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Somatotype and its Associated Factors Among Nigerian Type 2 Diabetes: A Preliminary Study

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ABSTRACT

Even though the somatotype gives a gestalt summary of the body physique and composition, by extension, a morphological marker of a predisposition to various illnesses, the somatotype and associated factors in Nigerian type 2 diabetes mellitus (T2DM) have not been fully explored. This study aimed to provide new information on the somatotype and its associated factors in a sample of patients with T2DM in Nigeria. The sample population comprised 40 males and 50 females with confirmed T2DM, aged 30-65, randomly selected and recruited for the study. Blood biochemical parameters, blood pressure and other covariates were collected from the subjects who met the inclusion criteria, and subsequently, they were somatotyped using the Heath and Carter method. In the T2DM patients, mean somatotypes: were 5.8-4.9-0.6 (mesomorphic endomorph) in females and mean somatotype: was 4.3-4.6-1.1 (endomorphic mesomorph) in the males and were statistically different ($F = 5.58$, $P = 0.021$). In this study, gender, level of education, occupation, T2DM disease duration, HbA1c, hypertension, total cholesterol, triglyceride, body mass index (BMI) and physical activities were significant predictors of endomorphy and mesomorphy ($p<0.050$). However, only BMI was a significant predictor of ectomorphy ($p<0.050$). The present study found endomorphic and mesomorphic somatotypes as the dominant and high-risk in Nigerian T2DM. Thus, the duo and their predictors should be considered when developing an effective type 2 diabetes health prevention and promotion program in Nigeria.

Keywords: ***Endomorphy, Mesomorphy, Ectomorphy, Diabetes, Nigeria***

INTRODUCTION

Diabetes mellitus (DM) is one of the century's most significant global health issues, with an exponential rise in prevalence [1]. DM affects around 20 million people in Africa, which is predicted to more than double in the next two decades, posing a significant danger to Africa's already achieved socioeconomic accomplishments [2]. The raw national diabetic prevalence in Nigeria was estimated to be 4.99 per cent [2], and it is frequently linked to a high disease, social, and financial burden. According to experts, the primary cause of this condition is a shift in lifestyle caused by urbanization and capitalization [3], as well as a change from home-cooked meals to high-calorie junk foods [4]. Although researchers have made significant efforts to understand the aetiology and pathogenesis of this disease and its clinical course and treatment [5], anthropological and anthropometric evaluations of these individuals have remained unexplored or understudied.

Increased interest in medical anthropology and anthropometry among anatomists and clinicians worldwide has recently been observed [6]. Using anthropometry in clinical settings has already allowed for identifying connections between the bodily constitution and specific disorders [7, 8, 9], as well as somatic characteristics and immune system aspects [6]. Since the population is constitutionally and anatomically different, modern medicine is now focusing on the practical application of the theoretical understanding of the human constitution. [10, 11]. This fact demonstrates the importance of considering the human somatotype while diagnosing, preventing, and treating numerous diseases. [9, 12]. Somatotyping is a practical, noninvasive technique to describe overall body shape and composition [9]. Individual somatotype is defined by three numerical rating components representing endomorphy (relative adiposity), mesomorphy (musculoskeletal robustness by size unit), and ectomorphy (relative linearity primarily based on size/weight ratio) [9]. Factors such as age [13], gender [14], level of education and occupation [15], socioeconomic status [16], genetics [9], physical activity [17], and pathological conditions [7, 11] have been shown to affect somatotype.

In clinical settings, somatotypes could be used to determine phenotypic predictors of disease development, severity, and prognosis [18]. An individual's somatotype can be a somatic indicator of a tendency to certain diseases as well as a marker of metabolic processes in the body [19]. Techniques of somatotypological research may aid in the diagnosis and the better management and personalization of illness progression [19]. This technique's methodological validation can broaden our perspective on treating diabetic patients (19). Few studies have reported the somatotype and its associated factors of type 2 diabetes mellitus (T2DM), especially among Caucasians [5, 20-23]. However, an extensive literature search on the somatotype and its associated factors of individuals with T2DM, particularly in the black community, including Nigeria, has not been fully explored. To obtain the best possible care for diabetic patients, research is needed to identify and validate ethnic-specific characteristics related to somatotypes in T2DM [5]. This is because the findings from earlier studies may not necessarily generalize to other ethnicities [24]. Hence, the present study attempts to provide new information on the somatotype and its associated factors of patients with T2DM in Nigeria to create a phenotype for this population and start a new line of research. This study's findings provide preliminary information that can help researchers better understand the disease's physical characteristics. The outcomes could aid in the timely development and modification of dietary intervention programs for preventive and therapeutic objectives, increasing the overall health and well-being of type 2 diabetic patients. Furthermore, these findings align with the United Nations Sustainable Development Goal 3: "Good Health and Well-Being" (SDG). Because one of the goals is to "reduce premature mortality from non-communicable illnesses through prevention and treatment and enhance mental health and well-being by 2030," the guidelines in this article will assist clinicians and nutritionists around the world in accomplishing this aim

