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EFFECT OF DIFFERENT BODY POSITIONS ON PEAK EXPIRATORY FLOW RATE IN PATIENTS WITH TYPE 2 DIABETES MELLITUS AND NON-DIABETIC INDIVIDUALS: A COMPARATIVE STUDY

¹Dr. Muhammad Nauman Kazi, ²Harmit Vgani, ²Krisheeka Ghevariya, ²Srushti Barbariya and ²Vishwa Dayani

¹Associate Professor Department of Cardio Pulmonary Physiotherapy the Sarvajanic College of Physiotherapy Surat; ²intern Students of the Sarvajaik College of Physiotherapy Surat Gujarat

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder that may adversely affect pulmonary function through mechanisms such as respiratory muscle weakness, microvascular changes, altered connective tissue properties, and chronic metabolic disturbances. Peak Expiratory Flow Rate (PEFR) is a simple and clinically useful measure of expiratory airflow. Body position may influence respiratory mechanics and expiratory performance; however, the effect of sitting and standing positions on PEFR in individuals with T2DM compared with non-diabetic individuals remains unclear. **Aim:** To evaluate the effect of different body positions on Peak Expiratory Flow Rate (PEFR) in patients with Type 2 Diabetes Mellitus and compare the findings with non-diabetic individuals. **Methods:** A comparative cross-sectional study was conducted on 180 participants aged 30–60 years, comprising 90 individuals with Type 2 Diabetes Mellitus and 90 non-diabetic individuals. Participants were assessed for PEFR in sitting and standing positions using a peak flow meter. Three measurements were obtained in each position, and the highest value was recorded. Participants were selected according to predefined inclusion and exclusion criteria. The effects of diabetic status, body position, and gender on PEFR were analysed using three-way analysis of variance (ANOVA), followed by Tukey-adjusted post hoc comparisons where appropriate. **Results:** Non-diabetic participants demonstrated a significantly higher mean PEFR than diabetic participants, with mean values of approximately 359 L/min and 319 L/min, respectively ($F = 25.76$, $p < 0.001$). A significant main effect of gender was also observed, with males demonstrating higher mean PEFR than females (398 ± 80.3 L/min vs. 297 ± 70.7 L/min; $F = 100.64$, $p < 0.001$). In contrast, body position did not produce a statistically significant difference in PEFR between sitting and standing positions ($F = 1.36$, $p = 0.245$). None of the interaction effects, including Group $\times$ Position, Group $\times$ Gender, Position $\times$ Gender, and Group $\times$ Position $\times$ Gender, were statistically significant ($p > 0.05$). Post hoc analysis further demonstrated consistently higher PEFR values among males compared with females, whereas differences between sitting and standing positions were generally not significant. **Conclusion:** The findings indicate that Type 2 Diabetes Mellitus is associated with significantly reduced PEFR compared with non-diabetic individuals, while gender has a significant influence on PEFR, with males demonstrating higher expiratory flow rates than females. However, the sitting and standing positions did not significantly affect PEFR in the study population. Therefore, either sitting or standing may be used for PEFR assessment in ambulatory adults when the measurement position is standardized and consistently documented. The findings highlight the importance of considering diabetic status and gender when interpreting PEFR values.

*Corresponding author:

Dr. Muhammad Nauman Kazi

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INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defective insulin secretion, insulin action, or both^(1,2). Type 2 diabetes mellitus (T2DM) constitutes the majority of cases worldwide and is closely linked with obesity, sedentary behavior, and genetic predisposition⁽²⁾. Its prevalence continues to rise globally, driven by urbanization and

lifestyle transition, placing an escalating burden on healthcare systems through its microvascular and macrovascular complications^(1,3,4). While retinopathy, nephropathy, neuropathy, and cardiovascular disease dominate the clinical narrative of diabetic complications, a growing body of literature has identified the lung as an additional, often clinically silent, target organ^(5,6,7). Chronic hyperglycemia is believed to damage pulmonary tissue through non-enzymatic glycosylation of collagen and elastin, microangiopathy of the

