure levels (Gezawa et al., 2019). Importantly, diabetes duration appears to have limited influence on key metabolic indices, including BMI, visceral adiposity index, leptin, and glycaemic measures, suggesting that cardiometabolic abnormalities may persist irrespective of disease duration (Ikoyo et al., 2025).

With respect to atherogenic risk, available Nigerian evidence indicates contributions from both demographic and clinical variables, though findings remain inconsistent. Some studies report associations between male sex and higher AIP, while others demonstrate significant relationships between adiposity indices and insulin resistance or dyslipidaemia, supporting a link between obesity and atherogenic risk (Gezawa et al., 2019; Mba et al., 2026). Nevertheless, direct and consistent evidence linking BMI to AIP is limited. Similarly, while HbA1c correlates with adverse lipid profiles, the independent contribution of fasting blood glucose (FBG) to atherogenic indices is not well established (Abonyi et al., 2026; Mba et al., 2026).

Finally, the explanatory power of regression models in predicting cardiometabolic risk remains insufficiently characterized, particularly in Nigerian studies. Although multivariable regression approaches are commonly employed, many studies do not report standardized model fit indices such as R^2, limiting the ability to assess predictive performance and compare findings across populations (Gezawa et al., 2019; Abonyi et al., 2026). In all, both global and Nigerian evidence highlight the complex interplay between demographic and clinical factors in shaping cardiometabolic risk, with adiposity emerging as a central and modifiable determinant.

CONCLUSION

Cardiometabolic risk in diabetes reflects a complex interplay of sex, adiposity, and clinical factors. Adiposity such as central obesity, has emerged as a key modifiable driver of sex disparities, with women showing higher BMI and men often exhibiting more adverse atherogenic profiles. However, the independent roles of sex and age are inconsistent. Nigerian data mirror global trends but reveal heterogeneity and limited predictive utility of conventional indices such as BMI and AIP. Diabetes duration appears to have minimal influence on metabolic risk. These findings highlight the need for context-specific markers and validated composite indices. Clinically, prioritising obesity control and risk-factor management is essential to reduce cardiometabolic burden.

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ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue IV April 2026

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