



Physical Activity Patterns and Glycemic Control (HbA1c) Among Adults With Type 2 Diabetes Attending an Urban Health Training Centre in Telangana, India: A Cross-Sectional Study

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ABSTRACT :

Introduction: Regular physical activity is a cornerstone of type 2 diabetes mellitus (T2DM) management, yet locally relevant primary-care data from India remain limited.

Aim: To describe physical activity patterns and examine their cross-sectional association with glycated hemoglobin (HbA1c) among adults with T2DM attending an urban health training centre (UHTC) in Karimnagar, Telangana.

Methods: This cross-sectional study (May–December 2024) included 320 outpatients aged 30–70 years with T2DM of ≥ 1 year's duration. Physical activity was measured with the WHO Global Physical Activity Questionnaire (GPAQ) and classified as low (<600), moderate (600–1500) or high (>1500 MET-min/week). HbA1c was measured by NGSP-certified HPLC. Groups were compared by one-way ANOVA with Tukey post-hoc tests; association was assessed by Spearman correlation and multivariable logistic regression (outcome HbA1c $<7.0\%$).

Results: Of 320 participants (mean age 52.8 ± 8.4 years; 53.4% men), 136 (42.5%) had low, 122 (38.1%) moderate and 62 (19.4%) high activity. Mean HbA1c fell stepwise: $8.64 \pm 1.12\%$, $7.38 \pm 0.88\%$ and $6.48 \pm 0.54\%$ (ANOVA $p < 0.001$; low vs high difference 2.16 percentage points, 95% CI 1.82–2.50). Activity correlated inversely with HbA1c (Spearman $\rho = -0.642$, $p < 0.001$). Activity ≥ 600 MET-min/week was associated with higher odds of HbA1c $<7.0\%$ (adjusted OR 3.42, 95% CI 2.12–5.52). Occupational activity contributed 51.2% of total activity, transport 28.4% and recreation 20.4%.

Conclusions: Higher self-reported physical activity was strongly and inversely associated with HbA1c, and most activity was occupational rather than recreational. The cross-sectional design precludes causal inference and the effect sizes likely include confounding. Brief activity assessment and individualized counseling should be integrated into routine diabetes care, with prospective evaluation.

Keywords: type 2 diabetes; physical activity; GPAQ; HbA1c; glycemic control; primary care; India; cross-sectional study

Introduction

Type 2 diabetes mellitus (T2DM) is a major and growing public-health challenge worldwide, affecting an estimated 589 million adults aged 20–79 years in 2024 [1]. India carries one of the largest burdens: the ICMR–INDIAB national survey estimated that about 101 million people were living with diabetes in India [2,3], and diabetes is increasingly reported from urban and semi-urban Indian settings [4]. Long-term glycemic management combines pharmacotherapy with nutrition, physical activity, sleep and other self-management behaviors, and HbA1c remains the principal marker of medium-term glycemia and prognosis [5,6].

Physical activity improves insulin sensitivity and increases insulin-independent glucose uptake in contracting skeletal muscle [7], and it supports weight, blood-pressure and cardiovascular risk management. Randomized trials and meta-analyses show that structured aerobic, resistance or combined training lowers HbA1c in T2DM [8–10], with network meta-analytic evidence supporting several exercise modalities [11]. Observational data also link higher activity to lower cardiovascular and all-cause mortality among people with diabetes [12,13]. Current international guidance recommends regular aerobic activity, resistance exercise where appropriate, and reduced prolonged sitting, individualized to functional status, complications and treatment [14–17].

Physical activity is multidimensional. Work-related movement and active transport may contribute heavily to total activity in India, where more than half of adults have been classified as insufficiently active [18], while planned leisure-time exercise can be limited by working hours, heat, safety and facilities. The WHO Global Physical Activity Questionnaire (GPAQ) provides a standardized self-report approach across work, transport and recreation domains [19,20], although self-report overestimates activity relative to direct measures [21]. Evidence describing the domain structure of activity and its relationship with HbA1c among patients in routine Indian urban primary care is limited.

