ORIGINAL ARTICLE

Intraocular Pressure Changes During Valsalva Manoeuvre in Young and Middle-Aged Adult Populations

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Intraocular pressure (IOP); Valsalva manoeuvre (VM); dynamic IOP; IOP fluctuation

ABSTRACT

Background: Intraocular pressure (IOP) is a critical physiological parameter that maintains the structural integrity and function of the eye. Understanding its dynamic behaviour under transient physiological stressors is essential for comprehensive ocular assessment. The Valsalva manoeuvre (VM) acutely increases central and episcleral venous pressures, providing a natural model for studying short-term IOP fluctuations. This study aimed to investigate and compare dynamic IOP changes during the VM between young and middle-aged adults to establish age-specific response patterns. **Methods:** A cross-sectional study was conducted among 42 healthy participants, equally divided into a young adult group (18–25 years) and a middle-aged adult group (40–65 years). IOP was recorded at four time points: pre-VM (0 s), intra-VM (10 s and 20 s) and post-VM (900 s). The VM was standardized by maintaining an expiratory pressure of 40 mmHg for 20 seconds using an aneroid manometer. Repeated-measures ANOVA with Bonferroni-corrected paired t-tests assessed IOP changes within each group, while independent-samples t-tests compared responses between age groups. **Results:** Both age groups exhibited a significant transient IOP elevation, peaking at 10 s during the VM before declining toward baseline. In young adults, mean IOP increased from 14.48 ± 3.34 mmHg (pre-VM) to 18.05 ± 3.53 mmHg (10 s), while in middle-aged adults, it rose from 14.00 ± 3.05 mmHg to 17.81 ± 3.06 mmHg (10 s). By 900 s post-VM, IOP had returned to near-baseline levels in both groups. No statistically significant inter-group difference in IOP change was found across any VM phase ($p > 0.05$). **Conclusion:** The transient IOP elevation observed in both groups reflects the physiological mechanism in which the VM raises episcleral venous pressure, temporarily impeding aqueous humour outflow. The rapid recovery of IOP to baseline indicates effective ocular and systemic autoregulation following acute venous congestion. The absence of a significant age-related difference suggests that hemodynamic defence and ocular pressure regulatory mechanisms remain comparably efficient between young and middle-aged adults.

INTRODUCTION

Intraocular pressure (IOP) is a fundamental physiological parameter essential for maintaining the structural integrity and optical function of the eye (Fautsch & Johnson, 2006). Its homeostasis depends on the balance between aqueous humour production and outflow resistance. Even minor deviations from this equilibrium can have significant clinical implications, as elevated IOP remains the most important modifiable risk factor for primary open-angle glaucoma, the leading cause of irreversible blindness globally (Asrani et al., 2024). While routine clinical evaluation emphasizes static IOP measurement, emerging evidence highlights the importance of understanding IOP's dynamic behaviour under various physiological and environmental stressors, as transient fluctuations may contribute to retinal ganglion cell damage and glaucoma progression (Liu et al., 2025; Rabiolo et al., 2024).

Among these stressors, the Valsalva manoeuvre (VM) is particularly relevant as a physiological model for acute IOP elevation. The VM involves a forced expiratory effort against a closed glottis, resulting in a transient rise in intrathoracic and intra-abdominal pressures, which in turn elevate central and episcleral venous pressures (Montes et al., 2016; Kimura et al., 2011; Aleksandrova et al., 2007). Because aqueous humour drainage requires IOP to exceed episcleral venous pressure (EVP), any acute rise in EVP can transiently impede outflow, leading to an elevation in IOP (Kazemi et al., 2025). This mechanism has been observed in both physiological contexts, such as resistance training

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or Valsalva-like straining, and clinical settings involving venous congestion (Lara et al., 2023; Saha et al., 2022).
Previous studies have demonstrated the VM's reproducible effects on IOP and ocular blood flow (Aykan et al., 2010; Brody et al., 1999). However, comparative data across age groups remain scarce. Physiological ageing may alter autonomic regulation, vascular compliance and ocular biomechanical properties potentially influencing the magnitude and recovery of VM-induced IOP changes (Cui et al., 2024). Understanding whether these responses differ between younger and middle-aged adults is crucial, as it may reveal early age-related differences in ocular hemodynamic resilience.

