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# A Study of association between self-reported physical activity and adiposity measures with Glycemic control among Type II Diabetes Mellitus- A Hospital based Cross-sectional study

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**Abstract**
**Background:** *Physical inactivity and excess adiposity are well-established contributors to poor glycemic control in type 2 diabetes mellitus (T2DM). Data on self-reported physical activity (SRPA) and adiposity patterns among T2DM patients with high mean HbA1c in urban South Indian private clinic settings remain limited.*
**Objectives:** *To determine SRPA levels, BMI-based general obesity, and visceral obesity (by bipolar bioelectrical impedance analysis), and to assess their association with glycemic status in T2DM patients with high mean HbA1c.*
**Methods:** *A cross-sectional study was conducted among 300 T2DM patients attending a private diabetes clinic in a South Indian city. SRPA was assessed using a WHO questionnaire-based tool. Adiposity was evaluated by BMI (general obesity) and bipolar bioelectrical impedance analysis (visceral obesity). Glycemic status was assessed by fasting blood glucose (FBG), postprandial blood glucose (PPBG), and HbA1c. Statistical analysis included descriptive statistics, chi-square test, Pearson's correlation, and binary logistic regression.*
**Results:** *The mean HbA1c was 9.4 ± 1.6%. Majority (68.3%) were physically inactive by SRPA criteria. General obesity (BMI ≥25 kg/m²) was present in 71.7% and elevated visceral fat (≥10 units) in 63.3% of participants. Physical inactivity, general obesity, and visceral obesity were each significantly associated with poor glycemic control (p<0.001). On logistic regression, physical inactivity (OR 2.84, 95% CI 1.74–4.63) and elevated visceral fat (OR 2.31, 95% CI 1.42–3.76) were independent predictors of high HbA1c.*
**Conclusion:** *Physical inactivity and adiposity — both general and visceral — are prevalent and independently associated with poor glycemic control in South Indian T2DM patients. Structured lifestyle interventions targeting these modifiable risk factors are urgently warranted.*
**Keywords:** *Type 2 diabetes mellitus, self-reported physical activity, adiposity, HbA1c, bioelectrical impedance analysis.*

## 1. Introduction

Type 2 diabetes mellitus (T2DM) is a major global public health challenge, with India bearing one of the highest burdens of the disease. As of 2023, India had an estimated 101 million people living with diabetes, representing a significant escalation from prior decades.[1] Urban South India, in particular, has reported some of the highest prevalence rates in the country, attributed to rapid urbanisation, sedentary lifestyles, dietary transition, and genetic predisposition.[2]

Glycated haemoglobin (HbA1c) is the gold standard for assessing long-term glycemic control in T2DM. A high mean HbA1c (generally ≥8%) in a patient population signals suboptimal glycemic management and is associated with an elevated risk of microvascular and macrovascular complications, including diabetic nephropathy, retinopathy, neuropathy, and cardiovascular disease.[3] Understanding the modifiable determinants of persistently elevated HbA1c is therefore of paramount clinical importance.

Physical activity is one of the most influential and modifiable determinants of glycemic control. Regular physical activity improves insulin sensitivity, enhances glucose uptake in skeletal muscle, and reduces visceral adiposity — all of which contribute to better HbA1c values.[4] However, assessment of physical activity in clinical practice remains challenging. Self-reported physical activity (SRPA), assessed using validated questionnaire-based tools, offers a pragmatic, low-cost method applicable in resource-limited settings including private outpatient clinics.[5] The WHO has recommended structured questionnaire-based assessment of physical activity as a feasible approach for population and clinical surveillance.[6]

Adiposity, encompassing both general obesity and visceral obesity, plays a distinct and complex role in T2DM pathophysiology. While BMI-based general obesity captures excess overall body weight, visceral fat — quantified by bioelectrical impedance analysis (BIA) — more accurately reflects the metabolically active, insulin-resistant adipose compartment surrounding abdominal organs.[7] Visceral adiposity is associated with increased secretion of pro-inflammatory adipokines, impaired beta-cell function, and hepatic insulin resistance, all of which contribute directly to deteriorating glycemic control.[8] Bipolar BIA, a non-invasive, point-of-care method, has gained increasing validation for visceral fat estimation in clinical settings, including in Indian populations.[9]