MATERIALS AND METHODS

Study design, setting, and ethical statement: A cross-sectional study was conducted from January to April 2021 at Ahmadu Bello University Teaching Hospital (ABUTH) Zaria, Kaduna State, Nigeria. Though there are other tertiary hospitals in Northwestern Nigeria, ABUTH remains the primary referral center for the whole region. Hence, the reason for the choice of this hospital. The study protocol was approved by the Health Research Ethics committee (ABUTH/HREC/G13/2020), and signed written informed consent to participate in the research was obtained from participants before data collection.

The sample: The sample size was calculated using this formula [(25)]:

Sample size, $n = [(Z)^2\ (p)(1-p)]/(\Delta)^2] = [(1.96)2\ (0.03)\ (1-0.03)] / (0.05)^2] + 20\% = 45 + 20\% = 55$ subjects

Where n = sample size, Z = value representing the desired confidence level, Δ = precision, and p = anticipated population proportion.

With 80% power of the study, a precision value of 0.05 and a confidence level of 95%, Z-score will be 1.96, whereas the prevalence of type 2 diabetes at 3.0% was obtained (24). Considering a 20% nonresponse rate, the final number of participants included in this research was about 55. However, a total number of 90 selected confirmed cases of T2DM based on case record review [(26)] were recruited to increase the generalizability of the result.

The sample population comprised 40 males and 50 females, aged 30-65, randomly selected during their visit for laboratory analyses and routine checkups in the Endocrine outpatient Clinic of ABUTH, Zaria. The participants were of Nigerian origin, traced back to the first generation of parents. All participants enrolled were on treatment with either oral hypoglycemic drugs, diet, or both, with a disease duration of not less than two years and a controlled disease state at the time of the study. Three months before the study, patients admitted to a hospital or with any apparent deformity that could compromise the anthropological profile were excluded. Pregnant and lactating mothers and T2DM with severe comorbidities like stroke, chronic renal failure, and chronic lung disease (defined from patient records) were also excluded from the study. The participants were well informed about the procedures to be employed for the study before consenting to participate. Patients that met the inclusion criteria were somatotyped in an enclosed cubicle in the Medical outpatient department of ABUTH after blood sample collection in the laboratory.

Assessment of Anthropometric measurements: Ten anthropometric measurements were taken according to the standard protocols [27]. Height was measured with a portable anthropometer (Holstein Ltd) to the nearest 0.1cm; during the measurement, participants were requested to inhale deeply and maintain a fully erect stance. A movable spring scale was used to record body weight with an accuracy of 0.1kg (Holstein Ltd). The flexed upper arm and calf circumferences were measured to the closest 0.1 cm using a Luftkin metallic anthropometric tape. Humerus and femur breadths were measured with a sliding bi-epicondylar calliper (D.S. Medica, Milan) to the nearest 0.1cm. A Harpenden calliper was used to measure the skinfolds of the triceps, subscapular, supraspinal, and medial calf, with a measurement accuracy of -10 g/mm2 pressure and 0.5 mm. Two trained raters took all anthropometric measurements. Two measurements were taken at each site, with the mean value used by each rater. The raters were blinded to each other's measures to reduce bias. A reliability test was conducted to assess interobserver and intra-observer errors.

Assessment of Somatotype: The three somatotype components of each individual, i.e., endomorphy, mesomorphy, and ectomorphy, were computed using the Heath-Carter technique from the ten anthropometric parameters using the following equations [9]:

Endomorphy = - 0.7182 + 0.1451 (X) – 0.00068 (X2) + 0.0000014 (X3)

Where X = sum of triceps, subscapular and supraspinal skinfold.

For stature-corrected endomorphy, multiply X by 170.18/stature in cm.

Mesomorphy = [(0.858 x humerus breadth) + (0.601x femur breadth) + (0.188

+ corrected arm girth) + (0.161 x corrected calf girth)] – (height x 0.131) + 4.5

Ectomorphy = HWR x 0.732 – 28.58

If HWR is less than 40.75 but more than 38.25, Ectomorphy = HWR x 0.463 – 17.63.

