Original Article

Acute Effects of Caffeine on Ocular Functions in Young Adults

Rohan Kalita[1], Bonela Giridhar[1], Saudhan Desai[2], Kewal Mehta[2], Moksh Rajawat[1], Sahil Parmar[1]

[1]Parul Institute of Allied and Healthcare Sciences, Parul University, Department of Ophthalmic Sciences, Vadodara, Gujarat, India
[2]Parul Sevashram Hospital, Department of Ophthalmology, Vadodara, Gujarat, India

Abstract

Objectives: To assess the short-term effects of a standardized dose of caffeine on selected ocular parameters in young adults and to examine its possible influence on visual performance during screen-based activities.

Materials and Methods: This prospective experimental study included 52 healthy university students aged 18-30 years. Participants consumed a standardized dose of 240 mg of caffeine in the form of black coffee. Ocular parameters including intraocular pressure (IOP), pupil diameter, contrast sensitivity, near point of accommodation, accommodative facility, vergence facility, visual reaction time, stereopsis, and ocular motility were assessed before and 30 minutes after caffeine intake. Pre- and post-intervention measurements were compared using paired t-tests, with $p<0.05$ considered statistically significant.

Results: Significant improvements were observed in accommodative facility (right eye [OD]: p=0.04; left eye [OS]: p<0.001; both eyes [OU]: p=0.0003), vergence facility (p=0.01), and contrast sensitivity in OU (OD and OS: p<0.001). The near point of accommodation decreased significantly, indicating improved accommodative ability (OD: p=0.02; OS: p=0.009; OU: p<0.001). Visual reaction time improved in most participants, although the change was not statistically significant (p=0.08). Pupil diameter increased significantly (p<0.001). IOP showed a small but statistically significant increase (p<0.001), remaining within normal physiological limits. Changes in stereopsis were not statistically significant (p=0.06). Minor changes were also observed in saccadic and pursuit eye movements.

Conclusion: A single dose of caffeine led to measurable short-term improvements in visual performance, particularly in accommodation and contrast sensitivity, along with a modest improvement in reaction time. Small increases in pupil diameter and IOP were also observed. These findings suggest that moderate caffeine intake may offer some benefit during visually demanding tasks. However, caution may be needed for individuals at risk of ocular hypertension. Larger, placebo-controlled, and multicenter studies are recommended to confirm these findings and to evaluate long-term effects.

Keywords: Caffeine, pupil diameter, accommodation, intraocular pressure, visual reaction time, contrast sensitivity, ocular performance

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Address for Correspondence: Rohan Kalita, Parul Institute of Allied and Healthcare Sciences, Parul University, Department of Ophthalmic Sciences, Vadodara, Gujarat, India
E-mail: rohanoptom2016@gmail.com
ORCID-ID: orcid.org/0009-0008-2936-9457

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Introduction

Caffeine is one of the most widely consumed psychoactive substances worldwide and is commonly used to improve alertness and reduce fatigue. It primarily acts as an adenosine receptor antagonist, thereby increasing neural activity and enhancing cognitive performance.[1] While its systemic effects are well established, its influence on ocular physiology and visual performance remains incompletely understood.[2]

Several visual functions, including accommodation, pupil dynamics, contrast sensitivity, intraocular pressure (IOP), and eye movements, are regulated by neural and autonomic mechanisms susceptible to the effects of caffeine intake.[3] Previous studies have reported that caffeine may improve accommodative function, increase pupil diameter, and enhance reaction time.[4,5,6] However, findings remain inconsistent, and most studies have evaluated only a limited number of parameters.

Young adults, particularly university students, frequently consume caffeine during prolonged near-work and screen use. Understanding its short-term effects on visual performance may have both clinical and practical relevance in this population.

Therefore, the present study aimed to evaluate the acute effects of a standardized dose of caffeine on selected ocular parameters in healthy young adults.

