https://doi.org/10.46389/rjd-2024-1449
www.rjdnmd.org

Rom J Diabetes Nutr Metab Dis
2024; volume 31, issue 1, pages 5–10

Original Article

Study of association between fat composition and glycemic control in type 2 diabetic patients: Cross-sectional survey from coastal India

Liau ChiSu [1], Prabhath Matpady [2], Vijayalakshmi Sitanadhi Bhojaraja [3], Venkatesh Naik [4], Jeevan Kumar Shetty [3] *

[1] Medical student, PU-RCSI School of Medicine, Perdana University, Serdang, Selangor, Malaysia
[2] Department of WASH and CCES Policy, UNICEF India, Hyderabad, India
[3] Department of Biochemistry, School of Medicine, Royal College of Surgeons in Ireland Medical University of Bahrain, Muharraq, Bahrain
[4] Department of Pathology, Universiti Tunku Abdul Rahman (UTAR), Petaling Jaya, Malaysia

* Correspondence to: Jeevan Kumar Shetty, Department of Biochemistry, School of Medicine, Royal College of Surgeons in Ireland Medical University of Bahrain, P O Box 15503, Adliya, Muharraq, Bahrain. E-mail: drjkshetty1978@gmail.com

Received: 16 October 2023 / Accepted: 16 January 2024

Abstract

The increased prevalence of Type 2 diabetes mellitus (T2DM) and related complications in India has been related to rising obesity. Purpose: To evaluate the BMI, waist circumference (WC), body fat composition, and glycated hemoglobin (HbA1c) levels and explore the gender differences and association between these parameters. A total of 155 T2DM patients (89 males and 66 females) from Coastal Karnataka, India, participated in this study. Waist circumference (WC) and body mass index (BMI) were measured using standard procedure, and Body Fat Composition was measured using a bioelectric impedance analyzer. The mean BMI, WC, and HbA1c visceral fat values were higher, whereas skeletal muscle mass was lower than the reference range in both males and females. In age-matched males and females, the total body fat, WC and subcutaneous fat were significantly higher in females. In contrast, the skeletal muscle mass in males was significantly higher. The HbA1c levels were found to be higher in males compared to females. Total body fat and subcutaneous fat were negatively correlated, whereas visceral fat and skeletal muscle mass were positively correlated with HbA1c. There was slightly poor glycemic control in males compared to females, related to higher visceral fat. Hence, measuring the body fat composition and currently used clinical and laboratory parameters helps monitor and prevent T2DM-related complications. The study highlights the low skeletal muscle and high visceral fat in the Indian population. The study also relates the high visceral fat and poor muscle mass contributing to insulin resistance, which causes poor glycemic control and T2-DM-related complications.

Keywords: type 2 diabetes mellitus, body fat composition, visceral fat, waist circumference, glycated hemoglobin (HbA1c).

Introduction

Diabetes is a long-term metabolic disease characterized by elevated blood glucose levels, eventually damaging several organs, such as the heart, kidneys, eyes, nerves, and blood vessels [1]. According to the International Diabetes Federation (IDF), the global prevalence of diabetes in 2017 was 425 million, of which type 2 diabetes has contributed to 90% of the cases [2]. The top three countries that are expected to have the highest prevalence of diabetes in the year 2045 are China (147 million), India (134 million), and Pakistan (37 million) [3].

Diabetes mellitus (DM) is classified into two main categories: type 1 and type 2. Type 1 DM (T1DM) is caused by autoimmune-mediated damage to islet cells of the pancreas, triggered by environmental factors or

© 2024 The Authors. Romanian Journal of Diabetes, Nutrition and Metabolic Diseases published by Sanatatea Press Group on behalf of the Romanian Society of Diabetes Nutrition and Metabolic Diseases. This is an open access article under the terms of the Creative Commons Attribution License (CC-BY-NC-ND 3.0).