We therefore studied physical activity patterns and their association with HbA1c among adults with T2DM attending the Urban Health Training Centre (UHTC), Mankamthota, Karimnagar, Telangana, to inform practical counseling in primary care.

The objectives were (1) to describe physical activity levels across work, transport and recreation domains, (2) to compare HbA1c levels across physical activity categories, and (3) to estimate the association between physical activity and HbA1c, including the adjusted association with achieving HbA1c <7.0%.

Materials and Methods

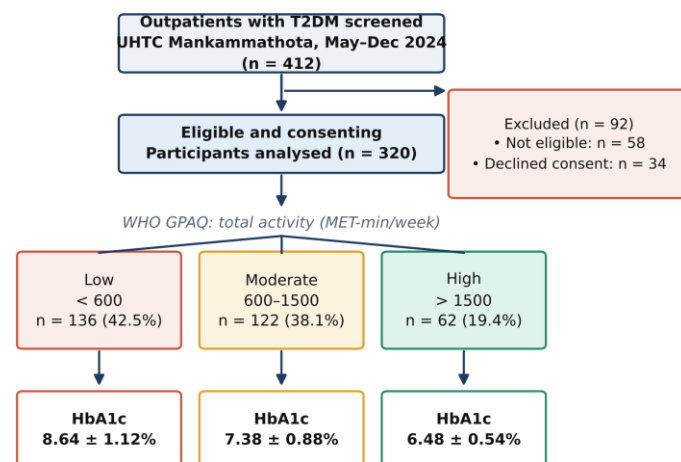
Study design, setting and reporting

This was a facility-based cross-sectional observational study conducted at the UHTC, Mankamthota, affiliated with Prathima Institute of Medical Sciences, Karimnagar, Telangana, India, from May to December 2024. The study is reported in accordance with the STROBE statement for cross-sectional studies [22].

Participants and sample size

Eligible participants were adults aged 30–70 years with a confirmed diagnosis of T2DM for at least one year. Exclusion criteria were locomotor disability limiting activity assessment, severe cardiovascular comorbidity (including recent myocardial infarction or unstable angina), end-stage renal disease requiring haemodialysis, pregnancy, and refusal of consent. Of 412 outpatients screened, 92 were excluded (58 ineligible; 34 declined consent), leaving 320 participants for analysis (Figure 1).

The minimum sample size was calculated with Cochran's formula assuming a 40% prevalence of the outcome of interest, 5% absolute precision and 95% confidence, giving approximately 369 participants. After adjustment for finite-population size and anticipated non-response, the final target was 320.



Cross-sectional comparison of HbA1c across activity categories (ANOVA, Tukey post-hoc)

Figure 1. Participant flow (STROBE) and analytic groups. T2DM, type 2 diabetes mellitus; GPAQ, Global Physical Activity Questionnaire; MET, metabolic equivalent of task; UHTC, Urban Health Training Centre.

Measures

Physical activity was assessed with the WHO GPAQ across work, transport and recreation domains [19,20]. Vigorous activity was assigned 8 METs and moderate activity and transport 4 METs, and total activity was expressed as MET-minutes/week. Participants were categorized as low (<600), moderate (600–1500) or high (>1500 MET-min/week).

HbA1c was measured in venous blood by an NGSP-certified high-performance liquid chromatography (HPLC) method on a Bio-Rad VARIANT II Turbo analyzer. Target glycemic control was defined as HbA1c <7.0%, in line with ADA glycemic goals for many non-pregnant adults [6]. Fasting plasma glucose was measured by the glucose oxidase–peroxidase method. Age, sex, body mass index (BMI), systolic blood pressure, diabetes duration and pharmacotherapy (monotherapy vs combination) were recorded.