Materials and Methods

Study Design and Participants

This prospective experimental study was conducted at Parul Sevashram Hospital and Pragya Advanced Skills and Simulation Centre, Parul University, Vadodara, Gujarat, over a period of six months (January to June 2025). The study was approved by the Institutional Ethics Committee of Parul University (approval no: PUIECHR/PIMSR/00/081734/8214; date: 31 December 2024) and written informed consent was obtained from all participants.

A total of 52 university students aged between 18 and 30 years were enrolled through purposive sampling. Participants were generally healthy and regular caffeine consumers, with no history of ocular or systemic disease. Inclusion criteria required participants to have no significant refractive error (refractive error within ±1.00 diopter [D] sphere and ±0.50 D cylinder), no ocular or systemic pathology, and no use of any medication affecting vision or caffeine metabolism. Exclusion criteria included pregnancy or breastfeeding, a history of systemic conditions such as diabetes or hypertension, caffeine allergy, ocular trauma or surgery, and substance abuse or excessive caffeine dependency.

Intervention and Ocular Assessments

Each participant consumed a standardized dose of 240 mg caffeine in the form of black coffee. Ocular parameters were assessed before and 30 minutes after caffeine intake (Table 1). All measurements were taken under controlled lighting conditions between 9:00 AM and 12:00 PM. Post-intervention measurements occurred 30 minutes after caffeine intake, using the same instruments and procedures. The following variables were analyzed:

a. Visual Acuity

Distance visual acuity was assessed monocularly using a standard Snellen chart at a testing distance of 6 m under standardized room illumination. Participants wore their habitual refractive correction, if required. Visual acuity was recorded as Snellen fractions, converted to decimal notation, and subsequently converted to logarithm of the minimum angle of resolution for analysis.[7]

b. Contrast Sensitivity

Contrast sensitivity was measured monocularly using the Pelli-Robson Contrast Sensitivity Chart (Precision Vision, Woodstock, IL, USA) at a testing distance of 1 m under standardized photopic illumination.[8] Participants identified letters of progressively decreasing contrast until the threshold level was reached, and the score was recorded in log contrast sensitivity units.

Table 1. Instruments and techniques used for assessing visual and ocular parameters

Parameters	Tools/methods used	Units
Visual acuity	Snellen chart	logMAR (converted from decimal)
Pupil diameter	Millimeter scale in constant lighting	Millimeter (mm)
Stereopsis	Random Dot 2S test	Seconds of arc (arc sec)
Contrast sensitivity	Pelli-Robson Chart (Precision Vision, Woodstock, IL, USA)	logCS
Near point of accommodation	RAF ruler (Good-Lite Co., Elgin, IL, USA)	Centimeters (cm)
Accommodative facility	±2.00 D flipper lenses	Cycles/min
Vergence facility	Base-in/base-out prism flippers	Cycles/min
Visual reaction time	Computerized reaction time test	Milliseconds (ms)
Saccades and pursuits	Adult Developmental Eye Movement test	Seconds (s)
Intraocular pressure	Goldmann applanation tonometer (Haag-Streit, Köniz, Switzerland)	Millimeters of mercury (mmHg)

logMAR: Logarithm of the minimum angle of resolution, logCS: Log contrast sensitivity

c. Pupil Diameter

Pupil diameter was measured under constant ambient illumination using a millimeter scale before and 30 minutes after caffeine consumption. Measurements were obtained with participants fixating on a distant target to minimize accommodative influence and were recorded in millimeters.

d. Stereopsis

Stereoacuity was assessed using the Random Dot 2S stereopsis test under habitual near correction at a working distance recommended by the manufacturer.[9] Participants identified stereoscopic targets, and the smallest disparity correctly identified was recorded in seconds of arc.

e. Intraocular Pressure

IOP was measured using a Goldmann applanation tonometer (Haag-Streit, Köniz, Switzerland).[10] Following instillation of topical anesthetic and fluorescein dye, measurements were obtained according to standard Goldmann applanation tonometry procedures. The average of two consecutive readings was recorded for each eye.