Therefore, this study aimed to (1) characterize the dynamic changes in IOP during the Valsalva manoeuvre in young and middle-aged adults, and (2) compare the response profiles between these two age groups. The findings are expected to contribute to the growing body of evidence on dynamic IOP assessment and enhance clinical understanding of how acute venous stress influences ocular pressure regulation across different stages of adulthood.

MATERIALS AND METHODS

Study Design

This cross-sectional study aimed to examine IOP fluctuations during the VM among healthy young and middle-aged adults. IOP measurements were recorded before (pre-VM), during (intra-VM) and after (post-VM) the VM. Mean values at each phase were compared within and between groups.

Participants

A total of 42 healthy volunteers were recruited using purposive sampling. Participants were equally divided into two age-based groups: young adults (18–25 years) and middle-aged adults (40–65 years). Both male and female participants were included. Demographic data, refractive error status and central corneal thickness (CCT) were collected to verify homogeneity across groups and to exclude potential confounding factors (Table 1).

All participants were non-smokers, free from systemic diseases and had no contraindications to performing the VM. None had a history of ocular trauma, ocular surgery, glaucoma or any ocular pathology. Contact lens wearers and individuals on ocular medications were excluded. Only eyes with normal CCT (540 ± 30 µm) and baseline IOP values within 10–21 mmHg were included for analysis.

Ethical approval for the study was obtained from the IIUM Research Ethics Committee (IREC ID No: 85 IIUM/ 310/G/13/4/4-199- KAHS 22) and all procedures adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection.

Table 1: Demographic and baseline ocular characteristics of young and middle-aged adult participants.

	Young adults N=21 (mean±SD)	**Middle-aged adults N=21 (mean±SD)**	***p*-value***
Mean age (years)	22.33 ± 1.24	49.05 ± 6.24	<0.001
Refractive error (DS)	-0.42 ± 0.73	0.12 ± 1.11	0.063
CCT (µm)	555.67 ± 36.91	542.00 ± 22.65	0.155

*Values are presented as mean ± standard deviation (SD). Between-group comparisons were analyzed using the Mann–Whitney U test.

Instrumentation and Materials

IOP was measured using the AccuPen handheld tonometer (Accutome, Pennsylvania, USA), which offers portability and reliability in clinical research (Horowitz et al., 2004). Prior to measurement, proparacaine hydrochloride 0.5 % (Alcon, Texas, USA) was instilled to achieve topical anaesthesia.

To standardize the Valsalva manoeuvre, participants exhaled through a sterile mouthpiece connected to an aneroid manometer (Ruicare, Shanghai, China), allowing real-time monitoring of expiratory pressure. The Oculus Pentacam (Oculus, Wetzlar, Germany) was used to measure CCT in a dark room to minimize fixation variability and light-induced accommodation.

Procedures

Pre-VM Ocular Assessment

CCT was measured with the participant's head stabilized on the chin and forehead rest. Each scan captured 100 Scheimpflug images over 2 s using the automatic release mode to minimize operator bias. Participants maintained fixation on a central red target to ensure alignment consistency.

Baseline IOP Measurement

The tonometer probe was fitted with a sterile latex tip and calibrated to zero prior to each measurement. The probe was gently tapped perpendicularly on the corneal apex and the mean of three valid readings was recorded as the baseline IOP.

Valsalva Manoeuvre and Intra-VM IOP Measurement

Participants were seated upright and instructed to take a deep inspiration, form a tight seal around the mouthpiece with their lips and exhale forcefully to maintain an expiratory pressure of 40 mmHg for 20 s. Verbal feedback ensured steady pressure. IOP was measured at 10 s and 20 s while the target pressure was sustained, following methods adapted from prior physiological IOP studies (Aykan et al., 2010).

Post-VM IOP Measurement

Following the VM, participants rested for 900 s (15 min) in a seated position. A final IOP measurement was taken using the same procedure. This post-VM measurement represented IOP recovery following venous pressure normalization.

