RESEARCH PAPER

Altered Body Composition in Type 2 Diabetes Mellitus: A Case–Control Study of Body Fat Percentage, Fat Free Mass and Fat Free Mass Index

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Received: 15th Jul, 2026 | Revised: 25th Jul, 2026 | Accepted: 5th Aug, 2026 | Available Online: 12th Aug, 2026

ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is accompanied by metabolic dysregulation that alters the partitioning of body mass between fat and lean tissue. The Asian Indian phenotype is characterised by higher adiposity and lower skeletal muscle mass at any given body mass index (BMI), yet body composition in long-standing Indian diabetics remains inadequately characterised. Fat free mass index (FFMI) is considered a superior descriptor of lean tissue because it adjusts for stature.

Objectives: To compare body fat percentage, fat free mass (FFM) and fat free mass index (FFMI) between patients with long-standing type 2 diabetes and age- and sex-matched non-diabetic controls.

Methods: A cross-sectional case–control study was conducted at SCB Medical College and Hospital, Cuttack, comprising 200 type 2 diabetic cases (aged 41–55 years, disease duration 10–15 years) and 200 age- and sex-matched non-diabetic controls. Body composition was assessed by bioelectrical impedance analysis (Omron HBF-375 Karada Scan) and height by wall-mounted stadiometer. Data were analysed in IBM SPSS v21.0 using independent t-tests, with $p<0.05$ taken as significant.

Results: Diabetic cases were shorter (163.0 ± 13.7 vs 169.26 ± 11.5 cm) yet heavier (72.9 ± 11.2 vs 70.8 ± 9.9 kg) than controls. Body fat percentage was significantly higher in cases (30.35 ± 5.1 vs 25.83 ± 2.4, $p<0.01$), while fat free mass (50.7 ± 7.65 vs 52.46 ± 7.2, $p=0.01$) and fat free mass index (17.74 ± 1.9 vs 18.29 ± 2.1, $p=0.02$) were significantly lower. Mean disease duration was 12.3 ± 1.65 years, with fasting (147.43 ± 32.96 mg/dl) and postprandial (227.8 ± 64.4 mg/dl) glucose markedly elevated despite ongoing therapy.

Conclusion: Long-standing type 2 diabetics display a body composition profile of excess adiposity coupled with a concurrent deficit in lean tissue, evident on both absolute (FFM) and stature-adjusted (FFMI) measures. Routine bioelectrical impedance assessment may add clinically useful information beyond BMI in this population.

Keywords: Type 2 diabetes mellitus, body composition, body fat percentage, fat free mass, fat free mass index, bioelectrical impedance analysis.

How to cite this article: Debadarsini G, Rout B, Mishra I., Altered Body Composition in Type 2 Diabetes Mellitus: A Case–Control Study of Body Fat Percentage, Fat Free Mass and Fat Free Mass Index. Int J Drug Deliv Technol. 2026;16(76s): 189; DOI: 10.25258/ijddt.16.76s.20

INTRODUCTION

The Indian subcontinent has emerged as a major reservoir of the global diabetes burden, with consequences that threaten both the economy and the healthcare infrastructure.[1] India ranks second only to China in the number of people living with diabetes, and the South Asian region is projected to have the world's largest diabetic population by 2030.[2] The Indian Council of Medical Research–India Diabetes (ICMR–INDIAB) study, the largest population-based survey of its kind, carried out across 15 states, estimated an overall diabetes prevalence of 7.3%, underscoring the scale of the problem.[3]

A distinctive feature of the Indian population is a predisposition to diabetes at a younger age and at a lower body mass index (BMI) than Western counterparts. This phenomenon is attributed to the "Asian Indian phenotype," characterised by low BMI, higher body fat, greater visceral adiposity and waist circumference, lower skeletal muscle mass, and higher rates of insulin resistance.[4] Obesity and elevated body fat are linked to diabetes across all ethnic groups,[5] and the two conditions frequently coexist, with hyperglycaemia remaining the defining phenotype of the disease.[6]

Body mass can be partitioned into fat mass and fat free mass, the latter comprising skin, muscle, bone, organs and blood. Because BMI cannot distinguish between these two compartments, two individuals of identical BMI may differ substantially in the proportion of metabolically active lean tissue they carry. Fat free mass index (FFMI), which normalises fat free mass to the square of height, is therefore regarded as a superior indicator of body composition, since it adjusts for stature and permits meaningful comparison across individuals of differing height.