f. Near Point of Accommodation (NPA)

NPA was measured using a RAF (Royal Air Force) rule.[11] A near accommodative target was moved slowly towards the participant along the midline until the first sustained blur was reported. Measurements were obtained monocularly for each eye and binocularly, and the distance was recorded in centimeters.

g. Accommodative Facility

Accommodative facility was assessed using ±2.00 D flipper lenses with a near target positioned at 40 cm. Participants alternately viewed through plus and minus lenses while maintaining a clear image. The number of complete cycles achieved within one minute was recorded as cycles per minute. Monocular and binocular measurements were obtained.[12]

h. Vergence Facility

Vergence facility was evaluated using 12Δ base-out and 3Δ base-in prism flippers while participants fixated on a near accommodative target at 40 cm. The number of complete prism cycles achieved in one minute was recorded in cycles per minute.[13]

i. Visual Reaction Time

Visual reaction time refers to the time interval between the presentation of a visual stimulus and the initiation of an appropriate motor response. It reflects the efficiency of visual information processing, cognitive decision-making, and motor execution. In the present study, visual reaction time was assessed using the Human Benchmark Reaction Time Test.[14] Participants were instructed to click the mouse as quickly as possible when the screen changed from red to green, indicating the appearance of the visual stimulus. Before data collection, participants completed practice trials to familiarize themselves with the testing procedure. Five consecutive trials were recorded for each participant, and the average reaction time was calculated and expressed in milliseconds. Testing was performed under standardized lighting conditions using the same computer system for all participants.

j. Saccades and Pursuits

Ocular motor performance was assessed using the Adult Developmental Eye Movement test. Participants were instructed to read the numerical targets as quickly and accurately as possible, following the standardized test procedure. The time required to complete the assessment was recorded in seconds, with lower completion times indicating faster performance.[15,16]

Statistical Analysis

Statistical analysis was performed using SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY, USA). Paired t-tests were used to compare pre- and post-intervention values. A p value <0.05 was considered statistically significant.

Results

A total of 52 participants completed the study. Comparison of pre- and post-caffeine measurements revealed significant changes in several ocular parameters. Visual acuity showed no change following caffeine intake and therefore was not included among the reported outcome measures. However, following caffeine intake, accommodative facility demonstrated a statistically significant improvement in both monocular and binocular conditions, with the greatest improvement observed in binocular measurements (Figure 1; Table 2). Vergence facility also showed a significant increase after the intervention (Table 2).

NPA values decreased significantly in both monocular and binocular measurements, indicating enhanced accommodative ability after caffeine intake (Figure 2; Table 2).

Contrast sensitivity exhibited a small but statistically significant improvement bilaterally (Figure 3; Table 2).

IOP showed a modest but statistically significant increase in both eyes, though values remained within normal physiological limits (Figure 4; Table 2). Pupil diameter also showed a small but consistent increase following caffeine intake (Table 2).