If HWR is equal to or less than 38.25, given a rating of 0.10

HWR = stature/cube root of weight

The mean somatotype of each age group was plotted on a somatochart after calculating X and Y coordinates according to the following formula using the mean score of each somatotype component:

X coordinate = ectomorphy – endomorphy

Y coordinate = 2 x mesomorphy – (endomorphy + ectomorphy)

However, this study's somatotype components and ratings were computed using Somatotype calculation and analysis software [28].

Assessment of Covariates: The baseline examination included information on age (years), gender (male/female), educational level (no formal education, primary school, secondary school, and tertiary), alcohol/smoking history (yes or no), occupation (farmer, merchant, civil servant) and disease duration (2-5 years and greater than 5 years) using a general questionnaire. The validated short version (nine-item) of the International Physical Activity Questionnaire (IPAQ-SF) (internal consistency reliability indicated by Cronbach's alpha=0.99) was used to assess physical activity (PA) [(29)]. The IPAQ-SF form tracks three categories of physical activity (vigorous PA like aerobics, moderate-intensity activities like leisure, riding, and walking) and time spent sitting. Only activities lasting ≥10 minutes at a time were taken into consideration. The IPAQ scoring protocol was used to convert responses to metabolic equivalent task minutes per week (MET-min/wk): total minutes spent on a vigorous activity, moderate-intensity activity, and walking over the previous seven days were multiplied by the energy cost of each exercise: 8.00 MET, 4.00 MET, and 3.30 MET for vigorous, moderate, and walking, respectively. The sum of the three subcomponents' MET scores (vigorous, moderate, and walking) was used to calculate overall PA [(29)]. The difference between active and inactive people was determined using current PA guidelines [(29)], which require at least 30 minutes of moderate PA five times per week: 30 minutes × factor 4×5 times per week =600 MET-min/wk. According to their responses to the IPAQ-SF questionnaire, people might be classed as active (meeting PA recommendations of 600 MET-min/wk) or inactive (PA less than 600 MET-min/wk).

Right arm blood pressure (sitting or recumbent position) was measured twice to the nearest 2 mm Hg using a standard mercury sphygmomanometer (Korotkoff phases I and V) by a trained nurse. Blood pressure ≥ 140/90 mm Hg was considered hypertension [(29)]. Fasting serum lipid levels [including serum triglycerides (TG), total cholesterol, high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein cholesterol], fasting blood glucose and glycated haemoglobin (HbA1c) were determined by standard laboratory techniques (performed by a laboratory scientist in the chemical pathology laboratory of ABUTH). In this study, values of FBG≥8mmol/L and HbA1c≥6.5% were considered poor glycemic control [(26)]. Values of LDL<130 mg/dl are normal, while values> 130 mg/dL (abnormal); HDL>60mg/dl (normal) while <60mg/dl (abnormal); Total cholesterol: less than 200 mg/dL (normal) while greater than 200mg/dl (abnormal); Triglycerides: <150 mg/dL (normal) while >150mg/dl (abnormal).

Data Analyses: The Shapiro-Wilk test was used to determine whether the data was normal. The intraclass correlation coefficient, which assesses the level of agreement between two or more raters, was utilized to determine inter- and intra-rater reliabilities using the Shrout-Fleiss technique. The somatotype calculation and analysis software calculated the somatotype component ratings, somatotype attitudinal distance (SAD), and somatocharts [(9).] Height, weight, three somatotype components (endomorphy, mesomorphy, and ectomorphy), and SAD were all given descriptive statistics. The significance of gender differences was tested using a somatotype analysis of variance

(SANOVA), which compares the somatotype of each group by applying the SAD within and between groups. In this study, the dependent variables (continuous) include endomorphy, mesomorphy and ectomorphy.

In contrast, the independent variables are age, gender, educational level, alcohol/smoking history, occupation, disease duration, physical activity, hypertension, serum triglycerides (TG), total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein cholesterol, fasting blood glucose and glycated haemoglobin (HbA1c). The relationship between the covariates and somatotype components was determined using a one-way analysis of variance for continuous variables. Fisher's exact test (with an expected cell count of < 2) was used for categorical variables. The factors associated with the somatotype components were investigated using multiple linear regression (MLR). Before running the MLR, all possible 2-way interactions, multicollinearity, model assumptions (normality, linearity, and homoscedasticity) and the presence of outliers were checked using plots of residuals. SPSS software was used for all statistical analyses (version 27.0; IBM Corp., Armonk, NY, USA). The level of statistical significance was fixed at 0.05. (2-tailed).