alveolar-capillary bed, and autonomic neuropathy affecting respiratory muscle function^(5,8,9). Cross-sectional studies have consistently demonstrated a restrictive pattern of pulmonary function impairment in T2DM patients, with reductions in forced vital capacity, forced expiratory volume, and peak expiratory flow rate compared with non-diabetic individuals^(5,8,10,9,11). Beyond its role as a marker of localized airway function, reduced PEFR in diabetic patients has also been linked to broader systemic outcomes. Long-term follow-up data from the Wisconsin Epidemiologic Study of Diabetic Retinopathy demonstrated that lower PEFR values in diabetic individuals were associated with established cardiovascular and renal risk variables and independently predicted increased mortality⁽¹²⁾, while related analyses from the same cohort found that PEFR could serve as a predictor of other diabetic complications, suggesting that it reflects generalized microvascular vulnerability rather than an isolated respiratory abnormality⁽¹³⁾. These observations, together with evidence that diabetes independently worsens pulmonary outcomes in the context of concurrent conditions such as pulmonary tuberculosis⁽¹⁴⁾ and acute pulmonary embolism⁽¹⁵⁾, underscore the potential clinical value of incorporating simple, reproducible pulmonary function screening into routine diabetes care.

Aims and objective

AIM:

- To evaluate the effect of different body positions on Peak Expiratory Flow Rate (PEFR) in patients with Type 2 Diabetes Mellitus and to compare the results with those of non-diabetic subjects.

OBJECTIVES

- To measure Peak Expiratory Flow Rate (PEFR) in different body positions in patients with Type 2 Diabetes Mellitus.
- To measure Peak Expiratory Flow Rate (PEFR) in different body positions in non-diabetic individuals.
- To compare PEFR values between different body positions within each group.
- To compare PEFR values between diabetic and non-diabetic individuals in different body positions.
- To identify which body position produces the highest PEFR value.

MATERIALS AND METHODS

Study Design and Setting: This was a cross-sectional, comparative, observational study conducted in the outpatient medicine and physiotherapy departments of a lokhat hospital Surat and other diabetics clinics. Ethical clearance was obtained from the institutional ethics committee prior to commencement, and written informed consent was obtained from all participants.

Study Population: A total of 180 participants were enrolled and divided into two groups: Group A comprised 90 patients with a confirmed diagnosis of T2DM of at least six year's duration, and Group B comprised 90 patients with normal individual. position, Gender -matched non-diabetic healthy controls.

Inclusion criteria: Participants of either sex, aged 30–60 years; for Group A, a documented diagnosis of T2DM based on standard diagnostic criteria; ability to perform the PEFR maneuver correctly after demonstration and practice.

Exclusion criteria: Current or past smokers; diagnosed cases of asthma, chronic obstructive pulmonary disease, interstitial lung disease, or other chronic respiratory illness; history of thoracic or abdominal surgery; uncontrolled hypertension or overt cardiac failure; musculoskeletal or neurological conditions limiting the ability to stand unsupported; pregnancy; and type 1 diabetes mellitus.

Outcome Measures and Procedure: PEFR was measured using a standard, calibrated Wright-type peak flow meter, with the same instrument used for all participants to minimize inter-device variability⁽¹⁶⁾. Each participant was familiarized with the technique and allowed two practice attempts before formal data collection. PEFR was recorded in two positions, in randomized order to minimize order effects: (i) sitting, with the participant seated upright on a stool with feet flat on the floor and back unsupported, and (ii) standing, with the participant standing erect and unsupported. In each position, three forced expiratory maneuvers were performed after a full inspiration, with at least thirty seconds of rest between attempts, and the highest of the three readings in each position was recorded for analysis, consistent with standard peak flow testing protocols^(11,18,19). For Group A, duration of diagnosed diabetes and the most recent glycated hemoglobin (HbA1c) value were obtained from medical records.

