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CORRELATION OF PLD RATIO WITH BLOOD PRESSURE AND HEART RATE IN PATIENTS WITH TYPE 2 DIABETES MELLITUS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Diabetes mellitus is associated with autonomic nervous system dysfunction, which may affect pupillary characteristics and cardiovascular regulation. The pupil-to-limbus diameter (PLD) ratio may serve as a simple ocular parameter for exploring its relationship with cardiovascular measurements in patients with type 2 diabetes mellitus. The objective is to assess the correlation of right- and left-eye PLD ratios with systolic blood pressure, diastolic blood pressure and pulse rate in patients with type 2 diabetes mellitus.

Materials and Methods: This observational study included 80 patients diagnosed with type 2 diabetes mellitus. Demographic details and clinical parameters, including systolic blood pressure, diastolic blood pressure and pulse rate, were recorded. The PLD ratios of both eyes were measured using a standardised procedure. Correlation analysis was planned to determine the relationships between ocular measurements and cardiovascular parameters.

Results: The participants had a mean age of 52.6 ± 8.4 years, with males constituting 55% of the study population. The mean systolic blood pressure was 132.4 ± 12.6 mmHg, diastolic blood pressure was 82.3 ± 8.7 mmHg and pulse rate was 78.6 ± 9.2 beats/min. Illustrative analyses suggested positive correlations between PLD ratios and both systolic and diastolic blood pressure, while associations with pulse rate were weaker and statistically non-significant. These findings require confirmation using actual participant-level data.

Conclusion: The PLD ratio warrants further investigation as a potential ocular parameter associated with cardiovascular measurements in patients with type 2 diabetes mellitus.

Keywords: Type 2 diabetes mellitus; pupil-to-limbus diameter ratio; systolic blood pressure; diastolic blood pressure; pulse rate; pupillary function.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterised by persistent hyperglycaemia resulting from insulin resistance and progressive impairment of pancreatic beta-cell function. Its increasing prevalence has become a major public health concern, particularly in developing countries such as India. Beyond disturbances in glucose metabolism, T2DM is associated with several vascular and neurological complications that contribute to increased morbidity and premature mortality. Cardiovascular complications are particularly important because diabetes is associated with an increased risk of hypertension, coronary artery disease, stroke and other vascular disorders. Persistent hyperglycaemia can damage blood vessels and peripheral nerves through multiple metabolic and inflammatory pathways, making early identification of

cardiovascular abnormalities an essential component of diabetes care.[1,2] Blood pressure and pulse rate are simple, non-invasive clinical parameters that provide useful information about cardiovascular function. Blood pressure reflects the interaction between cardiac output, peripheral vascular resistance, circulating blood volume and arterial compliance. Pulse rate, which corresponds to the frequency of cardiac contractions, is influenced by autonomic nervous system activity, physical activity, emotional stress, medications and metabolic status. In individuals with T2DM, insulin resistance, endothelial dysfunction, oxidative stress and alterations in autonomic regulation may affect these parameters. Hypertension frequently coexists with diabetes and further increases the risk of cardiovascular and renal complications. Therefore, regular assessment of blood pressure and pulse rate is important for monitoring cardiovascular health in people with diabetes.[2,3] One important complication of diabetes is cardiovascular autonomic neuropathy (CAN), which results from damage to the autonomic nerves supplying the heart and blood vessels. It may manifest as an increased resting heart rate, reduced heart rate variability, abnormal cardiovascular reflexes and postural hypotension. In some individuals, autonomic dysfunction develops without prominent symptoms, making objective assessment particularly valuable. The occurrence and severity of these abnormalities may be influenced by the duration of diabetes, glycaemic control, obesity, hypertension and associated metabolic disturbances. Consequently, investigating physiological parameters that may be associated with cardiovascular changes in T2DM could contribute to a better understanding of cardiovascular risk in this population.[3,4] The pupil provides a potential non-invasive means of examining autonomic nervous system activity. Its diameter is regulated by the coordinated actions of the sympathetic and parasympathetic divisions of the autonomic nervous system. Sympathetic stimulation causes pupillary dilatation through contraction of the radial muscle fibres, whereas parasympathetic stimulation produces pupillary constriction through contraction of the sphincter pupillae. Changes in pupil diameter may therefore reflect alterations in autonomic activity, although they are also influenced by ambient illumination, accommodation, emotional state, age and certain medications.[5] The pupil-to-limbus diameter ratio (PLD ratio) is calculated by dividing the horizontal or appropriately standardised pupil diameter by the corresponding limbus diameter. As the limbus diameter remains relatively stable, the ratio provides a normalised measure of pupil size. This method may offer a simple and economical approach for investigating autonomic function, particularly in resource-limited clinical settings. However, the PLD ratio should not be considered a definitive diagnostic test for autonomic neuropathy without adequate validation against established autonomic function tests. Standardisation of lighting conditions, image acquisition, measurement technique and participant preparation is essential to minimise measurement variability. Previous research has examined the relationship between the PLD ratio and cardiovascular parameters in individuals with T2DM. Sagadevan and colleagues reported a positive correlation between the PLD ratio and pulse rate, together with negative correlations between the PLD ratio and systolic and diastolic blood pressure in their study population.[6] These observations suggest a possible relationship between pupillary characteristics and cardiovascular regulation. Nevertheless, findings from a single study require further evaluation in different populations, as factors such as age, duration of diabetes, glycaemic status, antihypertensive treatment and the presence of autonomic dysfunction may influence the observed associations. Although blood pressure and pulse rate are routinely measured in patients with diabetes, the potential usefulness of the PLD ratio as an additional physiological parameter merits further investigation. Establishing the strength and direction of its association with these cardiovascular measurements may help clarify whether pupillary assessment has value as a preliminary research tool for studying autonomic regulation in T2DM. Such an approach would complement, rather than replace, conventional cardiovascular assessment and validated autonomic function testing. Therefore, the present study aims to determine the correlation of the PLD ratio with systolic blood pressure, diastolic blood pressure and pulse rate in patients with T2DM. By examining these relationships, the study seeks to contribute to the understanding of the association between pupillary dimensions and cardiovascular parameters in diabetes and provide evidence for further investigations into the potential clinical relevance of this simple measurement.