exposure to viral infections [4]. Many times, the cause is unknown. In contrast, type 2 diabetes (T2DM) is a disease due to decreased insulin production from beta cells of the pancreas or/and peripheral insulin resistance [4]. Several risk factors are associated with T2DM, such as family history, overweight, unhealthy diet, physical inactivity, aging and ethnicity [2]. T2DM is managed mainly by using oral drugs. The level of plasma glucose or/and glycated hemoglobin (HbA1c) is used to determine the dosage of oral medicine [5]. HBA1c is used routinely to manage diabetes because it provides a better idea of long-term glycemic control [5]. IDF and the American Diabetes Association have recommended HbA1c levels of <7% as the target of optimal glycemic control to prevent micro and macrovascular complications such as neuropathy, retinopathy, nephropathy, and cardiovascular diseases [6–9].

In recent years, the epidemic of obesity has led to the prevalence of T2DM and its complications to escalate significantly in India [4, 6]. T2DM is one of the components of metabolic syndrome in which patients also have obesity, dyslipidemia, low-density lipoprotein cholesterol (LDL-c), elevated blood pressure and insulin resistance [7]. The patterns of diabetes incidence in India vary due to geographical distribution [8]. This is related to the diversity of Indians concerning their genetic constitution, diet and lifestyle [8].

T2DM management involves glycemic control (HbA1c) under optimal levels as guided by IDF, which helps reduce T2DM-related complications [2]. To attain effective glycemic control, in addition to oral drugs, T2DM patients are also required to follow a diabetic diet and modify their lifestyle [6]. This highlights the importance of awareness regarding diet and optimum body composition in diabetic patients. Since there were no studies in the literature to ascertain the body fat composition of T2DM patients from Coastal Karnataka, we have designed this secondary data analysis. This study evaluates BMI, waist circumference, body fat composition and HbA1c levels. Also, to explore the gender differences and association between these parameters.

Material and methods

Study design and study subjects

A cross-sectional study design was employed for this study. The study protocol was approved, and ethical clearance (IEC 453/2016) was obtained from the Institutional Research and Ethics Committee.

Written informed consent was obtained from all participants before data collection. Privacy and confidentiality were ensured. About 512 patients were recruited using a simple random sampling technique from a diabetes registry with 19000 people from Udupi, Coastal Karnataka, India. Out of 512, 467 responded and participated in the study, and the remaining 45 did not respond. From the 467 patients, we recruited 155 T2DM patients (89 males and 66 females) who met the inclusion criteria.

Inclusion criteria

Both males and females between the age group 30–65 years old are on prescribed oral anti-diabetic drugs with excellent adherence were included. These subjects follow a diabetic diet, are under regular follow-up with HbA1c and have not reported any complications.

Exclusion criteria

Some of the participants had more than one exclusion criterion. The study does not include T1DM and T2DM patients who are on insulin (n=31), patients on alternative medicines (Ayurveda, n=308), have complications(n=200), and not following the diabetic diet were excluded from this study.

Table 1: Normal body fat composition in males and females (Omron Instruction Manual Body Composition Monitor Model HBF-375 Karada Scan).

Parameters	Males	Females
BMI (kg/m^2)	23	23
waist circumference (cm)	84	80
Total body fat (%)	10–24.99	30–34.99
Visceral fat (cm^2)	9–14.5	9–14.5
Skeletal muscle mass	32.9–35.7	25.9–27.9

https://doi.org/10.46389/rjd-2024-1449
© 2024 The Authors

Research method

The following methods measured the BMI, waist circumference, total body fat, subcutaneous fat, visceral fat, skeletal muscle mass and HbA1c levels.

Anthropometric measurements

BMI was measured using the formula BMI = weight (kg)/height (m^2) [10]. WC was measured at the midpoint between the top of the iliac crests and the lower margin of the last rib in the midaxillary line at the end of several consecutive breaths [10]. Omron Karada HBF-375 Scan for Bioelectric Impedance Analysis (BIA) was used to analyze body fat composition, such as subcutaneous fat, visceral fat, total body fat, and skeletal muscle percentage [11]. The normal values of BMI were taken as 23 as recommended for the Indian population, and normal values for other anthropometric measurements for males and females are provided in Table 1 [12, 13].