Table 1. Study variables, measurement and operational definitions.

Variable	Instrument / method	Coding in analysis
Physical activity (exposure)	WHO GPAQ (work, transport, recreation)	Total MET-min/week; low <600, moderate 600–1500, high >1500; binary ≥ 600 vs <600
HbA1c (outcome)	Venous blood, NGSP-certified HPLC (Bio-Rad VARIANT II Turbo)	Continuous (%); target control <7.0%
Fasting plasma glucose	Glucose oxidase–peroxidase	Continuous (mg/dL)
BMI	Measured weight and height	Continuous; <25 vs ≥ 25 kg/m ²
Systolic blood pressure	Clinic measurement	Continuous (mmHg)
Diabetes duration	Clinical record / history	Continuous; <5 vs ≥ 5 years
Age, sex	Interview	Years; <50 vs ≥ 50 ; men/women
Pharmacotherapy	Treatment record	Monotherapy vs combination therapy

GPAQ scoring: vigorous activity = 8 METs; moderate activity and transport = 4 METs; total = sum across domains (MET-min/week). HPLC, high-performance liquid chromatography; NGSP, National Glycohemoglobin Standardization Program.

Statistical analysis

Continuous variables are presented as mean $\pm$ standard deviation (SD) and categorical variables as numbers and percentages. Groups were compared by one-way ANOVA with Tukey's post-hoc test, and categorical variables by the chi-square test. The monotonic association between total activity and HbA1c was assessed by Spearman rank correlation. A multivariable binary logistic regression modelled HbA1c <7.0% as the outcome, with activity (≥ 600 vs <600 MET-min/week) as the exposure, adjusted for age, sex, BMI, diabetes duration, systolic blood pressure and pharmacotherapy; results are given as odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was set at two-sided $p < 0.05$.

Ethics

The study was approved by the Institutional Ethics Committee of Prathima Institute of Medical Sciences, Karimnagar (PIMS/IEC/2024/042). Written informed consent was obtained from all participants in Telugu or English before enrolment, in accordance with the Declaration of Helsinki.

Results

Participant characteristics

The analysis included 320 participants: 171 men (53.4%) and 149 women (46.6%), with mean age 52.8 ± 8.4 years and mean diabetes duration 6.4 ± 3.6 years. Compared with the low-activity group, participants with higher activity were younger, leaner, had lower blood pressure and shorter diabetes duration, and had lower fasting glucose (Table 2; Figure 4). Sex distribution did not differ across groups.

Table 2. Characteristics of participants by physical activity category.

Characteristic	Low (n=136)	Moderate (n=122)	High (n=62)	Total (N=320)	p-value
Age, years	54.6 ± 8.1	51.9 ± 8.5	50.1 ± 7.9	52.8 ± 8.4	<0.001
Men / women, n	68 / 68	69 / 53	34 / 28	171 / 149	0.557
BMI, kg/m ²	27.9 ± 3.4	25.3 ± 2.7	23.2 ± 2.2	26.0 ± 3.2	<0.001
Systolic BP, mmHg	134.2 ± 12.1	128.5 ± 10.4	124.1 ± 8.8	130.1 ± 11.2	<0.001
Diabetes duration, years	7.1 ± 3.8	6.0 ± 3.3	5.6 ± 3.2	6.4 ± 3.6	0.006
Fasting glucose, mg/dL	168.4 ± 32.5	138.2 ± 24.1	118.6 ± 16.4	147.2 ± 31.8	<0.001
HbA1c, %	8.64 ± 1.12	7.38 ± 0.88	6.48 ± 0.54	7.74 ± 1.28	<0.001

Values are mean $\pm$ SD unless stated. p-values: one-way ANOVA (continuous) and chi-square (sex). BP, blood pressure; BMI, body mass index.