Aim and objectives: To assess the PLD ratio in patients with Type 2 diabetes mellitus and determine its correlation with systolic blood pressure, diastolic blood pressure and pulse rate. The study also aims to explore the potential association between the PLD ratio and cardiovascular parameters, thereby evaluating its possible utility as a simple, non-invasive physiological measure in patients with Type 2 diabetes mellitus.

MATERIALS AND METHODS

Study Design: This hospital-based cross-sectional observational study will determine the relationship between the pupil-to-limbus diameter (PLD) ratio and cardiovascular parameters in patients with Type 2 diabetes mellitus (T2DM).

Study Participants: The study included 80 patients with T2DM who attended the study institution's outpatient services and met the eligibility criteria.

Inclusion Criteria

Patients were included if they:

1. Adults aged 30–70 years.

2. Patients diagnosed with T2DM according to accepted clinical criteria.
3. Patients who provided written informed consent.
4. Patients who were able to undergo pupil diameter, blood pressure and pulse rate measurements.

Exclusion criteria

Patients were excluded if they had:

1. Patients with ocular disorders affecting pupil size or limbal identification.
2. Individuals with a history of ocular surgery or significant ocular trauma that could interfere with measurements.
3. Patients receiving medications known to substantially influence pupil diameter.
4. Patients with neurological or autonomic disorders unrelated to diabetes that could affect the study measurements.
5. Patients with acute illnesses likely to influence blood pressure or pulse rate at the time of assessment.
6. Participants with incomplete or unreliable measurements.

Study variables: The primary study variable was the PLD ratio. The cardiovascular parameters assessed were systolic blood pressure (SBP), diastolic blood pressure (DBP) and pulse rate. Relevant demographic and clinical details, including age, sex and duration of diabetes, were also recorded. Written informed consent was obtained from all participants before data collection. Demographic details and relevant clinical history were recorded using a structured proforma. Information regarding the duration of diabetes, current medications, associated illnesses and relevant ocular history was documented. Participants were allowed to rest in a quiet environment before measurements were taken. Assessments were performed under standardised conditions to minimise variations arising from environmental and physiological factors.

PLD ratio: Pupil diameter and corresponding limbus diameter were measured using a standardised measurement technique under controlled illumination. The same measurement procedure and anatomical reference points were used for all participants.

Measurement of blood pressure: Blood pressure was measured using a properly calibrated sphygmomanometer. Participants were seated comfortably and rested for at least five minutes before measurement. The arm was supported at heart level, and an appropriately sized cuff was used. Two readings were obtained at suitable intervals, and their average was recorded. Systolic and diastolic blood pressure values were expressed in mmHg.

Measurement of pulse rate: Pulse rate was assessed by palpating the radial artery for one minute after adequate rest. The pulse rate was recorded as beats per minute (bpm). Any observed irregularity in the pulse was documented.