Data Analysis

Data were analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). The normality of the data distribution was confirmed using the Shapiro–Wilk test. Descriptive statistics were reported as mean ± standard deviation (SD).

Within-group comparisons across the four VM phases (pre-VM = 0 s, intra-VM = 10 s, intra-VM = 20 s, post-VM = 900 s) were analyzed using repeated-measures analysis of variance (RM-ANOVA). Bonferroni-corrected paired t-tests were applied as post-hoc analyses to determine specific phase differences. Between-group comparisons (young vs. middle-aged) were analyzed using independent-samples t-tests at each time point. The significance level was set at $\alpha = 0.05$.

RESULTS

IOP Change During the VM in Young and Middle-Aged Adults

Young Adult Group

The mean baseline (pre-VM) intraocular pressure (IOP) among young adults was 14.48 ± 3.34 mmHg. A significant transient increase was observed during the VM, peaking at 18.05 ± 3.53 mmHg at the 10-second mark. This represented an approximate 24.6 % rise from baseline.

IOP decreased to 14.05 ± 3.07 mmHg at 20 s and further stabilized to 14.29 ± 2.69 mmHg at 900 s post-VM, returning to near-baseline values. Repeated-measures ANOVA revealed a significant effect of time on IOP, $F(3, 60) = 9.72$, $p < 0.001$. Bonferroni-corrected post-hoc tests indicated that IOP at 10 s differed significantly from pre-VM (0 s), intra-VM (20 s) and post-VM (900 s) measurements ($p = 0.001$, $p < 0.001$ and $p < 0.001$, respectively) (Figure 1).

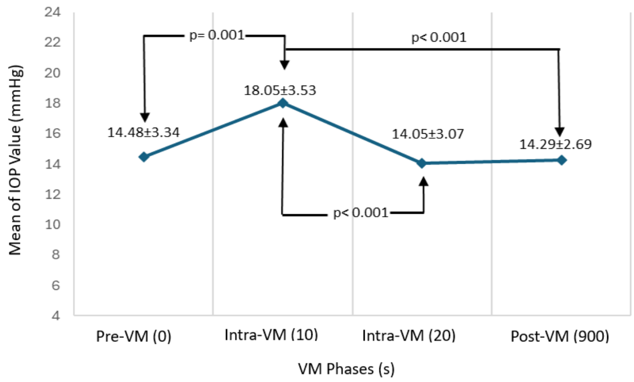

Figure 1: Mean (±SD) IOP changes across VM phases in young adults. *P*-value indicates significant differences as measured using Bonferroni-corrected paired t-tests.

Middle-Aged Adult Group

In middle-aged adults, baseline IOP was 14.00 ± 3.05 mmHg, which increased significantly to 17.81 ± 3.06 mmHg at 10 s of VM ($p = 0.001$). The mean IOP then decreased to 13.90 ± 3.19 mmHg at 20 s and 13.33 ± 2.72 mmHg at 900 s. The overall time effect was significant, $F(3, 60) = 8.83$, $p < 0.001$. Bonferroni post hoc tests indicated that only the 10-s phase differed significantly from all other phases ($p \leq 0.001$) (Figure 2).

These findings indicate a reproducible transient elevation in IOP during early VM, followed by rapid normalization in both age groups.

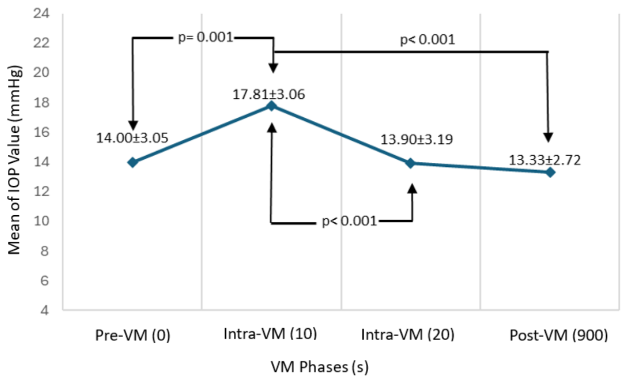

Figure 2: Mean (±SD) IOP changes across VM phases in middle-aged adults. *P*-value indicates significant differences as measured using Bonferroni-corrected paired t-tests.

independent paired t-tests are shown for inter-group comparisons at each phase.