RESULT

Reliability Test: Table 1 provides the intra-examiner and inter-examiner estimates with a 95.0% confidence interval for the reliability coefficients (RC) for the average measures of all measurements**.**

Intra-examiner differences: The two examiners had observed a consistently high intra-examiner reliability between the two measurements conducted before and after the routine clinic visit. The calculated reliability measurements were above RC 0.99. The ten measurements showed very high reliability with weight, triceps skinfold, subscapular skinfold, supraspinal skinfold, medial calf skinfold, and calf girth, indicating the highest agreement, RC 1.00.

Inter-examiner differences: When comparing the measurements by the two examiners, a very high-reliability distribution was also seen across the measures with a calculated RC greater than or equal to 0.98 with only weight and subscapular skinfold showing RC of 1.00 each. The time to perform all ten measurements on a participant was about 5-8 minutes.

The two examiners were trained with the same measuring instruments and techniques on the same day and in the same clinical settings. This was conducted to minimize potential sources of error during measurements. Measurements were taken before and after the patient saw the doctor, and the examiners were blindfolded from each other's measurements to avoid bias. Most of the measures were of actual anatomical landmarks, which were very easy to identify by the examiners. Thus, this might be the reason all measurements showed very high reliability.

Table 1: Intra- and inter-examiner reliability estimates and 95% CI (n=90)

Measurements	Intra-examiner reliability	Inter-examiner reliability
	Estimate (95.0% CI)	**Estimate (95.0% CI)**
Weight (kg)	1.00 (1.00 - 1.00)	1.00 (0.98 - 1.00)
Height (cm)	0.99 (0.99 - 1.00)	0.99 (0.98 - 0.99)
Femur B (cm)	0.99 (0.98 - 0.99)	0.97 (0.95 - 0.98)
Humerus B (cm)	0.99 (0.98 - 0.99)	0.98 (0.64 - 0.98)
Triceps SF (mm)	1.00 (1.00 - 1.00)	0.99 (0.97 - 0.99)
Subscapular SF (mm)	1.00 (1.00 - 1.00)	0.99 (0.98 - 1.00)
Supraspinal SF (mm)	1.00 (1.00 - 1.00)	0.99 (0.99 - 1.00)
Medial calf SF (mm)	1.00 (1.00 - 1.00)	0.99 (0.99 - 1.00)
Calf girth (cm)	1.00 (1.00 - 1.00)	0.92 (0.97 - 0.99)
Arm girth (cm)	0.99 (0.98 - 0.99)	0.98 (0.96 - 0.99)

CI: Confidence interval; B: Breadth; SF: Skin fold

Descriptive statistics of variables: Table 2 shows the mean [standard deviation (SD)] of age, height, weight, Height-Weight Ratio (HWR), the three somatotype components, and SAD in female and male diabetic patients.

Table 2: Descriptive statistics of anthropometric variables

Variables	Female (n = 50)	Male (n = 40)
	Mean (SD)	**Mean (SD)**
Age (Years)	49.48 (10.00)	50.52 (9.55)
Height (cm)	158.14 (4.96)	163.71 (6.33)
Weight (kg)	72.51 (14.13)	69.87 (9.95)
Height Weight Ratio (cm/kg^{-3})	38.22 (2.59)	39.90 (2.28)
Endomorphy	5.79 (1.59)	4.26 (1.63)
Mesomorphy	4.86 (1.66)	4.60 (1.06)
Ectomorphy	0.62 (0.91)	1.11 (1.07)
Somatotype Attitudinal Distance	2.20 (1.04)	1.88 (1.12)

Somatotype characteristics of the study population: Figure 1 is a somatochart showing the somatotype distribution of the female and male patients. For females, the mean age was 49.48 years, and most of the somatotype means clustered on the South Western and North Western axis of the boundary of the somatochart. On the Somatochart, there is a profile marker inside an empty circle representing the mean somatotype for the profiles in the document. Thus, the mean somatotype for the female profiles was mesomorphic endomorph (5.80-4.90-0.60). On the other hand, the mean age for males was 50.52 years, with the somatotype means clustering majority in the North, Western, and south-western axis of the boundary of the somatochart. Hence, the mean somatotype for the male profiles was endomorphic mesomorph (4.30-4.60-1.10).