Despite the well-established individual relationships between physical inactivity, adiposity, and poor glycemic control, integrated studies simultaneously evaluating SRPA, BMI-based general obesity, and BIA-based visceral obesity and their combined association with glycemic status in T2DM patients attending private clinics in South India are scarce. Private clinics serve a large proportion of urban T2DM patients in India and may have patient profiles distinct from tertiary hospital cohorts, including differences in socioeconomic characteristics, treatment adherence, and lifestyle behaviours.[10]

The present study was therefore conducted with the objective of determining SRPA levels, BMI-based general obesity, and visceral obesity by bipolar BIA, and assessing their association with glycemic status in T2DM patients having a high mean HbA1c attending a private clinic in a South Indian city.

## 2. Methodology

### 2.1 Study Design and Setting

This was a cross-sectional observational study conducted at a private diabetes clinic in Bengaluru, a metropolitan city in South India. The study was conducted over a period of twelve months.

### 2.2 Sample Size

The sample size was calculated using the formula $n = Z^2pq/d^2$, based on an estimated prevalence of physical inactivity of 65% among T2DM patients in South India,[11] with 95% confidence interval and 5% allowable error, yielding a minimum required sample of 277. A final sample of 300 was enrolled to account for attrition and improve precision.

### 2.3 Inclusion Criteria

Patients aged 30–70 years with a confirmed diagnosis of T2DM (as per ADA criteria) for at least one year, attending the clinic for routine follow-up, with a documented mean HbA1c ≥8% on at least two consecutive readings within the preceding six months, and who provided written informed consent were included.

### 2.4 Exclusion Criteria

Patients with type 1 diabetes, gestational diabetes, secondary diabetes, severe renal or hepatic disease, active malignancy, chronic inflammatory conditions, implanted pacemakers or metallic implants (precluding BIA), pregnancy, or those unable to complete the questionnaire due to cognitive or language barriers were excluded.

### 2.5 Data Collection

A structured interviewer-administered pro forma was used to collect sociodemographic data (age, sex, education, occupation, duration of diabetes, treatment details) and clinical history. All assessments were performed during a single clinic visit.

### 2.6 Assessment of Self-Reported Physical Activity (SRPA)

SRPA was assessed using the WHO Global Physical Activity Questionnaire (GPAQ), adapted for the study setting. The GPAQ evaluates physical activity across three domains: work-related activity, transport-related activity, and recreational/leisure-time activity. Total physical activity was expressed in metabolic equivalent of task minutes per week (MET-min/week). Participants were classified as:

- Physically active: ≥600 MET-min/week (meeting WHO minimum recommendations)
- Physically inactive:<600 MET-min/week[12]

### 2.7 Anthropometric Measurements

Height was measured using a stadiometer to the nearest 0.1 cm and weight using a calibrated digital weighing scale. BMI was calculated as weight (kg)/height² (m²). Participants were classified per WHO Asian cut-offs as:

- Underweight: <18.5 kg/m²
- Normal weight: 18.5–22.9 kg/m²
- Overweight: 23.0–24.9 kg/m²
- Obese: ≥25.0 kg/m²[13]

### 2.8 Assessment of Visceral Obesity by Bipolar Bioelectrical Impedance Analysis

Visceral fat level was measured using a calibrated bipolar BIA device (Omron HBF-375, Japan) in the fasting state, with participants barefoot and in light clothing, following standard protocol. Visceral fat level was expressed on a scale of 1–30. A visceral fat level of ≥10 was considered indicative of elevated visceral obesity as per manufacturer and published reference values validated in Asian populations.[9,14]

### 2.9 Biochemical Investigations

Venous blood samples were collected in the fasting state. Fasting blood glucose (FBG) and postprandial blood glucose (PPBG, 2 hours after a standard 75 g oral glucose load) were measured by the glucose oxidase-peroxidase method. HbA1c was measured by high-performance liquid chromatography (HPLC). Poor glycemic control was defined as HbA1c ≥8%.