HbA1c

HbA1c was estimated by Quantitative Turbidimetric Inhibition Immunoassay (TINIA) using Cobas c 511 Tina-Quant assays [14]. The assigned HbA1c and total hemoglobin values are certified with the National Glycohemoglobin Standardization Program (NGSP) [14]. Optimal glycemic control was defined as HbA1c ≤7 g % based on the American Diabetes Association 2014 [11].

Statistical analysis

All analyses were performed using the SPSS version 24. The measurements and calculated values are expressed as mean±SD values. One sample t-test was used to compare the mean value in males and females with their respective ideal mean values reported in the literature. The comparison of HBA1c, WC, BMI and body fat parameters between age-matched males and females was made by independent t-test. Bivariate (Pearson) correlation was used to determine relationships between two variables. The P-value of <0.05 was considered statistically significant.

Results

Table 2 shows the baseline characteristics of 155 South Indian patients (89 males, 66 females) with T2DM in this study. The mean age of male and female patients is 55.7 years and 55.2 years, respectively. The mean duration of their diabetes is 7.1 years.

The mean values of BMI and WC are significantly higher than the respective ideal normal values of each parameter in both subjects. In contrast, the mean value

Table 2: Comparison of baseline characteristics in males and females.

	Male (Mean±SD) **n=89** **(Normal range)**	**Female (Mean±SD)** **n=66** **(Normal Range)**
Age	55.8±8.7	55.2±7.7
Duration	7.3±5.3	6.8±4.9
BMI	25.3±3.8** (23)	26.3±5.7** (23)
WC	92.3±9.9** (84)	97±11** (80)
Total body fat	28.2±5.4 (10–24.9)	37.2±4.6 (30–34.9)
Visceral fat	12.1±5.3* (10–14.5)	9.9±4.4 (10–14.5)
Subcutaneous fat	19.7±4.5	31.3±5.5
Skeletal muscle mass	27.7±3.1 (32.9–35.7)	21.95±2.2 (25.9–27.9)
HbA1c	8.01±1.89** (<7%)	7.99±1.83** (<7%)

Note: ( ) – normal values; *– p<0.05; ** – p<0.001 on comparing the mean value using a one-sample t-test.

© 2024 The Authors

Table 3: Comparison of baseline characteristics between the age-matched males and females.

	Male (Mean±SD) n=55	Female (Mean±SD) n=55	P-value
Age	55.91±7.91	55.98±7.87	0.962
Duration	7.58±5.08	7.35±5.02	0.807
WC	92.00±9.86	96.91±10.29	0.012*
Total body fat	28.02±5.24	37.53±4.58	0.001**
Visceral fat	11.74±5.074	10.27±4.51	0.111
Subcutaneous fat	19.31±3.97	31.525±5.74	0.001**
Skeletal muscle mass	27.68±2.62	21.82±2.22	0.001**
BMI	25.00±3.59	26.64±5.98	0.085
HbA1c	8.31±1.94	7.79±1.57	0.124

Note: * – $p<0.05$; ** – $p<0.001$ on comparing the age-matched males and females.

of skeletal muscle mass was lower than the reference muscle mass in males and females. Both subjects' mean visceral fat values are significantly higher than the reference visceral fat value. The HbA1c mean values in both males and females are significantly higher than the lower end of the target value recommended for HbA1c.

To compare the age-matched males and females, we have excluded the subjects with no matching age in both groups. This exercise resulted in 110 T2DM patients with equal numbers of males and females (55 males, 55 females). As shown in Table 3, the total body fat and subcutaneous fat are significantly higher ($p<0.001$) in females than males. The WC in females is significantly higher ($P<0.05$) than in males. Males' skeletal muscle mass percentage is considerably higher ($p<0.001$). The HbA1c and visceral fat were slightly higher in males than females; however, it is not statistically significant ($p=0.124$ for HbA1c and $p=0.111$ for visceral fat). Table 4 shows that HbA1c was negatively correlated with total body fat and subcutaneous fat. In contrast, visceral fat and skeletal muscle mass were correlated positively with HbA1c. However, all these correlations were statistically not significant.