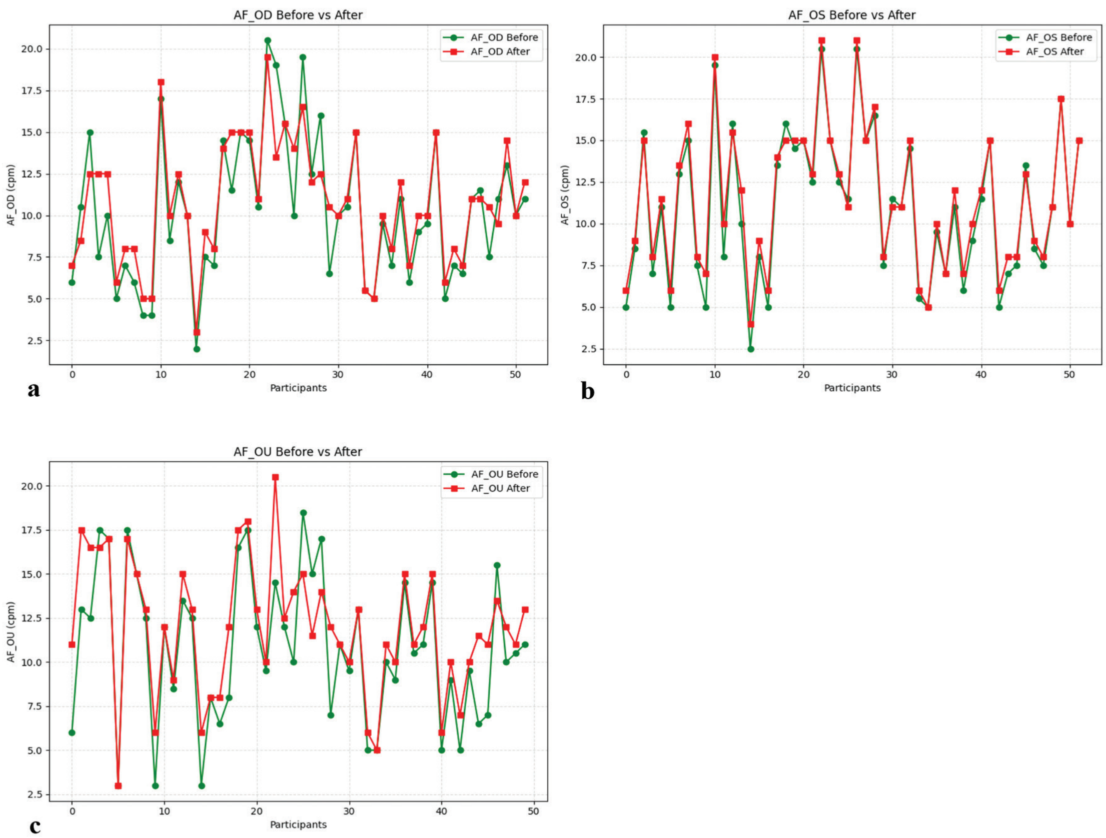

Figure 1. Changes in accommodative facility (AF, in cycles/min) before and after caffeine intake in the right eye (OD; a), left eye (OS; b), and both eyes (OU; c)

Table 2. Summary of ocular measurements before and after caffeine consumption

Parameter		Pre-caffeine		Post-caffeine		p value	t statistic
		Mean	SD	Mean	SD		
AF (cycles/min)	OD	10.21	4.26	10.72	3.61	0.04	-2.048
	OS	10.98	4.47	11.46	4.19	<0.001	-5.471
	OU	10.81	4.22	11.95	3.74	0.0003	-3.853
CS (logCS)	OD	2.04	0.08	2.07	0.08	<0.001	-6.171
	OS	2.03	0.08	2.07	0.08	<0.001	-6.171
IOP (mmHg)	OD	12.96	2.31	13.94	2.33	<0.001	-10.536
	OS	13.42	2.45	14.37	2.54	<0.001	-6.945
NPA (cm)	OD	10.96	3.74	10.19	2.72	0.02	2.362
	OS	10.71	3.21	10.04	2.45	0.009	2.695
	OU	9.52	2.42	9.00	2.00	<0.001	4.397
PD (mm)	OD	2.02	0.42	2.19	0.52	<0.001	-3.656
	OS	2.02	0.42	2.19	0.52	<0.001	-3.656
A-DEM completion time (s)		59.67	10.27	57.48	11.74	<0.001	1.865
Stereopsis (arc sec)		44.38	23.26	39.83	23.3	0.06	1.856
VF (cycles/min)		13.85	3.61	14.89	3.74	0.01	-2.61
VRT (ms)		483.73	131.52	455.07	90.53	0.08	1.743

SD: Standard deviation, AF: Accommodative facility, CS: Contrast sensitivity, logCS: Log contrast sensitivity, IOP: Intraocular pressure, NPA: Near point of accommodation, PD: Pupillary diameter, A-DEM: Adult Developmental Eye Movement test, VF: Vergence facility, VRT: Visual reaction time, OD: Right eye, OS: Left eye, OU: Both eyes