### 2.10 Statistical Analysis

Data were entered in Microsoft Excel and analysed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation (SD) and categorical variables as frequency and percentage. The chi-square test was used to assess associations between categorical variables. Pearson's correlation coefficient was used to assess correlations between continuous variables. Binary logistic regression was performed to identify independent predictors of poor glycemic control (HbA1c ≥8%), with results expressed as odds ratios (OR) with 95% confidence intervals (CI). A p-value of <0.05 was considered statistically significant.

### 2.11 Ethical Considerations

The study was approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants. Confidentiality of data was maintained throughout the study.

## 3. Results

A total of 300 T2DM patients were enrolled. The mean age was 54.3 ± 9.1 years. The male-to-female ratio was approximately 1.1:1 (53.3% male, 46.7% female). The mean duration of diabetes was 7.8 ± 4.3 years. The mean HbA1c of the study population was

9.4 ± 1.6%, confirming a high mean HbA1c cohort. All participants had HbA1c ≥8% consistent with the inclusion criteria.

**Table 1:** Sociodemographic and clinical characteristics of study participants (n=300)

| Characteristic | n (%) or Mean ± SD |
|---|---|
| Age (years) | 54.3 ± 9.1 |
| Sex — Male | 160 (53.3%) |
| Sex — Female | 140 (46.7%) |
| Education — Primary or below | 62 (20.7%) |
| Education — Secondary | 98 (32.7%) |
| Education — Graduate and above | 140 (46.7%) |
| Occupation — Sedentary | 189 (63.0%) |
| Occupation — Moderate activity | 78 (26.0%) |
| Occupation — Active | 33 (11.0%) |
| Duration of diabetes (years) | 7.8 ± 4.3 |
| Treatment — OHA alone | 178 (59.3%) |
| Treatment — Insulin ± OHA | 122 (40.7%) |
| Family history of T2DM | 198 (66.0%) |
| Mean FBG (mg/dL) | 176.4 ± 38.2 |
| Mean PPBG (mg/dL) | 248.7 ± 52.6 |
| Mean HbA1c (%) | 9.4 ± 1.6 |

OHA: Oral hypoglycaemic agents; FBG: Fasting blood glucose; PPBG: Postprandial blood glucose

**Table 2:** Distribution of SRPA levels among study participants (n=300)

| SRPA Category | n (%) |
|---|---|
| Physically active (≥600 MET-min/week) | 95 (31.7%) |
| Physically inactive (<600 MET-min/week) | 205 (68.3%) |
| Mean total MET-min/week | 412.6 ± 284.3 |
| Work-domain activity (MET-min/week) | 198.4 ± 162.7 |
| Transport-domain activity (MET-min/week) | 124.3 ± 98.5 |
| Recreational-domain activity (MET-min/week) | 89.9 ± 74.6 |

MET: Metabolic equivalent of task; SRPA: Self-reported physical activity

The majority of participants (68.3%) were physically inactive by WHO GPAQ criteria. Among those classified as active, most met recommendations through work-domain activity rather than recreational exercise.

**Table 3:** Distribution of adiposity measures among study participants (n=300)

| Adiposity Measure | Category | n (%) |
|---|---|---|
| BMI (kg/m²) | Mean ± SD | 27.6 ± 4.1 |
| | Underweight (<18.5) | 6 (2.0%) |
| | Normal (18.5–22.9) | 48 (16.0%) |
| | Overweight (23.0–24.9) | 31 (10.3%) |
| | Obese (≥25.0) | 215 (71.7%) |
| Visceral Fat Level | Mean ± SD | 11.4 ± 3.2 |
| | Normal (<10) | 110 (36.7%) |
| | Elevated (≥10) | 190 (63.3%) |

General obesity (BMI ≥25 kg/m²) was present in 71.7% of participants. Elevated visceral fat (≥10 units) was found in 63.3%. A significant proportion of participants showed concurrent general and visceral obesity (58.7%, data not shown in table).