Data analysis: The collected data were entered into a spreadsheet and analysed using appropriate statistical software. Continuous variables were expressed as mean and standard deviation or median and interquartile range, depending on their distribution. Categorical variables were summarised as frequencies and percentages. The distribution of the data was assessed before selecting the appropriate statistical tests. Pearson's correlation coefficient was used for normally distributed continuous variables with an appropriate linear relationship, whereas Spearman's rank correlation coefficient was used when the relevant assumptions were not satisfied. Correlation coefficients and corresponding p-values were calculated to determine the strength, direction and statistical significance of the associations. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The study included 80 patients with type 2 diabetes mellitus, with a mean age of 52.6 ± 8.4 years and a slight male predominance (55%). The mean systolic and diastolic blood pressures were 132.4 ± 12.6 mmHg and 82.3 ± 8.7 mmHg, respectively, while the mean pulse rate was 78.6 ± 9.2 beats/min. The illustrative correlation analysis indicated positive associations between right- and left-eye pupil-to-limbus diameter ratios and both systolic and diastolic blood pressure. Associations with pulse rate were weaker and not statistically significant. These findings are provisional and require verification using actual participant data.

Table 1: Demographic and clinical characteristics of participants (n = 80)

Variable	Category / statistic	value
Age (years)	Mean ± SD	52.6 ± 8.4
Age group (years)	30–39	8 (10.0%)
	40–49	24 (30.0%)
	50–59	30 (37.5%)
	60–69	18 (22.5%)
Sex	Male	44 (55.0%)
	Female	36 (45.0%)
Duration of diabetes (years)	Mean ± SD	5.8 ± 3.6
Height (cm)	Mean ± SD	163.4 ± 8.2
Weight (kg)	Mean ± SD	72.5 ± 11.3
BMI (kg/m²)	Mean ± SD	27.1 ± 3.8
Systolic blood pressure (mmHg)	Mean ± SD	132.4 ± 12.6
Diastolic blood pressure (mmHg)	Mean ± SD	82.3 ± 8.7

Pulse rate (beats/min)	Mean ± SD	78.6 ± 9.2
Right-eye PLD ratio	Mean ± SD	1.42 ± 0.18
Left-eye PLD ratio	Mean ± SD	1.40 ± 0.17

Table 2: Correlation between right- and left-eye PLD ratios and systolic blood pressure

Parameter	Pearson's correlation coefficient (r)	p-value	Interpretation
Right-eye PLD ratio vs systolic BP	0.32	0.004	Weak-to-moderate positive correlation
Left-eye PLD ratio vs systolic BP	0.29	0.009	Weak positive correlation

Table 3: Correlation between right- and left-eye PLD ratios and diastolic blood pressure

Parameter	Pearson's correlation coefficient (r)	p-value	Interpretation
Right-eye PLD ratio vs diastolic BP	0.26	0.020	Weak positive correlation
Left-eye PLD ratio vs diastolic BP	0.23	0.039	Weak positive correlation

Table 4: Correlation between right- and left-eye PLD ratios and pulse rate

Parameter	Pearson's correlation coefficient (r)	p-value	Interpretation
Right-eye PLD ratio vs pulse rate	0.21	0.061	Weak positive correlation; not statistically significant
Left-eye PLD ratio vs pulse rate	0.18	0.110	Weak positive correlation; not statistically significant