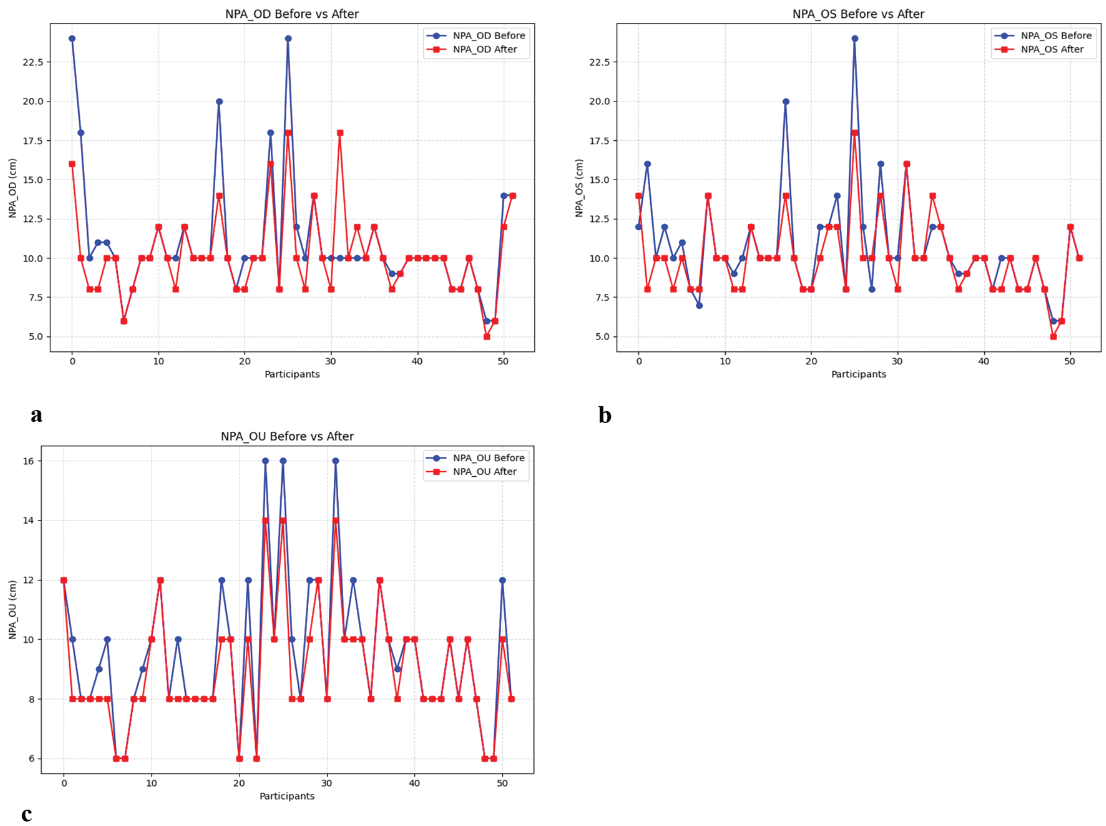

Figure 2. Changes in near point of accommodation (NPA, in cm) before and after caffeine intake in the right eye (OD; a), left eye (OS; b), and both eyes (OU; c)