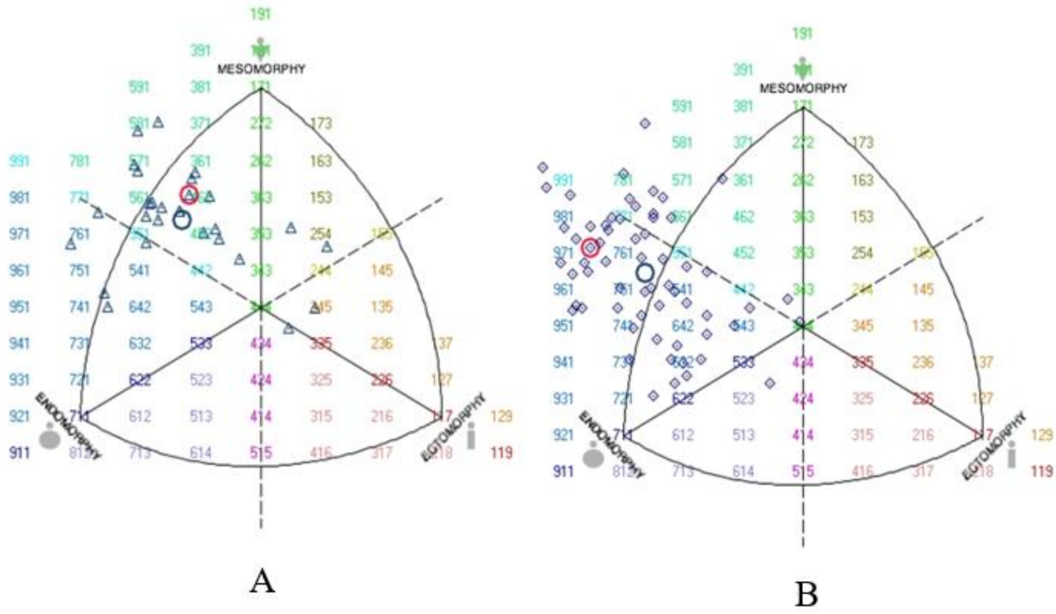

Figure 1: Somatotype distribution of (A) male (n=40) and (B) female (n=50) T2DM

The somatotype analysis of variance (SANOVA) table for the study population, which compares the somatotype of females and males using the somatotype attitudinal distance (SAD), is presented in Table 3. The males had a relatively average endomorphic rating of 4.26 and a high mesomorphic rating of 4.60. On the other hand, females had a high mesomorphic and endomorphic ratings of 4.86 and 5.79, respectively. Both males and females had very low ectomorphic ratings of 1.1 and 0.62, respectively (Table 3). There was a statistically significant difference in the overall somatotypes of both male and female subjects (F = 15.58, $P = 0.021$) (Table 3). Moreover, shown in Table 4 is an analysis of the variance of the dominant somatotype component of males and females. The females were statistically significantly more endomorphic than males (F = 12.68, $P = 0.002$). However, mesomorphic and ectomorphic components did not differ statistically between the sexes (F = 0.39, $P = 0.426$) and (F = 2.93, $P = 0.090$), respectively.

Table 3: Somatotype Analysis of Variance table

Group	Count	Mean	Standard Deviation
Male	38.00	4.26 - 4.60 - 1.11	1.63 - 1.06 - 1.07
Female	52.00	5.79 - 4.86 - 0.62	1.59 - 1.66 - 0.91
ANOVA	F = 15.58	$P = 0.021$	

Table 4: Analysis of variance of the individual somatotype components in both sexes

Variable	DF – within	DF – between	F – ratio	*P* – value
Endomorphy	46.00	1.00	12.68	0.002
Mesomorphy	46.00	1.00	0.39	0.476
Ectomorphy	46.00	1.00	2.93	0.090

Relationship between covariates and the somatotype components

The relationship between covariates and the somatotype components of T2DM patients is presented in Table 5. The following covariates, gender (P = 0.037), level of education (P = 0.010), occupation (P = 0.041), disease duration (P = 0.040), HbA1c (P = 0.031), hypertension (P = 0.007), TC (P = 0.017), TG (P = 0.041), HDL (P = 0.013), physical activity (P = 0.002), and BMI (P = 0.002) showed a significant relationship with the somatotype components. Others did not establish a significant relationship with the somatotype components ($P > 0.050$).