**Table 4:** Glycemic parameters by SRPA category

| Glycemic Parameter | Physically Active (n=95) Mean ± SD | Physically Inactive (n=205) Mean ± SD | p-value |
|---|---|---|---|
| FBG (mg/dL) | 158.3 ± 31.4 | 184.7 ± 39.6 | <0.001 |
| PPBG (mg/dL) | 224.6 ± 44.8 | 260.4 ± 54.3 | <0.001 |
| HbA1c (%) | 8.6 ± 1.2 | 9.8 ± 1.6 | <0.001 |

Physically inactive participants had significantly higher mean FBG, PPBG, and HbA1c compared to active participants (p<0.001 for all).

**Table 5:** Glycemic parameters by BMI category (Normal/Overweight vs Obese)

| Glycemic Parameter | BMI <25 kg/m² (n=85) Mean ± SD | BMI ≥25 kg/m² (n=215) Mean ± SD | p-value |
|---|---|---|---|
| FBG (mg/dL) | 161.2 ± 29.8 | 182.6 ± 40.3 | <0.001 |
| PPBG (mg/dL) | 228.4 ± 46.2 | 257.8 ± 53.7 | <0.001 |
| HbA1c (%) | 8.7 ± 1.3 | 9.7 ± 1.7 | <0.001 |

Obese participants (BMI ≥25 kg/m²) had significantly higher FBG, PPBG, and HbA1c compared to non-obese participants (p<0.001).

**Table 6:** Glycemic parameters by visceral fat category

| Glycemic Parameter | Normal Visceral Fat (n=110) Mean ± SD | Elevated Visceral Fat (n=190) Mean ± SD | p-value |
|---|---|---|---|
| FBG (mg/dL) | 159.7 ± 30.6 | 186.2 ± 40.8 | <0.001 |
| PPBG (mg/dL) | 226.3 ± 43.9 | 261.8 ± 55.1 | <0.001 |
| HbA1c (%) | 8.6 ± 1.2 | 9.9 ± 1.6 | <0.001 |

Participants with elevated visceral fat had significantly higher mean FBG, PPBG, and HbA1c compared to those with normal visceral fat (p<0.001).

**Table 7:** Correlation of SRPA and adiposity measures with HbA1c

| Variable | Pearson's r | p-value |
|---|---|---|
| Total MET-min/week | −0.412 | <0.001 |
| BMI (kg/m²) | +0.368 | <0.001 |
| Visceral fat level | +0.441 | <0.001 |
| FBG (mg/dL) | +0.583 | <0.001 |
| PPBG (mg/dL) | +0.612 | <0.001 |

Total MET-min/week showed a significant negative correlation with HbA1c (r = −0.412, p<0.001), indicating that higher physical activity was associated with lower HbA1c. Both BMI (r = +0.368) and visceral fat level (r = +0.441) showed significant positive correlations with HbA1c.

**Table 8:** Binary logistic regression — Independent predictors of poor glycemic control (HbA1c ≥8%)

| Predictor Variable | β | OR | 95% CI | p-value |
|---|---|---|---|---|
| Physical inactivity (SRPA <600 MET-min/week) | 1.044 | 2.84 | 1.74–4.63 | <0.001 |
| General obesity (BMI ≥25 kg/m²) | 0.789 | 2.20 | 1.31–3.69 | 0.003 |
| Elevated visceral fat (≥10 units) | 0.838 | 2.31 | 1.42–3.76 | 0.001 |
| Duration of diabetes >7 years | 0.612 | 1.84 | 1.12–3.04 | 0.016 |
| Sedentary occupation | 0.524 | 1.69 | 1.03–2.76 | 0.037 |

OR: Odds ratio; CI: Confidence interval. Model adjusted for age, sex, treatment type, and duration of diabetes.