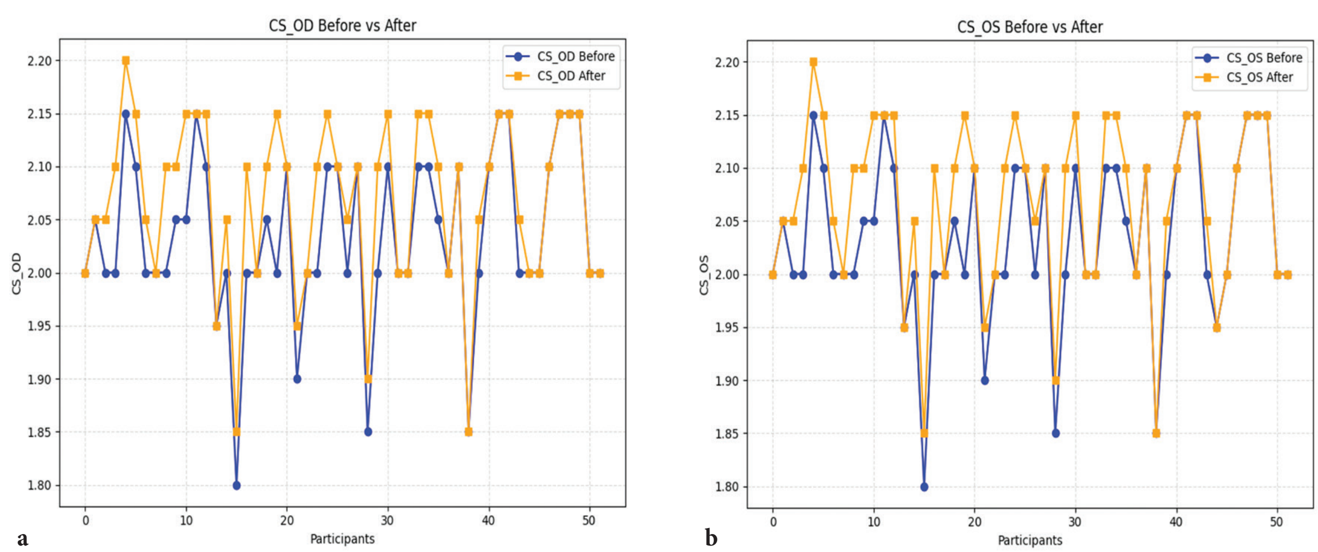

Figure 3. Changes in contrast sensitivity (CS, in logCS) before and after caffeine intake in the right eye (OD; a) and left eye (OS; b)
logCS: Log contrast sensitivity

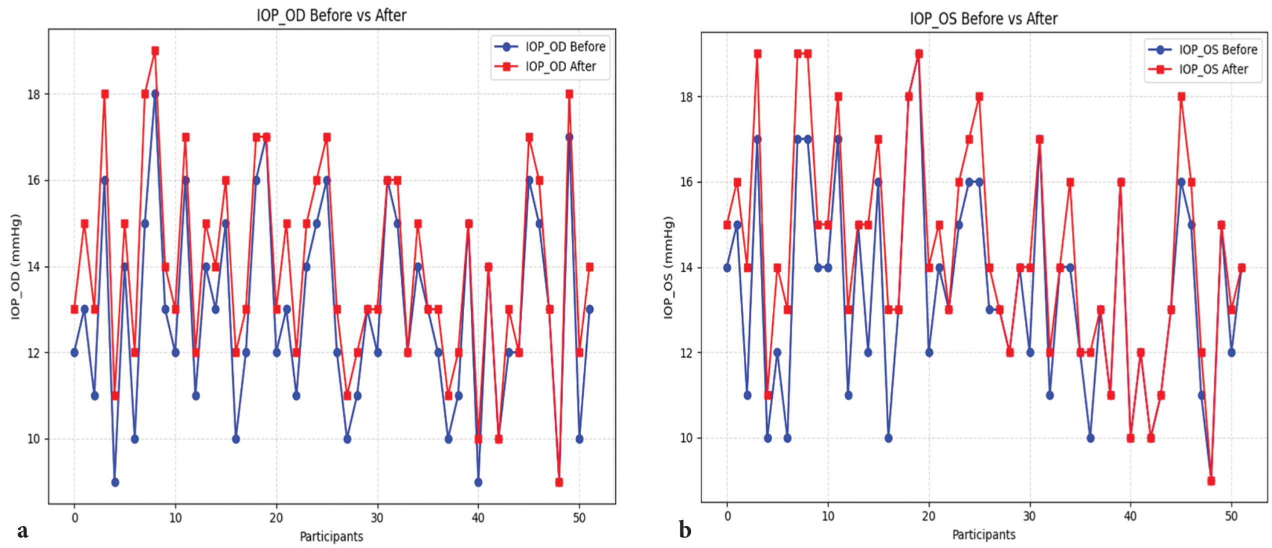

Figure 4. Changes in intraocular pressure (IOP, in mmHg) before and after caffeine intake in the right eye (OD; a) and left eye (OS; b)