Table 4: Correlation between the HbA1c and body fat parameters.

	R-values	P-values
Total body fat	-0.69	0.39
Visceral fat	0.05	0.94
Subcutaneous fat	-0.05	0.50
Skeletal muscle mass	0.02	0.74

Discussion

In the current study, we have evaluated and compared the pattern of the body fat composition, WC, BMI and HbA1c in T2DM males and females. We have also correlated glycemic control (HbA1c) with body fat parameters. According to our study, BMI is significantly higher in males and females than the ideal BMI adopted for the Indian population. In both genders, the BMI is in the overweight category. WC is also significantly higher than the reference WC in both subjects. This is consistent with the previous studies in India, which reported that higher BMI and WC in diabetes mellitus had been related to sedentary behavior and reduced physical activity in the Indian population [15]. Our study also has shown a significantly higher visceral fat than the ideal visceral fat in both subjects. Relatively higher total body fat than ideal total fat was found in both male and female T2DM patients. The reason could be multifactorial, such as genetic factors, high refined sugar intake, high carbohydrate intake, high fat intake, low fiber diet, environmental factors, physical inactivity to excess fat deposition, and poor glycemic control in T2DM [8, 14, 15].

The HbA1c level was significantly higher than the optimal target HbA1c (<7%) in both subjects but within the higher end of acceptable target HbA1c (7–8%). According to our study, skeletal muscle mass measured in males and females is below the ideal muscle mass. Previous studies have reported higher muscle mass is protective against insulin resistance, whereas low muscle mass was found to be associated with insulin resistance and type 2 diabetes [16]. Previous studies have also

https://doi.org/10.46389/rjd-2024-1449
© 2024 The Authors

shown that excess body fat and low muscle mass have been hypothesized to explain the high prevalence of insulin resistance and poor glycemic control in Asian Indians [15, 17, 18]. In line with previous studies, we relate the high HbA1c levels in our study group to excess body fat and muscle mass-linked insulin resistance.

On comparing the BMI, WC, body fat composition, and HBA1c levels in age-matched males and females, WC, total body fat, and subcutaneous fat are significantly higher in females than in males. In contrast, the muscle mass in males is significantly higher than in females, even after adjusting for age and sex. The BMI in a female is slightly higher than in a male, consistent with a previous study in India [19]. The study suggested this is likely due to culture and society preventing women from living healthy [20]. Males have a higher skeletal muscle mass because they are more physically active than females [21]. The visceral fat is slightly higher in males compared to females. This is consistent with previous studies, suggesting a more pronounced increase in visceral deposition in men than in women [22, 23].

The HbA1c level is higher in males than females but did not differ significantly. However, HbA1c correlated positively with visceral fat. However, the correlation was statistically insignificant, which may be due to the small sample size. Previous study data suggest a clear association between visceral fat and glycemic control, which causes insulin resistance and poor glycemic control in patients with T2DM [24–26]. This is because excess visceral fat reduces the glucose uptake sensitivity initiated by insulin and reduces the re-esterification rate of free fatty acids (FFA) [22]. In our study, the correlation between visceral fat and HbA1c is not statistically significant, which we relate to the small sample size and inclusion of subjects following the diet and exercise regime. In our study, females have a significantly higher subcutaneous fat than males, negatively correlated with the HbA1c. This aligns with several earlier studies, which reported that subcutaneous fat intrinsically differs from visceral fat and exerts protective effects [20, 25].

This study's limitations are its small sample size (n=155). Further studies with a larger population are needed to precisely evaluate fat composition with glycated hemoglobin (HbA1c) in T2DM. Besides comparing the anthropometric data with healthy controls, we have used the literature-reported normal values to compare the mean within the gender.