Table 5: Comparison of baseline characteristics according to the somatotype components

Characteristics	Endomorphy (n = 50)	Mesomorphy (n = 32)	Ectomorphy (n = 8)	*P* – value
Age (Years)	49.36 (9.58)	49.19 (9.88)	57.00 (9.72)	0.322[a]
Gender				
Male/Female	13/37	20/12	6/2	0.037[b]
HbA1c	11.40 (3.24)	10.11 (3.45)	12.04 (2.24)	0.031[a]
Alcohol consumption				
Yes/No	8/42	4/28	2/6	0.836[b]
Cigarette smoking				
Yes/No	6/44	6/26	2/6	0.647 [b]
Level of education				
No formal education	10	16	0	
Primary education	22	10	2	
Secondary education	4	4	6	
Tertiary education	14	2	0	0.010 [b]
Occupation				
Farmer	14	14	6	
Merchant	14	10	1	
Civil servant	22	8	1	0.041 [b]
Disease duration				
2 – 5 years	26	16	2	
>5 years	24	16	6	0.040 [b]
Hypertension				
Yes/No	18/32	12/20	6/2	0.007 [b]
LDL (mg/dl)				
Normal/Abnormal	8/42	6/26	0/8	0.479 [b]
HDL (mg/dl)				
Normal/Abnormal	24/26	8/24	2/6	0.013 [b]
TC (mg/dl)				
Normal/Abnormal	13/37	6/26	0/8	0.017 [b]
Triglyceride (mg/dl)				
Normal/Abnormal	13/37	4/28	0/8	0.041 [b]
Physical activity				
Active	14	12	2	
Inactive	36	20	6	0.002 [b]
BMI (kg/m^2)				
Normal weight	20	4	8	
Overweight	30	28	0	0.020 [b]

LDL: Low density lipoprotein; HDL: High density lipoprotein; TC: Total cholesterol; TG: Triglyceride; BMI: Body mass index; a: One-way analysis of variance; b: Fischer exact test

Factors associated with the somatotype components: Multiple linear regression statistics using the enter method were used to determine the factors associated with the somatotype components in T2DM patients (Table 6). From the table, gender (β = 0.256, P = 0.004), level of education (β = 0.168, P = 0.008), occupation (β = 0.034, P = 0.009), HbA1c (β = 0.272, P = 0.033), TC (β = 0.689, P = 0.003), TG (β = 0.444, P = 0.041), HDL (β = -0.390, P = 0.018), hypertension (β = 0.226, P = 0.046), physical activity (β = 0.619, P = 0.041), and BMI (β = 0.619, P = 0.001), were significant predictors of endomorphy, accounting for 43% endomorphic changes in T2DM (R^2 = 0.43).

In table 6, also, gender (β = 0.122, P = 0.012), occupation (β = 0.252, P = 0.010), disease duration (β = 0.131, P = 0.027), HbA1c (β = 0.175, P = 0.022), TC (β = 0.034, P = 0.009), hypertension (β = 0.226, P = 0.046), physical activity (β = 0.070, P = 0.006), BMI (β = 0.624, P = 0.001), and level of education (β = -0.317, P = 0.039) were significant predictors of mesomorphy, accounting for 33% mesomorphic changes in T2DM (R^2 = 0.33).

Finally, in table 6, only BMI (β = -0.755, P = 0.001) was a significant predictor of ectomorphy, accounting for 21% ectomorphic changes in T2DM (R^2 = 0.21).

Table 6: Factors associated with the somatotype components in T2DM

	Multiple Linear Regression					
	Endomorphy (n=50)		Mesomorphy (n=32)		Ectomorphy (n=8)	
Factors	Adjusted β (95% CI)	*P* - value	Adjusted β (95% CI)	*P* - value	Adjusted β (95% CI)	*P* - value
Age	0.058 (-0.03 - 0.06)	0.635	-0.136 (-0.06 - 0.02)	0.333	0.220 (0.01 - 0.05)	0.091
Gender	0.256 (-0.16 - 1.97)	0.004	0.122 (-0.64 - 1.33)	0.012	-0.283 (-1.20 - 0.07)	0.079
Alcohol consumption	0.161 (-0.57 - 2.17)	0.244	0.084 (-0.94 - 1.60)	0.595	0.028 (-0.74 - 0.89)	0.847
Cigarrete smoking	0.045 (-1.21 - 1.66)	0.751	0.279 (-0.21 - 2.44)	0.097	-0.235 (-1.52 - 0.19)	0.125
Level of education	0.168 (-0.16 - 0.74)	0.008	-0.317 (-0.85 - -0.02)	0.039	-0.089 (-0.35 - 0.18)	0.513
Occupation	0.034 (-0.54 - 0.69)	0.009	0.252 (-0.10 - 1.03)	0.010	0.052 (-0.30 - 0.44)	0.709
Disease duration	0.025 (-0.65 - 0.82)	0.812	0.131 (-0.31 - 1.05)	0.027	0.063 (-0.31 - 0.56)	0.565
Hypertension	0.226 (-1.64 - -0.02)	0.046	0.018 (-0.69 - 0.80)	0.886	0.069 (-0.34 - 0.63)	0.549
HbA1c (%)	0.272 (0.01 - 0.28)	0.033	0.175 (-0.04 - 0.20)	0.022	-0.124 (-0.12 - 0.04)	0.341
LDL (mg/dl)	-0.253 (-2.87 - 0.36)	0.123	-0.125 (-1.99 - 0.99)	0.501	-0.200 (-1.53 - 0.39)	0.242
HDL (mg/dl)	-0.390 (-2.51 - -0.25)	0.018	-0.031 (-1.13 - 0.96)	0.865	0.008 (-0.66 - 0.69)	0.961
TC (mg/dl)	0.689 (1.62 - 7.10)	0.003	0.034 (-2.37 - 2.71)	0.009	0.320 (-0.49 - 2.79)	0.162
TG (mg/dl)	0.444 (-0.61 - 1.25)	0.041	0.041 (-2.60 - 3.08)	0.864	-0.191 (-2.62 - 1.05)	0.391
Physical activity	0.085 (1.42 - 3.17)	0.041	-0.007 (-0.88 - 0.84)	0.006	-0.243 (-1.08 - 0.04)	0.065
BMI	0.619 (-0.03 - 0.05)	0.001	0.624 (1.06 - 2.67)	0.001	-0.755 (-2.12 - -1.07)	0.001