Physical activity distribution and domains

Low activity was found in 136/320 participants (42.5%), moderate activity in 122/320 (38.1%) and high activity in 62/320 (19.4%). Occupational activity accounted for 51.2% of total reported activity, transport 28.4% and recreation 20.4% (Table 3; Figure 2).

Table 3. Distribution of physical activity categories and domain contributions.

Measure	n	%
Low activity (<600 MET-min/week)	136	42.5
Moderate activity (600–1500)	122	38.1
High activity (>1500)	62	19.4
Occupational domain (share of total activity)	—	51.2
Transport domain	—	28.4
Recreational domain	—	20.4

Domain values are the proportional contribution to total reported MET-min/week.

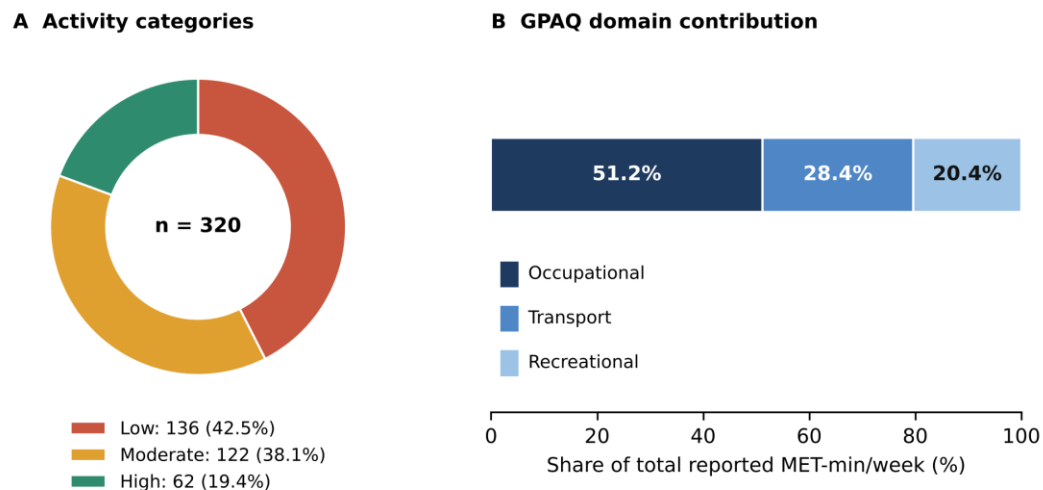


Figure 2. Physical activity profile of the study population. (A) Distribution of participants across activity categories. (B) Relative contribution of GPAQ domains to total activity.

HbA1c across activity categories

Mean HbA1c declined stepwise across activity categories: $8.64 \pm 1.12\%$ (low), $7.38 \pm 0.88\%$ (moderate) and $6.48 \pm 0.54\%$ (high) (one-way ANOVA $F(2,317) \approx 126.7$, $p < 0.001$). All Tukey pairwise comparisons were significant (Table 4; Figure 3). The mean group difference between low and high activity was 2.16 percentage points (95% CI 1.82–2.50).

Table 4. Tukey post-hoc pairwise comparisons of mean HbA1c between activity categories.

Comparison	Mean difference (percentage points)	95% CI	p-value
Low vs moderate	1.26	0.98 to 1.54	<0.001
Low vs high	2.16	1.82 to 2.50	<0.001
Moderate vs high	0.90	0.55 to 1.25	<0.001

Confidence intervals computed from group means, SDs and sample sizes using the pooled ANOVA error term.