Bioelectrical impedance analysis (BIA) using Omron Karada Scan has its limitations. Evidence has shown that a relatively increased amount of total body water and extracellular fluid will underestimate body fat percentage and overestimate fat-free mass [26–28].

Conclusion

There was slightly poor glycemic control in males compared to age-matched females, which showed a slight correlation to visceral fat in males. Hence, measuring the body fat composition in individuals with poor glycemic control and currently used clinical and laboratory parameters may be beneficial to monitor T2DM. This practice will help plan targeted interventions such as reducing visceral fat and enhancing muscle mass for better glycemic control to prevent T2DM-related complications in the early stage.

Conflict of interest

The authors declare no conflict of interest.

References

1. Diabetes [Internet]. World Health Organization. World Health Organization; [cited 2021Jul17]. Available from: https://www.who.int/news-room/fact-sheets/detail/diabetes
2. Forouhi NG, Wareham NJ. Epidemiology of diabetes. Medicine (Baltimore). 2019 Jan 1;47(1):22–7.
3. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, Colagiuri S, Guariguata L, Motala AA, Ogurtsova K, Shaw JE, Bright D, Williams R; IDF Diabetes Atlas Committee. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. Diabetes Res Clin Pract. 2019;157:107843. doi: 10.1016/j.diabres.2019.107843. Epub 2019 Sep 10. PMID: 31518657.
4. Al-Goblan AS, Al-Alfi MA, Khan MZ. Mechanism linking diabetes mellitus and obesity. Diabetes Metab Syndr Obes. 2014;4;7:587-91. doi: 10.2147/DMSO.S67400. PMID: 25506234; PMCID: PMC4259868.
5. Al-Alawi SA. Serum lipid profile and glycated hemoglobin status in Omani patients with type2 diabetes mellitus attending a primary care polyclinic. Biomed Res. 2014;25(2):161–6.
6. Solanki JD, Makwana AH, Mehta HB, Kamdar P, Gokhale PA, Shah CJ. Effect of current glycemic control on qualitative body composition in sedentary ambulatory Type 2 diabetics. Niger Med J. 2016;57(1):5-9. doi: 10.4103/0300-1652.180562. PMID: 27185972; PMCID: PMC4859114.
7. Tenenbaum A, Fisman EZ, Motro M. Metabolic syndrome and type 2 diabetes mellitus: focus on peroxisome proliferator activated receptors (PPAR). Cardiovascular Diabetology. 2003Mar23;2(4):1–7.