While stereopsis and visual reaction time demonstrated trends toward improvement, these differences did not reach statistical significance (Table 2).

Minor changes were observed in pursuits and saccades, indicating slight alterations in oculomotor performance after caffeine intake (Table 2).

Discussion

This study investigated the acute effects of a single 240 mg dose of caffeine on various visual and ocular parameters in healthy young adults. Following caffeine intake, significant improvements were observed in accommodative facility, vergence facility, NPA, and contrast sensitivity. Furthermore, pupil diameter and IOP increased significantly, although the IOP values remained within the normal physiological range (approximately 10-21 mmHg). While slight improvements in visual reaction time and stereopsis were also observed, these did not achieve statistical significance. Overall, the findings indicate that acute caffeine consumption induces measurable short-term changes in several aspects of visual performance.

One of the most notable findings was the improvement in accommodative facility and NPA following caffeine intake. Similar improvements have been reported by Abokyi et al.[17], who observed enhanced accommodative performance after caffeine consumption. Likewise, Redondo et al.[1,18] demonstrated significant improvements in dynamic accommodative response and binocular accommodative facility after acute caffeine intake. Earlier work by Kirshner and Schmid[19]also suggested that caffeine positively influences accommodative performance by improving near point plus acceptance. Together, these findings support the hypothesis that caffeine enhances accommodative efficiency during near visual tasks. A possible mechanistic explanation is the antagonistic effect of caffeine on adenosine receptors, which increases central nervous system stimulation and improves the neuromuscular responsiveness of the accommodative system.[20] Consequently, moderate caffeine intake may temporarily reduce visual fatigue and enhance performance during prolonged near work such as reading and computer use.

Vergence facility also improved significantly after caffeine consumption. Although relatively few studies have evaluated the direct effect of caffeine on vergence function, the improvement observed in the present study may be related to increased cortical alertness and better neuromuscular coordination. As accommodation and vergence are closely linked through the accommodative convergence/accommodation (AC/A) relationship, enhancement of accommodative performance may also contribute to improved vergence facility.[21] Further research is needed to better understand the mechanisms underlying these changes.

A small but statistically significant improvement in contrast sensitivity was also observed. This finding aligns with a study by Obinna et al.[5] that demonstrated increased contrast sensitivity following caffeine intake among healthy young adults. These findings may be attributable to improved neural processing within the visual pathways together with increased cortical arousal.[4,20] Although the observed improvement was modest, even small changes in contrast sensitivity can enhance visual performance during demanding visual tasks and under low-contrast conditions.

Pupil diameter increased significantly following caffeine intake. This finding is consistent with the observations of Abokyi et al.[17] and with a systematic review and meta-analysis by Hartmann et al.[6], both of which reported mild pupillary dilation after caffeine consumption. Caffeine-induced sympathetic stimulation may reduce parasympathetic activity at the iris sphincter muscle, resulting in mild mydriasis.[20,22] In addition, Lazar et al.[23] demonstrated that pupil size is influenced by autonomic balance, environmental illumination, and cognitive state, supporting the possibility that the increased alertness associated with caffeine contributes to the observed pupillary changes.