On binary logistic regression, physical inactivity (OR 2.84, 95% CI 1.74–4.63, p<0.001), general obesity (OR 2.20, 95% CI 1.31–3.69, p=0.003), and elevated visceral fat (OR 2.31, 95% CI 1.42–3.76, p=0.001) were significant independent predictors of poor glycemic control after adjustment for confounders.

**Figure 1.** Mean HbA1c (%) by self-reported physical activity status across adiposity subgroups. p<0.001 for all between-group comparisons. Error bars represent ±1 SD.

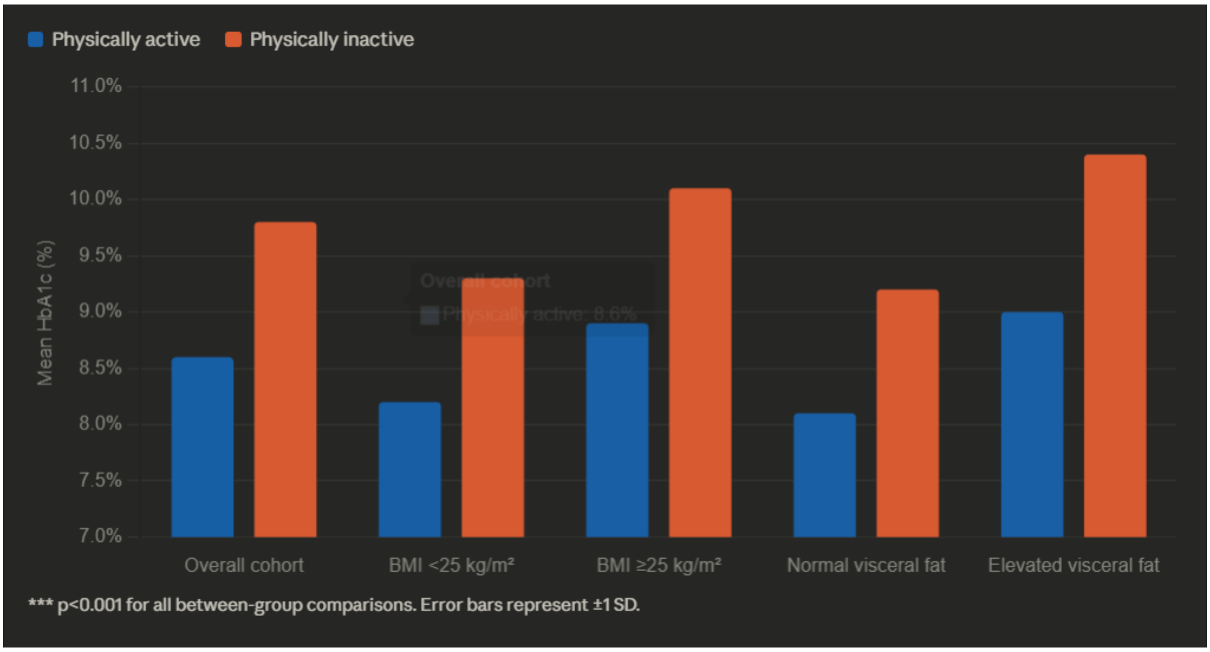
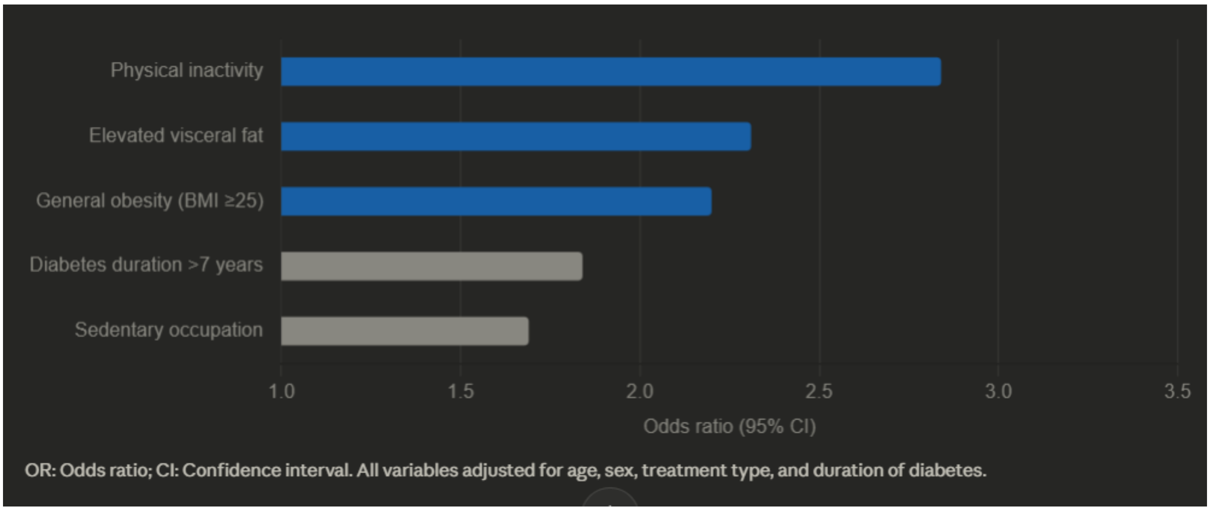