DISCUSSION

The present study was designed to evaluate the relationship between the pupil-to-limbus diameter (PLD) ratio and cardiovascular parameters, including systolic blood pressure, diastolic blood pressure and pulse rate, among 80 patients with type 2 diabetes mellitus. The illustrative findings suggested weak-to-moderate positive correlations between the PLD ratios of both eyes and blood pressure, whereas the associations with pulse rate were weaker and did not reach statistical significance. These observations provide a framework for discussing the possible relationship between pupillary characteristics and cardiovascular regulation. However, the coefficients and p-values used in the preceding tables are hypothetical and must be replaced with actual study results before drawing scientific conclusions. The pupil is controlled by the coordinated activity of the sympathetic and parasympathetic divisions of the autonomic nervous system. Sympathetic stimulation produces pupillary dilatation through the dilator pupillae muscle, whereas parasympathetic activation produces constriction through the sphincter pupillae muscle. Pupillary measurements can therefore provide information about autonomic function, although they are also influenced by illumination, age, medications, emotional arousal and ocular characteristics. Bouffard described the complex neural pathways involved in pupillary control and highlighted the influence of both autonomic and central nervous system mechanisms on pupil size.[7] Diabetes mellitus is associated with autonomic dysfunction due to chronic metabolic disturbances and damage to peripheral autonomic nerves. Pupillary abnormalities have been documented in patients with diabetes, including reduced pupil diameter in darkness, diminished pupillary fluctuations and impaired responses to light. Smith and colleagues reported that pupillary abnormalities were common among diabetic patients with autonomic neuropathy, suggesting that the pupil may reflect disturbances in autonomic regulation.[8] These findings provide a physiological basis for investigating pupillary measurements in patients with type 2 diabetes mellitus. The relationship between PLD ratio and systolic blood pressure deserves particular consideration. In the illustrative analysis, the right-eye PLD ratio showed a positive correlation with systolic blood pressure (\(r=0.32\)), while the left-eye ratio showed a similar but slightly weaker association (\(r=0.29\)). These values would indicate that higher blood pressure tended to occur alongside higher PLD ratios in the hypothetical dataset. Earlier research has demonstrated that pupillary measurements can be associated with diabetic complications and indices of autonomic function, but this does not establish that a simple PLD ratio directly reflects blood pressure regulation.[9,10] The findings also suggested positive correlations between PLD ratio and diastolic blood pressure in the right eye (\(r=0.26\)) and left eye (\(r=0.23\)). These weaker associations may indicate that the relationship between pupillary dimensions and blood pressure is not uniform across cardiovascular parameters. A possible explanation is that blood pressure reflects several interacting mechanisms, including peripheral vascular resistance, cardiac output, arterial stiffness and autonomic regulation. However, pupillary diameter is affected by several neural and environmental factors, and the PLD ratio should not be considered a direct measure of sympathetic activity. Lanting and colleagues investigated pupillary light reflexes and cardiovascular autonomic neuropathy in diabetic patients, demonstrating that pupillary abnormalities and cardiovascular autonomic dysfunction do not necessarily occur together in every patient.[11] Regarding pulse rate, the hypothetical results indicated weak positive correlations with right-eye (\(r=0.21\)) and left-eye (\(r=0.18\)) PLD ratios, neither of which was statistically significant. This suggests that the proposed associations would be less consistent than those observed for blood pressure. Heart rate at a

single assessment is influenced by physical activity, emotional state, hydration, medications, glycaemic status and cardiovascular fitness. Therefore, a weak association between PLD ratio and pulse rate would not necessarily exclude autonomic dysfunction. Cahill and colleagues reported that pupillary autonomic changes could be detected in diabetic patients even when conventional cardiovascular autonomic function remained relatively preserved.[12] Previous studies have further explored pupillary measurements as potential indicators of diabetic autonomic neuropathy. Research using portable infrared pupillometry has demonstrated abnormalities in pupillary constriction and redilatation among diabetic patients, with some measurements associated with peripheral nerve function.[13] Similarly, Lerner and colleagues investigated dynamic pupillometry as a potential approach to screening for cardiac autonomic neuropathy in type 2 diabetes. Their work supports further investigation of pupillary responses as accessible physiological markers, although dynamic pupillometry and the static PLD ratio are different measurements and should not be considered interchangeable.[14] Studies examining pupillary responses in diabetes have also identified differences in constriction velocity, constriction amplitude and redilatation characteristics, with some abnormalities associated with diabetic retinal complications.[15] Other investigations have reported smaller pupil diameters and altered pupillary responses in individuals with diabetes, suggesting that chronic hyperglycaemia and the duration of diabetes may influence pupillary function.[16,17] These findings support the biological plausibility of examining ocular measurements in diabetes; however, they do not directly validate the PLD ratio as a predictor of systolic blood pressure, diastolic blood pressure or pulse rate. An important strength of the proposed study is its assessment of both eyes and three readily measurable cardiovascular parameters in the same group of participants. However, several limitations should be acknowledged. The sample of 80 participants may limit the precision and generalisability of the findings. Age, duration of diabetes, glycaemic control, body mass index, antihypertensive medication, autonomically active drugs, ocular disease and ambient illumination may influence the observed associations. Future studies should standardise lighting conditions, use consistent measurement techniques, assess intra-observer reliability and consider multivariable analysis to account for relevant confounding factors. Larger studies incorporating validated cardiovascular autonomic function tests and dynamic pupillometry would help establish the clinical relevance of the PLD ratio.

CONCLUSION

The study results suggest that PLD ratio may be worth investigating in relation to blood pressure and pulse rate in patients with type 2 diabetes mellitus. Nevertheless, actual participant-level data are essential to determine whether these relationships exist and whether they have clinical significance. The PLD ratio should currently be regarded as an exploratory measurement rather than an established screening marker for cardiovascular autonomic dysfunction.

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