β: Standardized coefficient; CI: Confidence interval; HbA1c: Glycated hemoglobin; LDL: Low density lipoprotein; HDL: High density lipoprotein; TC: Total cholesterol; TG: Triglyceride; BMI: Body mass index

DISCUSSION

Consistent with previous findings, our type 2 diabetes patients were predominantly endomorph and mesomorph with low ectomorph scores (5, 21-23). The average somatotype values of type 2 diabetes mellitus aged 33–65 years in our study were endomorphic- mesomorph (4.3-4.6-1.1) for males and mesomorphic endomorph (5.8-4.9-0.60) for females. The female type 2 diabetics were also significantly more endomorphic than their male counterparts. This result could be due to hormonal variations, but it also fits with the general theory that females have total fat than males in the human species [30]. The observed morphological difference concerning endomorphy could also be attributed to occupation since, traditionally, males perform more physically demanding jobs like farming. In contrast, females mostly stay at home attending to household chores requiring less physical activity [14]. In this study, although not statistically significant, men were more mesomorphic than females. In comparison with the somatotype of an Italian diabetic sample population in Cagliari by Buffa et al. [21], whose mean somatotype was found to be mesomorphic endomorph for both males and females (6.8-5.6-0.6) and (8.6-6.4-0.2) respectively, the Nigerian diabetics were less endomorphic and mesomorphic and more ectomorphic. Dissimilar to our findings concerning the somatotype components score, this was also reported by Baltadeiv [5] and Baltadjiev and Vladeva [20]. Similarly, the mean somatotype of Mexican type 2 diabetes was also found to be endomorphic mesomorph (5.0-6.0-0.8) for males and mesomorph endomorph (7.3-6.7-0.4) for females by Urrtia-Garcia [23], however, the somatotype components score was different in the present study. Sample size, methodological inconsistencies, geographical location, genetic predispositions, nutrition, social and hormonal influences, physical activity, and lifestyle may all have a role in the observed morphological variances.

Type 2 diabetes is linked to a slew of lipid and lipoprotein abnormalities in the blood, including low HDL, a predominance of small dense LDL particles plus TC, and high triglycerides [31]. These changes are also part of the insulin resistance syndrome (also known as the metabolic syndrome), linked to type 2 diabetes in many cases. In reality, pre-diabetic or T2DM patients often have an atherogenic pattern of risk factors, such as higher total cholesterol, LDL cholesterol, and triglycerides, as well as lower HDL cholesterol, than people who do not acquire diabetes [32]. Each dyslipidemic characteristic has been linked to an increased risk of cardiovascular disease, the primary cause of mortality in type 2 diabetes patients [32]. Studies have also shown that abnormal BMI, body fat and blood lipids are critical determinants of metabolic disorders like type 2 diabetes, cardiovascular disease, dyslipidemia, and hypertension [20, 21, 33]. The present study has also confirmed TC, TG, HDL, BMI, hypertension as significant predictors of endomorphy and mesomorphy in T2DM. That is, endomorphy and mesomorphy were associated with increased susceptibility to obesity (abnormal BMI) and physical inactivity, thereby increasing insulin resistance, worsening glycemic control characterized by poor glycated HBA1c and increased risk of hypertension. Therefore, our results showed a clear association between physical inactivity, body fat accumulation (obesity), hyperglycemia (poor glycated HBA1c), hypertension risk, and the appearance of dyslipidemia. Chrzanowska et al. [35] and Junior et al. [36] had similar findings to the present study.