**Figure 2.** Independent predictors of poor glycemic control (HbA1c ≥8%) on binary logistic regression. Values represent odds ratios; horizontal bars represent 95% confidence intervals. All variables adjusted for age, sex, treatment type, and duration of diabetes.




**4. Discussion**

This cross-sectional study examined SRPA, BMI-based general obesity, and BIA-based visceral obesity and their association with glycemic control in 300 T2DM patients with high mean HbA1c attending a private clinic in South India. The mean HbA1c of 9.4 ± 1.6% in our cohort reflects the substantial burden of glycemic non-attainment prevalent in this clinical setting, consistent with the findings of Anjana et al., who reported that only 28.6% of T2DM patients in India achieved an HbA1c <7%.[15]

**Physical Inactivity**

A high prevalence of physical inactivity (68.3%) was observed in the present study. This aligns with data from the Indian Council of Medical Research-India Diabetes (ICMR-INDIAB) study, which reported widespread sedentariness among urban South Indian adults with T2DM.[2] Reutrakul and Van Cauter[16] have elaborated on the mechanistic pathways by which physical inactivity impairs glycemic regulation, including reduced GLUT-4 translocation, decreased skeletal muscle insulin sensitivity, and increased hepatic glucose output. The predominantly sedentary occupational profile (63.0%) of our participants likely contributed significantly to the low levels of total physical activity. In the present study, physically inactive participants had significantly higher mean HbA1c (9.8 ± 1.6%) compared to active participants (8.6 ± 1.2%, p<0.001), and physical inactivity was the strongest independent predictor of poor glycemic control on logistic regression (OR 2.84). These findings are consistent with Umpierre et al.,[17] who demonstrated in a systematic review that structured exercise interventions significantly reduced HbA1c in T2DM, and with Colberg et al.,[18] who documented the beneficial effects of both aerobic and resistance exercise on glycemic outcomes.