Increased adipose tissue is associated with a greater risk of diabetes mellitus and cardiovascular disease,[7] and body fat measures have been reported to predict insulin resistance more effectively than waist circumference or BMI.[8] On the lean side of the equation, abnormalities of protein metabolism in diabetes may adversely affect the maintenance of muscle mass,[9] and muscle in individuals with excess adiposity may undergo fatty infiltration with altered fibre composition.[10] Despite these converging lines of evidence, a systematic characterisation of fat and fat free compartments in Indian patients with long-standing type 2 diabetes is lacking. The present study was undertaken to compare body fat percentage, fat free mass and fat free mass index between type 2 diabetics and matched non-diabetic controls.

MATERIAL AND METHODS

Study design and setting: This cross-sectional study involving cases and controls was conducted jointly in the Department of Physiology and the Department of Endocrinology, SCB Medical College and Hospital, Cuttack, Odisha. The study protocol was reviewed and approved by the Institutional Ethical Committee prior to commencement.

Participants: A total of 400 participants were recruited, comprising 200 cases and 200 controls. Cases were diagnosed type 2 diabetic patients aged 41–55 years with a disease duration of 10–15 years. Age- and gender-matched healthy adults with no history of diabetes served as controls. Participants were required to understand the procedure and to provide signed or thumb-impression informed consent.

Exclusion criteria: Subjects with asthma, chronic obstructive pulmonary disease, congestive cardiac failure, myasthenia gravis or hypothyroidism were excluded, as were subjects with water–electrolyte imbalance (oedema or ascites), skin abnormalities at the electrode contact

sites, or BMI greater than 38 kg/m², since these conditions interfere with the validity of bioelectrical impedance measurement.

Apparatus: A bioelectrical impedance fat monitor (Omron Body Composition Monitor Model HBF-375 Karada Scan) and a wall-mounted stadiometer were used.

Procedure: After obtaining informed written consent in English or Odia, a detailed personal, medical and family history was recorded, including diabetes duration, mode of treatment, and the most recent fasting and postprandial blood glucose values.

Height was measured using a wall-mounted stadiometer, with the subject standing with heels together, and heels, calf and buttocks touching the stadiometer, and the head positioned in the Frankfurt plane.

Fat free mass and FFMI were derived using the bioelectrical impedance fat monitor. Age, gender and height were entered into the device; the subject stood barefoot on the foot electrodes and gripped the hand electrodes with both hands, arms extended at 90° with elbows straight. A safe weak current of 50 kHz and 500 µA was passed through the body. Measurements were taken at least two hours after food intake and at room temperature. FFM and FFMI were calculated as follows:

FFM = Body weight × (100 − Fat%) / 100

FFMI = [Body weight × (100 − Fat%) / 100] ÷ Height²

Statistical analysis: Data were tabulated in Microsoft Excel and analysed using IBM SPSS Version 21.0. Independent t-tests were used to compare groups. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Distribution of gender among cases and controls

Gender	Case (Diabetic) (n=200)	Control (Non-Diabetic) (n=200)
Female	80 (40%)	80 (40%)
Male	120 (60%)	120 (60%)

Both groups were sex-matched, comprising 40% female and 60% male participants.

Table 2: Distribution of age among cases and controls

Characteristic	Case (n=200)	Control (n=200)
Age in years (Mean ± SD)	50.7 ± 3.6	49.4 ± 3.7

The mean age of diabetic subjects (50.7 years) was marginally higher than that of controls (49.4 years).

Table 3: Distribution of height (cm)

Characteristic	Case (n=200)	Control (n=200)
Height in cm (Mean ± SD)	163.0 ± 13.7	169.26 ± 11.5

Table 4: Distribution of weight (kg)

Characteristic	Case (n=200)	Control (n=200)
Weight in kg (Mean ± SD)	72.9 ± 11.2	70.8 ± 9.9

Diabetic subjects were shorter but heavier than controls, consistent with diabetes being associated with excess body weight.

Table 5: Duration of diabetes among cases

Parameter	Case (n=200)
Duration in years (Mean ± SD)	12.3 ± 1.65

The majority of cases had long-standing diabetes, with a mean duration of 12.3 years.

Table 6: Fasting plasma glucose (FBS)

Parameter	Case (n=200)	Control (n=200)	t-value	p-value
FBS mg/dl (Mean ± SD)	147.43 ± 32.96	101.44 ± 9.67	6.88	<0.01

Table 7: 2-hour postprandial plasma glucose (PPBS)

Parameter	Case (n=200)	Control (n=200)	t-value	p-value
PPBS mg/dl (Mean ± SD)	227.8 ± 64.4	117.7 ± 14.4	12.22	<0.01

Glycaemic parameters were significantly higher in diabetic cases despite ongoing therapy, confirming their diabetic status.