Comparison of IOP Changes Between Age Groups

Figure 3 shows the mean IOP at each VM phase between the two groups. Both exhibited a similar trend: a sharp rise at 10 s, followed by a decline at 20 s and recovery at 900 s. The magnitude of IOP elevation did not differ significantly between groups at any phase ($p > 0.05$ for all comparisons).

At 10 s, the mean IOP was 18.05 mmHg in young adults and 17.81 mmHg in middle-aged adults, with no statistically significant difference ($t(40) = 0.21$, $p = 0.836$)(Table 2). Likewise, baseline and recovery IOP values were comparable, confirming that age did not significantly influence the amplitude or recovery of the VM-induced IOP response. RM-ANOVA indicated a significant effect of time within both groups ($p < 0.001$), but no significant interaction between time and age group ($p > 0.05$).

Table 2: Comparison of mean IOP between young and middle-aged adults across the four VM phases.

Parameter	Young adults (mean±SD, mmHg)	Middle-aged adults (mean±SD, mmHg)	*p*-value* (between groups)
Pre-VM (0 s)	14.48 ± 3.34	14.00 ± 3.05	0.701
Intra-VM (10 s)	18.05 ± 3.53	17.81 ± 3.06	0.816
Intra-VM (20 s)	14.05 ± 3.07	13.90 ± 3.19	0.883
Post-VM (900 s)	14.29 ± 2.69	13.33 ± 2.72	0.261

*Values are presented as mean ± standard deviation (mmHg). Between-group comparisons were performed using independent samples t-tests.

Figure 3 illustrates the mean IOP trend across time points for both groups, demonstrating parallel response curves.

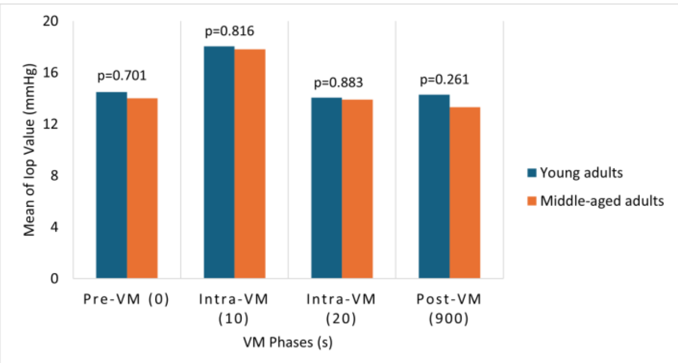

Figure 3: Comparison of IOP trajectories between young and middle-aged adults during VM phases. *P*-values from independent paired t-tests are shown for inter-group comparisons at each phase.

Both young and middle-aged adults exhibited a statistically significant but transient rise in IOP during the early phase of the VM. IOP rapidly returned to baseline within 15 minutes post-VM, demonstrating effective ocular autoregulation. No age-related differences were detected in the magnitude or recovery of IOP changes, indicating that compensatory ocular hemodynamics remain comparable between these age groups.

DISCUSSION

This study investigated the dynamic behaviour of IOP during the VM in healthy young and middle-aged adults. The main finding was a significant, transient rise in IOP during the early phase of the VM in both groups, followed by rapid recovery to baseline within 15 minutes. No statistically significant difference in the magnitude or recovery pattern of IOP was detected between age groups.

IOP Changes During the VM

The marked IOP elevation observed at 10 seconds of VM in both groups supports the well-established mechanism by which increased intrathoracic pressure leads to a rise in central and episcleral venous pressures, transiently impeding aqueous outflow and elevating IOP (Mete et al., 2016). Similar transient IOP surges during VM have been documented in earlier and recent studies, typically reaching 20–30 % above baseline before returning to normal within minutes (Lara et al., 2023; Saha et al., 2022; Aykan et al., 2010).