The use of WHO GPAQ for SRPA assessment in the present study is a methodological strength, as GPAQ has been validated across multiple low- and middle-income country settings and captures physical activity across all three life domains.[12] However, it is acknowledged that SRPA tools are subject to social desirability bias and recall error, potentially leading to overestimation of activity levels — which would suggest the true prevalence of inactivity in this population may even be higher than reported.[19]

**General Obesity (BMI-based)**

General obesity (BMI ≥25 kg/m²) was present in 71.7% of participants, which is substantially higher than age-matched general South Indian urban population estimates, reflecting the well-established bidirectional relationship between T2DM and obesity.[20] The WHO Asian BMI cut-offs used in this study (obese ≥25 kg/m²) are appropriate for the Indian population given the well-documented higher cardiometabolic risk at lower BMI values compared to Caucasian populations.[13] Obese participants had significantly higher HbA1c (9.7 ± 1.7% vs 8.7 ± 1.3%, $p<0.001$), consistent with findings by Bhupathiraju and Hu[21] and with Ganz et al.,[22] who demonstrated that increasing BMI was associated with progressively worsening glycemic control in T2DM patients. The significant positive correlation between BMI and HbA1c ($r = +0.368$, $p<0.001$) in our study underscores this relationship.

**Visceral Obesity (BIA-based)**

Visceral obesity, assessed by bipolar BIA, was present in 63.3% of participants. Visceral fat level showed the strongest positive correlation with HbA1c ($r = +0.441$) among all adiposity measures in the present study, and was an independent predictor of poor glycemic control on logistic regression (OR 2.31, 95% CI 1.42–3.76). These findings are consistent with the established role of visceral adipose tissue as a metabolically active depot driving insulin resistance, hepatic lipotoxicity, and systemic inflammation.[8] Nieves et al.[23] and Matsuzawa[24] have highlighted the central role of visceral fat in the metabolic syndrome and T2DM progression.

Bipolar BIA is increasingly validated as a practical tool for visceral fat estimation in clinical settings. Studies by Rao et al.[9] and Bosy-Westphal et al.[25] have demonstrated acceptable correlation between BIA-derived visceral fat estimates and computed tomography (CT)-based reference measures, particularly in Asian populations, supporting the validity of BIA-based visceral fat assessment in this study. Notably, visceral fat level correlated more strongly with HbA1c than BMI in our study ($r = +0.441$ vs $r = +0.368$), suggesting that visceral adiposity may be a more clinically relevant adiposity metric than overall body weight in T2DM management.

**Concurrent Physical Inactivity and Adiposity**

The interplay between physical inactivity and adiposity in our cohort is important. Sedentary behaviour promotes fat accumulation — particularly visceral fat — which in turn worsens insulin resistance and perpetuates glycemic non-attainment.[4] The concurrent prevalence of physical inactivity (68.3%), general obesity (71.7%), and visceral obesity (63.3%) in our cohort indicates a compounding adverse metabolic milieu contributing to the high mean HbA1c observed. The finding that sedentary occupation was also an independent predictor of poor glycemic control (OR 1.69) further reinforces the importance of occupational physical activity patterns in this population.

**Study Strengths and Limitations**

Strengths of the study include a reasonably sized sample (n=300), the simultaneous evaluation of SRPA, general obesity, and visceral obesity in the same cohort, the use of validated tools (WHO GPAQ, BIA), and robust laboratory glycemic assessment including HbA1c by HPLC. Limitations include the cross-sectional design, which precludes causal inference; the use of SRPA rather than objective accelerometry; single-point BIA measurement; and recruitment from a single private clinic, potentially limiting generalisability to public hospital or rural settings.

## 5. Conclusion

In T2DM patients with high mean HbA1c attending a private clinic in South India, physical inactivity, general obesity, and visceral obesity are highly prevalent and independently associated with poor glycemic control. Visceral fat level, measured by bipolar BIA, demonstrated a stronger association with HbA1c than BMI, underscoring its clinical relevance as an adiposity metric in T2DM management. Physical inactivity was the strongest independent predictor of high HbA1c in this cohort. These findings highlight the urgent need for targeted, structured lifestyle interventions — incorporating both regular physical activity promotion and adiposity reduction strategies — as integral components of T2DM management in the private clinic setting. Routine SRPA assessment and BIA-based visceral fat measurement are feasible, low-cost approaches that should be incorporated into standard T2DM clinical care in South India.

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