A modest but significant increase in IOP was also found after caffeine consumption. Similar findings have been reported by Higginbotham et al.[24], who demonstrated transient increases in IOP following caffeine intake in patients with glaucoma. Kim et al.[3] identified an association between caffeine consumption and IOP in genetically susceptible individuals. Although the increase observed in this study remained within the normal physiological range, it may be clinically relevant in individuals with glaucoma or ocular hypertension. The transient rise in IOP may result from changes in aqueous humor dynamics induced by caffeine.

Although visual reaction time decreased after caffeine intake, indicating faster responses, the difference was not statistically significant. Visual reaction time reflects the efficiency of visual information processing, cognitive function, and motor response. Caffeine is known to enhance alertness and psychomotor performance through blockade of adenosine receptors and increased neuronal activity.[20,25,26,27] The lack of statistical significance in the present study may be due to individual variability in caffeine sensitivity, habitual caffeine consumption, or the relatively small sample size. Larger studies are required to determine whether caffeine consistently improves visual reaction time.

Minor improvements were observed in saccadic and pursuit eye movements after caffeine intake. These findings may reflect enhanced oculomotor control associated with increased cortical activation. Connell et al.[28] similarly reported that caffeine increased the velocity of rapid eye movements in healthy individuals, supporting the possibility that caffeine positively influences ocular motor performance. Future studies using objective eye-tracking systems would provide a more detailed evaluation of these changes.

Although stereopsis showed a trend toward improvement, the difference was not statistically significant. Stereoacuity relies on accurate binocular sensory integration and cortical processing, and the short interval between caffeine intake and testing may have been insufficient to produce measurable changes.[29] Studies involving larger populations and different caffeine doses are required to further investigate the effect of caffeine on stereoscopic vision.

A major strength of the present study is the simultaneous evaluation of multiple visual and ocular parameters following acute caffeine consumption. While most previous studies have focused on individual outcomes such as accommodation, pupil diameter, or IOP, the present study provides a broader assessment of the short-term effects of caffeine on visual function. This comprehensive approach offers a more complete understanding of how caffeine influences different components of the visual system.

From a clinical perspective, the findings suggest that moderate caffeine intake may temporarily improve accommodative function, vergence facility, and contrast sensitivity, which could enhance visual performance during prolonged near work and other visually demanding activities. However, the observed increase in IOP suggests that individuals with glaucoma or ocular hypertension should consume caffeine cautiously.

Study Limitations

The study has several limitations. The sample size was relatively small and consisted only of healthy young adults from a single institution, which may limit the generalizability of the findings. The absence of a placebo-controlled, double-blind design may also have introduced expectation bias. Furthermore, only the short-term effects of a single caffeine dose were investigated, and habitual caffeine intake was not quantified. As plasma caffeine concentrations were not measured, inter-individual differences in caffeine metabolism could not be evaluated. Future studies should include larger and more diverse populations, randomized placebo-controlled designs, different caffeine dosages, and longer follow-up periods to better understand the effects of caffeine on ocular physiology and visual performance.

Conclusion

In this study, a single dose of caffeine produced measurable short-term changes in several visual and ocular parameters, particularly in accommodative function, vergence facility, and contrast sensitivity. A modest improvement in visual reaction time was also observed. These findings suggest that moderate caffeine intake may have a beneficial effect on visual performance during visually demanding tasks. However, while IOP values remained within normal physiological limits, the slight increase highlights the need for caution in individuals at risk of ocular hypertension or glaucoma. Further largescale, placebo-controlled clinical studies are required to confirm these findings and evaluate their long-term clinical significance.

Ethics

Ethics Committee Approval: The study was approved by the Institutional Ethics Committee of Parul University (approval no: PUIECHR/PIMSR/00/081734/8214; date: 31 December 2024).

Informed Consent: Written informed consent was obtained from all participants.

Declarations

Authorship Contributions

Concept: R.K., Design: R.K., Data Collection or Processing: R.K., B.G., S.D., K.M., Analysis or Interpretation: R.K., S.D., M.R., Literature Search: R.K., S.D., M.R., Writing: R.K., M.R., S.P.

Conflict of Interest: No conflict of interest was declared by the authors.

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