Statistical Analysis: Table 1 – Descriptive Statistics: Shows sample size, mean, median, SD, and range of PEFR (peak expiratory flow rate) for each combination of group (non-diabetic/diabetic), position (sitting/standing), and gender. Males consistently show higher mean PEFR than females across all groups and positions.

Table 2 – Three-Way ANOVA: Tests whether group, position, gender, and their interactions significantly affect PEFR. Group and Gender each have significant main effects ($p < .001$), while Position and all interaction terms are non-significant ($p > .05$). Table 3 – Post Hoc Comparisons: Pairwise comparisons of PEFR across all 8 group $\times$ position $\times$ gender subgroups, showing which specific subgroup differences are statistically significant. Most significant differences are gender-based (male vs. female), consistent with the ANOVA's significant Gender effect.

DISCUSSION

This study examined the effect of diabetes status, body position (sitting vs. standing), and gender on peak expiratory flow rate (PEFR) in 180 adult participants. The three-way ANOVA showed statistically significant main effects of group (diabetic vs. non-diabetic) and gender on PEFR (both $p < .001$), while the main effect of position and all two- and three-way interaction terms were non-significant ($p > .05$). These findings are broadly consistent with, and help extend, the existing literature on determinants of PEFR.

Effect of Diabetes on PEFR: Across all subgroups, non-diabetic participants recorded higher mean PEFR values than their diabetic counterparts, and this difference was statistically significant. This finding aligns with a growing body of evidence identifying the lung as an under-recognised "target organ" of diabetes mellitus, alongside the retina, kidney, and peripheral nerves⁽²⁰⁾. Large cohort work from the Wisconsin Epidemiologic Study of Diabetic Retinopathy similarly reported that PEFR was reduced in people with diabetes and was itself predictive of long-term survival, reinforcing that ventilatory impairment in diabetes is not a trivial or incidental finding^(21,32). Cross-sectional comparisons between diabetic and non-diabetic adults have likewise reported reductions across several spirometric indices, including PEFR, in the diabetic group⁽²⁰⁾.

The mechanism most often proposed for this reduction is non-enzymatic glycation of collagen and elastin within the lung parenchyma and airway walls, which stiffens pulmonary connective tissue and reduces its elastic recoil⁽²²⁾. Because the pulmonary microvasculature represents one of the largest capillary beds in the body, it is also thought to be vulnerable to the same diabetic microangiopathic processes that damage the retina and glomerulus, producing thickened alveolar-capillary basement membranes and impaired gas exchange⁽²³⁾. Chronic low-grade inflammation and oxidative stress associated with hyperglycaemia have also been implicated in progressive airway and parenchymal injury in diabetes⁽²⁴⁾.

Table 1. Descriptive Statistics of Peak Expiratory Flow Rate (PEFR, L/min) by Group, Position, and Gender

Group	Position	Gender	n	M	Mdn	SD	Min	Max
Non-diabetic	Sitting	Female	24	311	333	71.1	123	406
Non-diabetic	Sitting	Male	21	420	453	90.5	260	550
Non-diabetic	Standing	Female	33	318	333	66.9	180	426
Non-diabetic	Standing	Male	12	460	478	63.8	300	550
Diabetic	Sitting	Female	23	268	275	79.9	140	425
Diabetic	Sitting	Male	22	374	391	67.7	260	455
Diabetic	Standing	Female	25	282	285	55.6	197	385
Diabetic	Standing	Male	20	364	370	64.9	240	450

Note. ND = non-diabetic; D = diabetic. Position 1 = sitting; Position 2 = standing. M = mean; Mdn = median; SD = standard deviation.