The post-VM return of IOP to baseline demonstrates effective ocular autoregulation and venous pressure normalization. When the expiratory strain is released, the sudden drop in intrathoracic pressure restores venous return and triggers baroreflex-mediated cardiovascular compensation (Berlin et al., 2019; Firmino et al., 2019). These systemic adjustments, together with intrinsic ocular mechanisms, rapidly re-establish aqueous outflow and IOP homeostasis. This aligns with findings from Horowitz et al. (2004), who reported that transient systemic or venous stress does not cause sustained structural deformation in healthy eyes.

Physiological and Clinical Implications

Transient IOP spikes such as those induced by VM may be clinically relevant in patients with compromised outflow pathways or reduced scleral rigidity, such as in glaucoma or ocular hypertension (Asrani et al., 2024; Brody et al., 1999). Although healthy eyes compensate efficiently, repeated or prolonged venous stress could contribute to microvascular stress in susceptible individuals. Recognizing these short-term IOP fluctuations is important for interpreting tonometric measurements in situations involving breath-holding, coughing or heavy lifting (Saha et al., 2022).

Furthermore, studies on resistance exercise show similar patterns of transient IOP elevation during strain phases of weightlifting, emphasizing that ocular perfusion pressure and venous return are closely linked to systemic cardiovascular responses (Lara et al., 2023). These observations reinforce the need to consider body posture and breathing effort when interpreting dynamic IOP data.

Age-Related Comparison

The finding of no significant age-related effect in this study suggests that, within the examined range, ocular and systemic compensatory mechanisms remain largely preserved. Although ageing is associated with reduced vascular elasticity and altered autonomic reflexes (Cui et al., 2024), such changes may not yet be pronounced enough to affect short-term venous pressure responses in middle adulthood. Studies of older adults aged 65 and older have reported subtle delays in recovery time or smaller pressure peaks, suggesting that age-related vascular stiffness becomes increasingly influential later in life (Nilsson, 2014; Steppan et al., 2011).

Our findings indicate that the efficiency of ocular hemodynamic regulation is maintained throughout early and middle adulthood. Future studies, including older age groups and continuous IOP monitoring, could provide deeper insight into how ageing modifies ocular compliance and venous coupling.

Limitations and Future Directions

The study's limitations include its cross-sectional design and relatively small sample size, which restrict causal inference and generalization. IOP was measured at discrete time points rather than continuously; thus, potential micro-fluctuations between the 10- and 20-second intervals were not captured. In addition, systemic hemodynamic parameters such as blood pressure and heart rate were not simultaneously recorded, which could have enriched interpretation of the ocular–systemic interaction.

Future research should employ continuous tonometry or dynamic contour tonometry synchronized with cardiovascular monitoring to delineate the complete temporal IOP profile. Including older adults and patients with glaucoma or ocular hypertension would also clarify whether autoregulatory differences emerge with age or disease.

Summary

In summary, both young and middle-aged adults demonstrated a transient, statistically significant rise in IOP during the VM, followed by rapid normalization. The comparable response patterns between age groups indicate that ocular and systemic autoregulatory mechanisms maintain robust compensation during acute venous congestion. These findings enhance the understanding of dynamic IOP behaviour and provide reference data for interpreting physiological pressure changes in clinical and research contexts.

CONCLUSION

This study demonstrated that both young and middle-aged adults exhibit a transient but statistically significant elevation in IOP during the VM, peaking at the early phase before rapidly returning to baseline. The absence of significant differences between age groups suggests that ocular and systemic autoregulatory mechanisms remain efficient across early and middle adulthood in maintaining IOP stability during acute venous stress.

Clinically, these findings provide useful normative reference data for interpreting dynamic IOP fluctuations in healthy adults and underscore the need to consider transient venous influences when performing tonometric assessments. Future studies employing continuous IOP monitoring, alongside cardiovascular and choroidal measurements, could offer deeper insight into the coupling between ocular biomechanics, venous pressure, and age-related autoregulatory adaptation.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

DECLARATION OF AI ASSISTANCE

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