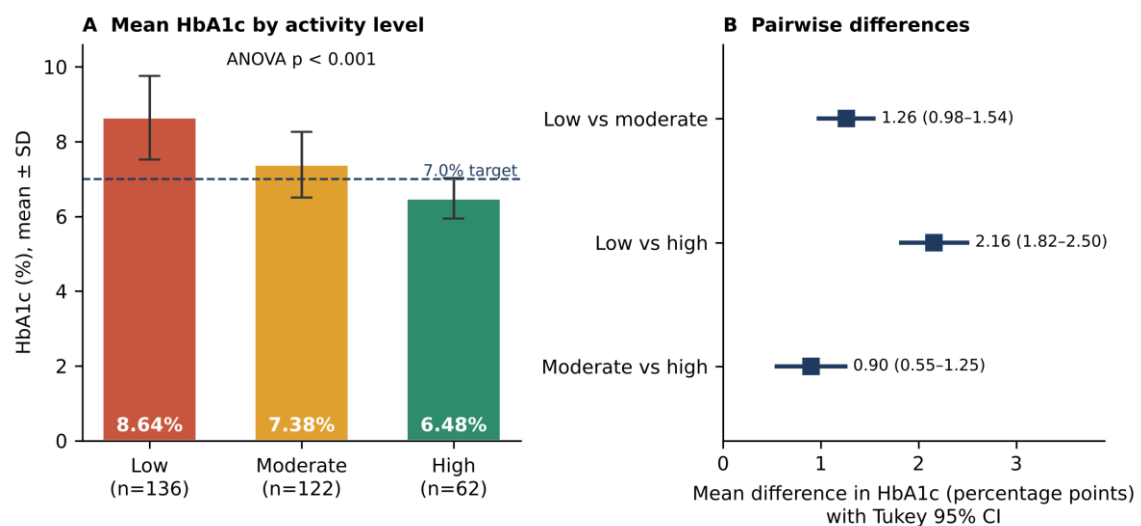
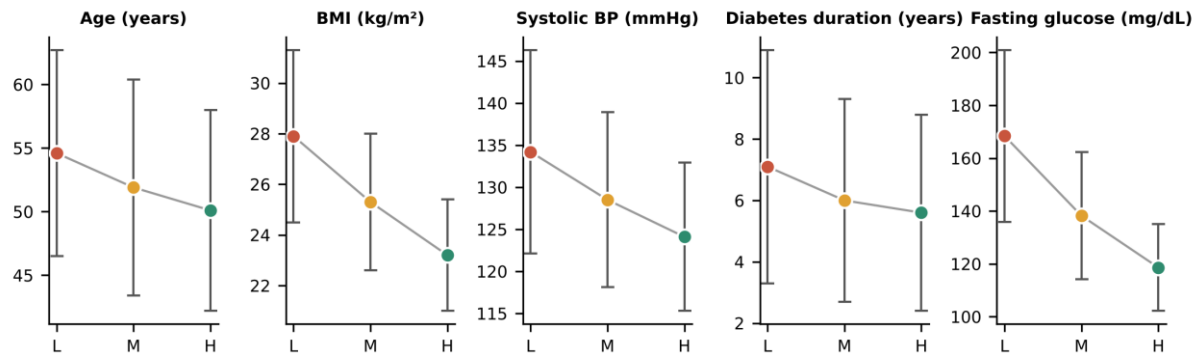


Figure 3. Glycemic control by physical activity category. (A) Mean HbA1c $\pm$ SD with the 7.0% target (dashed line). (B) Tukey pairwise mean differences with 95% confidence intervals.



Physical activity category (L = low, M = moderate, H = high); mean $\pm$ SD

Figure 4. Clinical gradients across activity categories (mean $\pm$ SD). Higher activity coincided with younger age, lower BMI, blood pressure, diabetes duration and fasting glucose.

Activity category accounted for a large proportion of the between-participant variance in HbA1c ($\eta^2 \approx 0.44$), and the standardized difference between low- and high-activity groups was very large (Cohen's $d \approx 2.5$ for HbA1c). Covariates were also unevenly distributed between these groups, most markedly BMI ($d \approx 1.6$), fasting glucose ($d \approx 1.9$) and systolic blood pressure ($d \approx 0.95$) (Figure 5). Effect sizes were derived from the group means and SDs in Table 2.