Table 2. Three-Way ANOVA of Group, Position, and Gender on PEFR

Source	SS	df	MS	F	p
Group	128678	1	128678	25.760	< .001
Position	6803	1	6803	1.362	.245
Gender	502739	1	502739	100.642	< .001
Group × Position	4943	1	4943	0.989	.321
Group × Gender	10156	1	10156	2.033	.156
Position × Gender	237	1	237	0.048	.828
Group × Position × Gender	8374	1	8374	1.677	.197
Residuals	859195	172	4995		

Note. SS = sum of squares; MS = mean square. df for residuals = 172.

Table 3. Post Hoc Pairwise Comparisons (ptukey-Adjusted) of PEFR Across Group × Position × Gender Combinations

Comparison A	Comparison B	Mean diff.	SE	df	t	ptukey
ND, Sitting, F	ND, Sitting, M	-108.59	21.1	172	-5.142	< .001
ND, Sitting, F	ND, Standing, F	-7.09	19.0	172	-0.374	1.000
ND, Sitting, F	ND, Standing, M	-148.71	25.0	172	-5.951	< .001
ND, Sitting, F	D, Sitting, F	43.12	20.6	172	-2.091	.425
ND, Sitting, F	D, Sitting, M	-62.60	20.9	172	-3.001	.060
ND, Sitting, F	D, Standing, F	29.48	20.2	172	-1.460	.827
ND, Sitting, F	D, Standing, M	-52.73	21.4	172	-2.464	.218
ND, Sitting, M	ND, Standing, F	101.50	19.7	172	5.145	< .001
ND, Sitting, M	ND, Standing, M	-40.12	25.6	172	-1.569	.768
ND, Sitting, M	D, Sitting, F	151.71	21.3	172	7.112	< .001
ND, Sitting, M	D, Sitting, M	45.99	21.6	172	2.133	.398
ND, Sitting, M	D, Standing, F	138.07	20.9	172	6.600	< .001
ND, Sitting, M	D, Standing, M	55.86	22.1	172	2.530	.190
ND, Standing, F	ND, Standing, M	-141.62	23.8	172	-5.944	< .001
ND, Standing, F	D, Sitting, F	50.21	19.2	172	2.615	.158
ND, Standing, F	D, Sitting, M	-55.52	19.5	172	-2.854	.089
ND, Standing, F	D, Standing, F	36.57	18.7	172	1.952	.518
ND, Standing, F	D, Standing, M	-45.64	20.0	172	-2.279	.311
ND, Standing, M	D, Sitting, F	191.83	25.2	172	7.622	< .001
ND, Standing, M	D, Sitting, M	86.11	25.4	172	3.395	.019
ND, Standing, M	D, Standing, F	178.19	24.8	172	7.179	< .001
ND, Standing, M	D, Standing, M	95.98	25.8	172	3.719	.006
D, Sitting, F	D, Sitting, M	-105.73	21.1	172	-5.016	< .001
D, Sitting, F	D, Standing, F	-13.64	20.4	172	-0.668	.998
D, Sitting, F	D, Standing, M	-95.85	21.6	172	-4.436	< .001
D, Sitting, M	D, Standing, F	92.09	20.7	172	4.457	< .001
D, Sitting, M	D, Standing, M	9.88	21.8	172	0.452	1.000
D, Standing, F	D, Standing, M	-82.21	21.2	172	-3.877	.004

Note. ND = non-diabetic; D = diabetic; F = female; M = male. Mean diff. = estimated marginal mean difference (Comparison A – Comparison B), in L/min. ptukey = Tukey-adjusted p value for multiple comparisons.

Taken together, these mechanisms provide a plausible physiological explanation for the significantly lower PEFR observed in the diabetic group of the present study, and support the argument that simple, low-cost measures such as PEFR could serve as an early screening tool for subclinical pulmonary involvement in diabetic patients.