Table 8: Treatment history among cases

Treatment	Case (n=200)
On OHA	113 (56.5%)
On Insulin	47 (23.5%)
On Insulin + OHA	40 (20%)

Table 9: Body fat percentage

Parameter	Case (n=200)	Control (n=200)	t-value	p-value
Body Fat % (Mean ± SD)	30.35 ± 5.1	25.83 ± 2.4	11.53	<0.01

Diabetic cases had a significantly higher mean body fat percentage than controls.

Table 10: Fat free mass (%)

Parameter	Case (n=200)	Control (n=200)	t-value	p-value
Fat Free Mass % (Mean ± SD)	50.7 ± 7.65	52.46 ± 7.2	−2.38	0.01

Table 11: Fat free mass index (FFMI)

Parameter	Case (n=200)	Control (n=200)	t-value	p-value
Body FFMI (Mean ± SD)	17.74 ± 1.9	18.29 ± 2.1	−3.15	0.02

Both fat free mass and fat free mass index were significantly lower in the diabetic group, the reduction persisting after adjustment for stature.

DISCUSSION

The present study compared body composition in 200 diabetic cases and 200 age- and sex-matched non-diabetic controls at SCB Medical College and Hospital, Cuttack, using bioelectrical impedance analysis.

The two groups were well matched for gender (40% female, 60% male) and comparable in age (mean 50.7 vs 49.4 years). Diabetic cases were shorter (163.0 cm vs 169.26 cm) yet heavier (72.9 kg vs 70.8 kg) than controls, a finding that aligns with the established understanding that diabetes is frequently a disease of the overweight and obese.[5] The cases had long-standing disease, with a mean duration of 12.3 years, and demonstrated markedly elevated fasting (147.43 mg/dl) and postprandial (227.8 mg/dl) glucose despite therapy, consistent with hyperglycaemia being the defining phenotype of diabetes mellitus.[6]

Body fat percentage was significantly higher in cases (30.35%) than in controls (25.83%, $p<0.01$). This finding is in harmony with the work of Chait and den Hartigh, who linked increased adipose tissue to a greater risk of diabetes mellitus and cardiovascular disease.[7] Similarly, Kurniawan et al reported a body fat percentage of 26.33% in insulin-resistant subjects compared with 19.46% in non-insulin-resistant individuals, and concluded that total body fat predicted insulin resistance better than waist circumference or BMI.[8]

The corresponding observation on the lean side of the equation is arguably the more instructive one. Fat free mass (50.7% vs 52.46%, $p=0.01$) and fat free mass index (17.74 vs 18.29, $p=0.02$) were both significantly lower in diabetics. Because FFMI normalises lean tissue to the square of height, the persistence of the deficit after this adjustment indicates that the reduced fat free mass in the diabetic group is not merely an artefact of their shorter stature. The pattern reflects the reduced skeletal muscle mass characteristic of the Asian Indian phenotype,[4] and may be compounded by the abnormalities of whole-body protein metabolism described in type 2 diabetes, in which impaired protein anabolism adversely affects the maintenance of muscle mass.[9] Fatty infiltration of muscle with altered fibre distribution, reported in individuals with excess adiposity, offers a further mechanism by which the quality as well as the quantity of lean tissue may be compromised.[10]

Taken together, these findings describe a reciprocal shift in body composition: diabetic subjects carry proportionally more fat and less lean tissue than non-diabetic subjects of similar age and sex. This is of practical relevance because BMI, the measure most often recorded in routine diabetic care, cannot detect such a shift; the diabetic and control groups in this study differed by only a small margin in weight, yet differed substantially in the composition of that weight. Body composition assessment by bioelectrical impedance is inexpensive, rapid and non-invasive, and may therefore add clinically meaningful information to the routine evaluation of the diabetic patient.

Certain findings could not be corroborated or refuted owing to the paucity of existing literature directly examining fat free mass index in Indian type 2 diabetics, underscoring the novelty of this work.

CONCLUSION

Type 2 diabetics experience abnormal fat deposition linked to metabolic dysregulation, with progressive worsening as disease duration advances. This study demonstrated that patients with long-standing type 2 diabetes have a significantly higher body fat percentage and significantly lower fat free mass and fat free mass index than age- and sex-matched non-diabetic controls. The deficit in lean tissue persisted after adjustment for stature, indicating a genuine reduction in the lean compartment rather than a consequence of body size. Body composition assessment may therefore serve as a useful clinical adjunct in monitoring diabetic progression.

Limitations: The findings should be interpreted in light of the relatively small sample size, limited resources, and interference in participants' health-seeking behaviour caused by the COVID-19 pandemic during the study period. Bioelectrical impedance, while practical, is an indirect method of body composition assessment and is sensitive to hydration status.

Recommendations: Further research is warranted on body composition and its relationship with diabetes mellitus, particularly longitudinal work tracking the lean compartment against disease duration, and studies assessing the impact of lifestyle modification on the fat–lean balance.

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