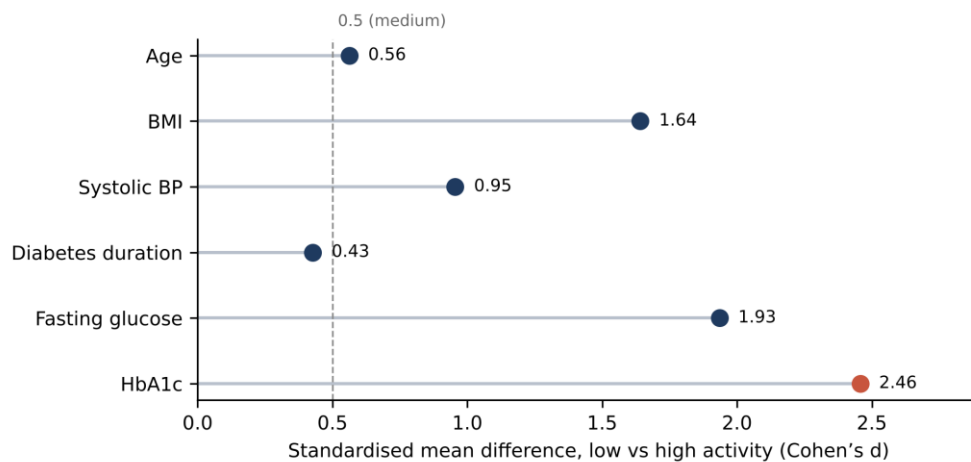


Figure 5. Standardized mean differences (Cohen's d , low vs high activity) for clinical variables, calculated from group means and SDs. The imbalance in BMI, blood pressure and fasting glucose illustrates the potential for confounding.

Correlation and regression

Total activity correlated inversely with HbA1c (Spearman $\rho = -0.642$, $p < 0.001$). In multivariable logistic regression, activity ≥ 600 versus < 600 MET-min/week was associated with an adjusted OR of 3.42 (95% CI 2.12–5.52; $p < 0.001$) for HbA1c $< 7.0\%$; BMI < 25 kg/m² was also independently associated (adjusted OR 1.75, 95% CI 1.08–2.84; $p = 0.023$). Diabetes duration, age and treatment regimen were not independently associated (Table 5; Figure 6).

Table 5. Logistic regression for achieving HbA1c $< 7.0\%$.

Predictor contrast	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	p-value
Activity ≥ 600 vs < 600 MET-min/week	4.12 (2.64–6.42)	3.42 (2.12–5.52)	< 0.001
BMI < 25 vs ≥ 25 kg/m ²	2.18 (1.41–3.38)	1.75 (1.08–2.84)	0.023
Diabetes duration < 5 vs ≥ 5 years	1.85 (1.20–2.86)	1.52 (0.94–2.45)	0.088
Age < 50 vs ≥ 50 years	1.45 (0.92–2.28)	1.21 (0.74–1.98)	0.442
Monotherapy vs combination therapy	1.62 (1.04–2.52)	1.38 (0.86–2.22)	0.182

OR, odds ratio; CI, confidence interval. p -values refer to adjusted estimates. The model was also adjusted for sex and systolic blood pressure.