Effect of Gender on PEFR: Gender exerted the strongest effect on PEFR in the present analysis, with males recording substantially higher values than females in every group-by-position subgroup, and the post hoc comparisons confirming that most of the statistically significant pairwise differences were gender-based rather than diabetes- or position-based. This pattern is well documented in the pulmonary physiology literature. Men typically have larger lungs, wider conducting airways, and greater respiratory muscle mass than

women even after adjusting for height, which together produce higher maximal expiratory flows in men⁽²⁵⁾. Reviews of sex-based differences in respiratory structure and function report that women's smaller airway calibre and lung volume translate directly into a smaller maximal flow-volume envelope and lower peak flows relative to men⁽²⁶⁾. A recent observational study of PEFR in young adults similarly found significantly higher PEFR in men than women and attributed the gap to differences in lung volume and expiratory muscle strength⁽²⁷⁾. The magnitude and consistency of the gender effect observed here, including its dominance over both diabetes status and posture in the post hoc comparisons, therefore fits well with the established understanding that sex is one of the strongest anthropometric determinants of PEFR, alongside height and age.

Effect of Body Position on PEFR: In contrast to group and gender, body position (sitting vs. standing) did not significantly affect PEFR, nor did it interact significantly with diabetes status or gender. This result is consistent with several previous investigations. A cross-over study comparing standing and sitting PEF measurements in adults found the two positions to be statistically equivalent in healthy individuals, with only a small, clinically negligible difference emerging in participants with asthma⁽²⁸⁾. Earlier work comparing sitting and standing peak flow readings likewise concluded that the two positions produced comparable values suitable for interchangeable clinical use⁽²⁹⁾. A systematic review of the effect of body position on pulmonary function similarly noted that, while several volume-based parameters vary meaningfully with posture, effort-dependent flow measures such as PEFR tend to be more robust to positional change in ambulatory, non-critically-ill adults⁽³⁰⁾. Comparable stability of expiratory flow parameters between sitting and standing has also been reported in patients with obstructive lung disease⁽³¹⁾. The absence of a significant position effect, and of any position-by-group or position-by-gender interaction, in the present study therefore corroborates this literature and suggests that, for ambulatory adults tested in a standardised manner, sitting and standing postures can reasonably be treated as equivalent when PEFR is used as the outcome of interest.

Interaction Effects and Post Hoc Findings: None of the two-way or three-way interaction terms reached significance, indicating that the effects of diabetes and gender on PEFR were additive rather than dependent on one another, and that posture did not modify either relationship. This is reflected in the post hoc comparisons, where the largest and most consistent mean differences were seen between male and female subgroups irrespective of diabetes status or position (e.g., non-diabetic standing males vs. females, and diabetic sitting males vs. females), while comparisons that varied only by position within the same diabetes-and-gender subgroup were uniformly non-significant. This pattern suggests that gender and diabetes status act as largely independent, additive risk factors for reduced PEFR, a conclusion consistent with reports that describe diabetes-related pulmonary impairment as being superimposed on, rather than interacting with, baseline sex differences in lung function⁽²¹⁾.

Clinical Implications and Limitations: These findings support the use of PEFR as a simple, inexpensive, and reproducible screening measure for early pulmonary involvement in diabetic patients, provided that gender-specific reference ranges are applied given the strong, independent effect of sex demonstrated here. Because posture had no meaningful influence on PEFR, clinicians and researchers can measure PEFR in either the sitting or standing position without materially affecting comparability of results, which may improve feasibility in bedridden or mobility-limited diabetic patients. Several limitations should be noted. The cross-sectional design precludes causal inference regarding the relationship between diabetes and reduced PEFR, and variables known to influence PEFR, such as glycaemic control (HbA1c), diabetes duration, smoking history, and body mass index, were not modelled here and may partly explain residual variance^(20,33). Future longitudinal studies incorporating glycaemic markers and larger, more balanced samples are warranted to clarify the trajectory and reversibility of diabetes-related PEFR decline.

CONCLUSION

In summary, this study found that diabetes status and gender independently and significantly reduce PEFR, while body position does not, and none of these factors interact with one another. These results reinforce the view of the lung as a target organ in diabetes and highlight gender as the strongest single determinant of PEFR, consistent with the broader pulmonary physiology literature.

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