In addition, the level of education and occupation theoretically would have influenced endomorphy (fat) and musculoskeletal compartment development (mesomorphy) which would facilitate the control and management of diabetes mellitus regarding exercise programs [21]. The present study showed level of education and occupation as significant predictors of endomorphy and mesomorphy.

Finally, the only factor found to be significantly associated and a predictor of ectomorphy (body linearity) in the present study was BMI in type 2 diabetes. This is because type 2 diabetes patients in this study had a decreased height-to-weight ratio, and this conforms with previous findings [5, 12, 20-23]. The implication of this is that ectomorphic physique in T2DM is protective and should be encouraged.

Furthermore, the finding of this study also has practical clinical implications. The aetiology of most diseases is multifactorial, with genetic or hereditary factors playing an indispensable role in increasing the propensity of an individual with a high somatotype risk of developing a disease. For instance, a person with dominant endomorphic or mesomorphic components and having a family background history of cardiovascular or metabolic disease stands a higher chance of developing the disease when compared to someone who has only the somatotype risk component. The present study found endomorphic and mesomorphic somatotypes as the dominant and high-risk in Nigerian type 2 diabetes. The clinical implication of the findings mentioned above is that high endomorphy and mesomorphy could be a prelude for the development of diabetes and other metabolic diseases and a precursor for poor glycemic control, especially if there is a background family history of diabetes. However, based on the study's findings, an ectomorphic body type may be at a lower risk of getting type 2 diabetes mellitus, especially if there is a negative family history of diabetes. High-risk somatotypes should be considered, particularly when establishing an effective health prevention and promotion program. Such a program should emphasize detailed anthropometric characterization with somatotype determination, as well as the use of somatotype tests in all clinical and fitness evaluations, to raise public awareness about measuring health through periodic somatotype testing rather than just body mass index (BMI) and laboratory testing of physiologic parameters, because very high endomorphy/mesomorphy and its associated health risk may be concealed inside various accepted non-obese body frames as well.

Somatotype changes during adolescence are, on average, relatively low; as such, this period can be taken to measure the baseline somatotype of an individual [37]. Any subsequent change in the somatotype can be regarded as high risk, and special attention should be given to such individuals. Other measures like body weight control and physical activity for persons with high endomorphy or mesomorphy can be recommended. For individuals with high endomorphy or mesomorphy, when identified, measures should target reducing body weight, lean mass, muscle, and fat mass. Healthy somatotype should be encouraged at 444, i.e., relative body adiposity, muscularity, and linearity maintained at approximately equal proportions.

The study has certain limitations which restrict its conclusion. Some of the weaknesses of this study are the small sample size used, non-involvement of control and use of only one tertiary hospital, which limits the generalization of the present finding. Another limitation is that this study is cross-sectional. Therefore, to confirm the results, it is better to design and conduct interventional studies on the somatotype and associated factors among type 2 diabetes patients. Despite the limitations, this study, to the best of our knowledge, is the first to assess the somatotype characteristics and associated factors among type 2 diabetes in Nigeria. Hopefully, it has set a pace for future research.

CONCLUSIONS

The mean somatotypes of the Nigerian T2DM patients are mesomorphic endomorph (5.8-4.9-0.6) in females and endomorphic mesomorph (4.3-4.6-1.1) in males and were statistically different. In this study, gender, level of education, occupation, T2DM disease duration, HbA1c, hypertension, total cholesterol, triglyceride, body mass index (BMI) and physical activities were significant predictors of endomorphy and mesomorphy. However, only BMI was a significant predictor of ectomorphy. Endomorphic and mesomorphic somatotypes were the dominant and high-risk somatotypes. Thus, the duo and their predictors should be considered when developing an effective and holistic T2DM health prevention and promotion programme in Nigeria. Finally, this study should serve as an impetus to stimulate the scientific community's interest in exploring and revalidating research on this subject matter because it is a cheap and promising proxy technique for T2DM prevention and management.

Author contributions

HLS wrote the original manuscript draft. WOH, AAS, FB, AA, and MM conceptualize the research idea and methodology. IA, AIA, and AUD did a literature search and data analysis and prepared the bibliography. WOH, AAS, FB, MM and AA review and modify the final draft of the manuscript. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare that they have no conflicts of interest

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