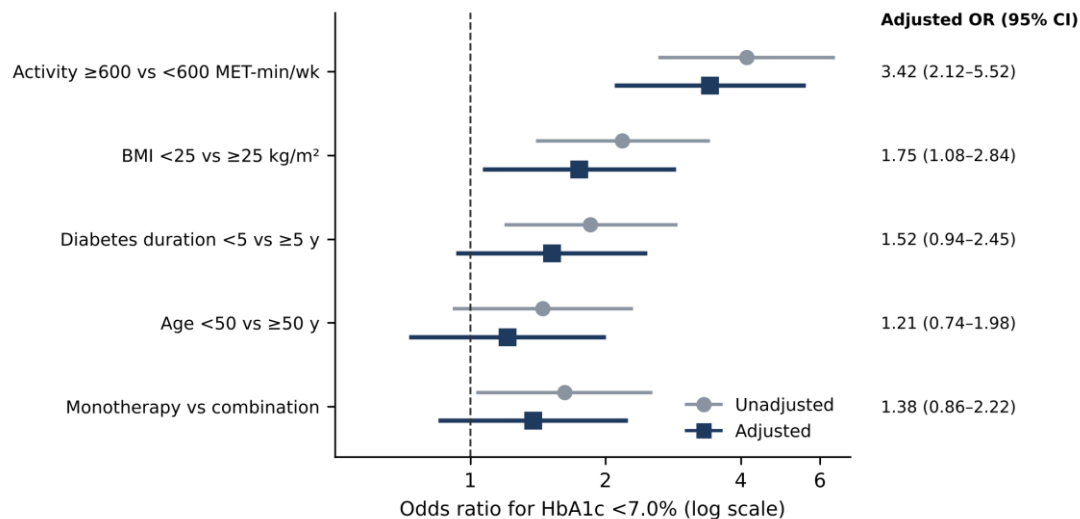


Figure 6. Forest plot of unadjusted and adjusted odds ratios for HbA1c <7.0% (log scale; dashed line = no association).

Discussion

In this clinic-based sample of adults with T2DM, higher self-reported physical activity was strongly and inversely associated with HbA1c, with a 2.16 percentage-point difference between the low- and high-activity groups, a moderate-to-strong rank correlation ($\rho = -0.642$) and a more than threefold adjusted odds of HbA1c <7.0% among those achieving ≥600 MET-min/week. The direction agrees with trial and meta-analytic evidence that exercise lowers HbA1c [8–11] and with cohort evidence that activity benefits people with diabetes [12,13,23].

The gradient is biologically plausible: muscle contraction stimulates GLUT4-mediated glucose uptake through partly insulin-independent pathways, and regular aerobic and resistance activity improves insulin sensitivity and cardiometabolic risk factors [7,24]. Breaking up prolonged sitting also improves postprandial glycemia [25], which suggests that even light activity may matter. Guidelines accordingly position activity as one component of individualized care [14–17].

However, the magnitude of the difference should be interpreted cautiously. Randomized trials report mean HbA1c reductions of roughly 0.3–0.7 percentage points with exercise training [8–10], far smaller than the between-group difference observed here. This gap indicates that factors beyond activity itself probably contribute. Participants in the higher-activity groups were younger, leaner, had lower blood pressure and shorter diabetes duration (Table 2), all of which relate to glycemic control. Reverse causation is also plausible: people with poorer control, higher weight or more complications may be less able to be active. Residual confounding by diet, adherence, socioeconomic position and disease severity cannot be excluded. The comparison in Table 6 shows that the difference in this study is two to six times larger than effects from controlled trials. Because the SMD analysis (Figure 5) shows marked imbalance in adiposity and blood pressure, and fasting glucose is closely tied to HbA1c by definition, the observed gradient should be read as an upper-bound, association-level signal rather than the effect of becoming more active.

Table 6. Magnitude of HbA1c difference: this study versus selected trial evidence.

Source	Design	Contrast	HbA1c difference (percentage points)
Church et al., 2010 [10]	RCT	Aerobic + resistance training vs control	≈0.34 lower
Umpierre et al., 2011 [8]	Meta-analysis of RCTs	Structured exercise vs control	≈0.67 lower
Sigal et al., 2007 [9]	RCT	Combined aerobic and resistance training vs control	≈0.97 lower
This study	Cross-sectional	High vs low activity (GPAQ)	2.16 lower (95% CI 1.82–2.50)

Trial estimates are approximate absolute differences quoted from the cited publications; designs and populations differ and the figures are not directly comparable.