8. Kaveeshwar SA, Cornwall J. The current state of diabetes mellitus in India. Australas Med J. 2014;7(1):45-8. doi: 10.4066/AMJ.2013.1979. PMID: 24567766; PMCID: PMC3920109.
9. Samdani TS, Mitra P, Rahim MA. Relationship of Glycated Haemoglobin with Lipid Profile among Patients with Type 2 Diabetes Mellitus. BIRDEM Med J. 2017;7(1):43–7.
10. Ahmad N, Adam SI, Nawi AM, Hassan MR, Ghazi HF. Abdominal Obesity Indicators: Waist Circumference or Waist-to-hip Ratio in Malaysian Adults Population. Int J Prev Med. 2016;7:82. doi: 10.4103/2008-7802.183654. PMID: 27330688; PMCID: PMC4910307.
11. Solanki JD, Makwana AH, Mehta HB, Gokhale PA, Shah CJ. Body Composition in Type 2 Diabetes: Change in Quality and not Just Quantity that Matters. Int J Prev Med. 2015;6:122. doi: 10.4103/2008-7802.172376. PMID: 26900436; PMCID: PMC4736063.
12. CONELCOM M. Instruction Manual Instruction Manual. Int Bus. 2016;1(35):1–183.
13. Snehalatha C, Viswanathan V, Ramachandran A. Cutoff values for normal anthropometric variables in asian Indian adults. Diabetes Care. 2003;26(5):1380-4. doi: 10.2337/diacare.26.5.1380. PMID: 12716792.
14. Food and Drug Administration. Decision Summary Assay and Instrument Combination Template. 2017;510(75):1–17. Available from: https://www.accessdata.fda.gov/cdrh_docs/reviews/K063209.pdf
15. Ahirwar R, Mondal PR. Prevalence of obesity in India: A systematic review. Diabetes Metab Syndr. 2019;13(1):318-321. doi: 10.1016/j.dsx.2018.08.032. Epub 2018 Sep 21. PMID: 30641719.
16. Choi SI, Chung D, Lim JS, Lee MY, Shin JY, Chung CH, Huh JH. Relationship between Regional Body Fat Distribution and Diabetes Mellitus: 2008 to 2010 Korean National Health and Nutrition Examination Surveys. Diabetes Metab J. 2017;41(1):51-59. doi: 10.4093/dmj.2017.41.1.51. Epub 2016 Dec 21. PMID: 28029016; PMCID: PMC5328696.
17. Heilbronn L, Smith SR, Ravussin E. Failure of fat cell proliferation, mitochondrial function and fat oxidation results in ectopic fat storage, insulin resistance and type II diabetes mellitus. Int J Obes Relat Metab Disord. 2004;28 Suppl 4:S12-21. doi: 10.1038/sj.ijo.0802853. PMID: 15592481.
18. Shishikura K, Tanimoto K, Sakai S, Tanimoto Y, Terasaki J, Hanafusa T. Association between skeletal muscle mass and insulin secretion in patients with type 2 diabetes mellitus. Endocr J. 2014;61(3):281-7. doi: 10.1507/endocrj.ej13-0375. Epub 2014 Jan 10. PMID: 24420336.
19. Mustelin L, Silventoinen K, Pietiläinen K, Rissanen A, Kaprio J. Physical activity reduces the influence of genetic effects on BMI and waist circumference: a study in young adult twins. Int J Obes (Lond). 2009;33(1):29-36. doi: 10.1038/ijo.2008.258. Epub 2008 Dec 2. PMID: 19048013.
20. Kalra S, Unnikrishnan AG. Obesity in India: The weight of the nation. J Med Nutr Nutraceuticals. 2012;1(1):37.
21. Karnehed N, Tynelius P, Heitman BL, Rasmussen F. Physical activity, diet and gene–environment interactions in relation to body mass index and waist circumference: The Swedish Young Male Twins Study. Public Health Nutr. 2006;9(7):851–8.
22. Tsao Y-C, Chen J-Y, Yeh W-C, Li W-C. Gender- and Age-Specific Associations between Visceral Obesity and Renal Function Impairment. Obes Facts. 2019;12(1):67–77.
23. Sandeep S, Velmurugan K, Deepa R, Mohan V. Serum visfatin in relation to visceral fat, obesity, and type 2 diabetes mellitus in Asian Indians. Metabolism. 2007;56(4):565–70.
24. Gastaldelli A, Miyazaki Y, Pettiti M, Matsuda M, Mahankali S, Santini E, *et al*. Metabolic Effects of Visceral Fat Accumulation in Type 2 Diabetes. J Clin Endocrinol Metab. 2002;87(11):5098–103.
25. Björntorp P, Rosmond R. Visceral Obesity and Diabetes. Drugs. 1999 Sep 1;58(1):13–8.
26. Anjana M, Sandeep S, Deepa R, Vimaleswaran KS, Farooq S, Mohan V. Visceral and Central Abdominal Fat and Anthropometry in Relation to Diabetes in Asian Indians. Diabetes Care. 2004;27(12):2948–53.
27. Tran TT, Yamamoto Y, Gesta S, Kahn CR. Beneficial effects of subcutaneous fat transplantation on metabolism. Cell Metab. 2008;7(5):410–20.
28. Coppini LZ, Waitzberg DL, Campos ACL. Limitations and validation of bioelectrical impedance analysis in morbidly obese patients. Curr Opin Clin Nutr Metab Care. 2005;8(3):329–32.

 https://doi.org/10.46389/rjd-2024-1449 © 2024 The Authors