Occupational activity contributed just over half of total activity, and recreation only about one fifth. This resembles the Indian pattern in which leisure-time activity is uncommon [18]. For counseling, clinicians can explore work and transport activity and build on them with feasible, safe additions such as brisk walking, breaks from sitting and resistance exercise. A domain's percentage contribution does not, however, show whether activity was continuous, of sufficient intensity or evenly distributed, and occupational activity may differ in physiological effect from structured exercise.

Self-reported activity is also vulnerable to recall and social-desirability bias, and questionnaires overestimate activity relative to direct measures [21]. GPAQ shows acceptable reliability and fair-to-moderate validity across settings [19,20], so misclassification is likely non-differential but may still alter estimates.

Practically, routine primary care can include brief activity assessment and tailored counseling, attending to safety, comorbidities and the risk of hypoglycemia in people taking insulin or insulin secretagogues [6,14,16]. Figure 7 outlines a proposed workflow. Prospective cohort studies or

pragmatic trials in Indian primary care are needed to test whether an activity-support program changes HbA1c over time.

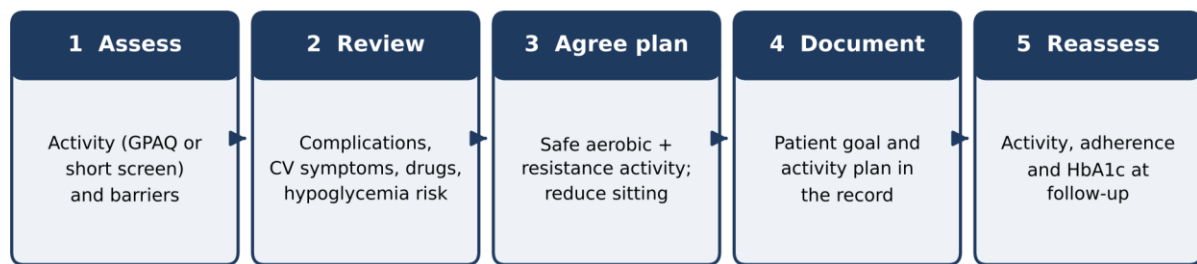


Figure 7. Proposed primary-care workflow for activity assessment and counseling in adults with T2DM.

Strengths and Limitations

Strengths include a well-defined primary-care setting, use of a standardized and internationally used questionnaire, laboratory HbA1c measurement by an NGSP-certified method, and reporting of both group comparisons and adjusted associations. Limitations are the cross-sectional design, which prevents causal and temporal inference; single-centre recruitment; self-reported activity; possible residual confounding (notably diet, medication adherence and socioeconomic status); the use of broad activity cut-points; the absence of detailed medication-adherence and diet data, and the lack of reported handling of missing data and regression diagnostics. Generalizability beyond similar urban outpatient settings is uncertain.

Conclusion

Among 320 adults with T2DM at an urban health training centre in Karimnagar, higher categories of self-reported physical activity were associated with progressively lower HbA1c, and activity ≥ 600 MET-min/week was independently associated with achieving HbA1c $< 7.0\%$. Most activity was occupational. These findings support asking about physical activity and offering individualized, safety-conscious counseling as part of routine diabetes care, while recognizing that this cross-sectional study cannot establish causality.

Additional Information

Disclosures

Human subjects: Consent was obtained from all participants in this study. The Institutional Ethics Committee, Prathima Institute of Medical Sciences, Karimnagar issued approval PIMS/IEC/2024/042. Written informed consent was obtained in Telugu or English.

Animal subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data availability: The anonymized dataset is available from the corresponding author on reasonable academic request.

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Atul Gopal Agrawal

Acquisition, analysis, or interpretation of data: Atul Gopal Agrawal

Drafting of the manuscript: Atul Gopal Agrawal, Ankita Agrawal

Critical review of the manuscript for important intellectual content: Atul Gopal Agrawal, Ankita Agrawal

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