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RESEARCH

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The impact of different postures on acute intraocular pressure and accommodation responses during reading

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Abstract

Introduction To investigate the effects of different reading postures on intraocular pressure (IOP) and near-work-induced transient myopia (NITM) in children with myopia.

Methods Sixty myopic children were instructed to read a book text placed at 33 cm for 30 min with two different reading postures: head bowed and head upright postures. The participants' IOP and NITM were assessed using a rebound tonometer and an open-field autorefractor. The measurement of IOP was conducted prior to reading, during reading sessions (at 5, 10, 20, and 30-min intervals), and after a 5-min recovery period.

Results For the head bowed posture, the mean baseline IOP was 16.13 ± 2.47 mmHg. A significant rise in IOP was observed after 5 min of reading (17.17 ± 2.97 mmHg; +1.03 ± 2.29 mmHg; $p = 0.014$). Subsequent measurements revealed a further increase after 20 min (17.87 ± 2.90 mmHg; +1.73 ± 2.58 mmHg; $p < 0.001$), which continued to persist even after 30 min of reading (17.57 ± 3.46 mmHg; +1.43 ± 2.66 mmHg; $p = 0.002$). The IOP at different time points measured in the head upright posture did not show any significant difference in comparison to the baseline measurement (all $p = 1.000$). Compared to reading with the head upright, reading with the head bowed resulted in a greater increase in IOP at each time point ($p < 0.05$). Furthermore, the NITM was higher for reading with the head bowed than for reading with head upright at 30 min (-0.24 ± 0.53 D vs. -0.12 ± 0.47 D, $p = 0.038$).

Conclusion Reading in a head bowed position resulted in greater increases in IOP and NITM compared to reading in a head upright posture.

Keywords Intraocular pressure, Near-work-induced transient myopia, Myopic children, Head bowed, Head upright

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Introduction

Myopia, a condition that is growing more prevalent worldwide, is of particular concern in East Asia [1–3]. It is predicted that by 2050, approximately 5 billion people would suffer from myopia [4], which amounts to nearly half of the world's population and is a staggering statistic. Therefore, there is an urgent need to identify preventable risk factors for myopia. Nowadays, it is widely acknowledged that near-work constitutes a significant risk factor for the occurrence and development of myopia [5, 6], and the near-work-induced accommodation play a crucial role in the progression of myopia via different mechanisms [7–9]. However, none of these mechanisms can fully explain the phenomenon of myopia progression induced by near-work. In recent years, the changes in intraocular pressure (IOP) and near-work-induced transient myopia (NITM) associated with accommodation have been proposed as potential factors that may contribute to the development of myopia [10–12].

Previous studies indicated that IOP might be a significant factor in the onset and progression of myopia, as the mean IOP value in myopic individuals was found to be markedly higher than that of emmetropes [13, 14]. However, some studies [15–17] demonstrated controversial findings, in which there were no significant differences in IOP values between myopic and emmetropic individuals, and even no clear relationship between baseline IOP value and myopia progression. The actual relationship between IOP and myopia appears to be contradictory, with some studies suggesting a significant association while others do not support this notion. In fact, our understanding of the exact relationship between refractive status and IOP is limited, as static IOP values can be easily influenced by numerous factors [14, 18–21], such as central corneal thickness, age, blood pressure, obesity, exercise and near work. Hence, the association between static IOP value and myopia progression remains uncertain. It is thought that IOP variations may be responsible for changes in refraction and axial length (AL), ultimately leading to myopia progression [10]. A previous study reported that baseline IOP levels were not obviously different between progressing myopes and emmetropes. However, during accommodation, progressing myopes exhibited a transient elevation in IOP levels, while emmetropes showed a slight decrease in IOP levels [10]. A series of evidences from in vitro and in vivo experiments indicated that IOP elevation could cause changes in AL elongation and posterior sclera stretching [22–24]. Despite this evidence, the underlying mechanism and associated structural modifications that cause an increase in IOP and ultimately lead to changes in AL elongation and posterior sclera stretching are not yet well understood.

A recent scientific study observed that there is an immediate change in IOP when the body position is suddenly altered [25]. Therefore, we hypothesize that the changes of body position may have influence on the IOP values. Another study reported that IOP in the left lateral decubitus position was remarkably higher than in the supine position [26]. Moreover, several human and animal studies have demonstrated that IOP values are greater in a horizontal position when compared to sitting and upright position [27–30]. It is widely recognized that individuals typically adopt either a bowed or upright head posture while reading. This can vary depending on the type of reading material and the individual's personal preference. Therefore, our study aimed to assess the impact of these two reading postures on IOP changes associated with near work, as well as to explore potential differences in NITM between the two postures. Given the rising prevalence of myopia and the increasing stress of studying, it is important to determine which reading posture has the potential to help control myopia progression.

Methods

Subjects

A total of 60 myopic children aged 6–16 years (26 males and 34 females) admitted to Beijing Tongren Hospital from August 2021 to August 2022 were enrolled in this study. The average age of the subjects was 10.63 ± 2.53 years. This study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Ethics Committee of Beijing Tongren Hospital. Written informed consent was obtained from at least one of each child's parents or other guardians, while verbal consent was provided by all the participants.

All patients fulfilled the following inclusion criteria: -6.00 D < spherical equivalent (SE) ≤ -0.50 D of both eyes; best-corrected visual acuity of 6/6; ≤ 0.75 D of astigmatism; ≤ 1.00 D of anisometropia; IOP less than 21 mm Hg; no accommodative anomalies; absence of severe ocular pathology or history; no topical or systemic medications; no severe systematic or mental diseases; full-time spectacle wearers to minimize the potential effects of changes in refractive correction methods on normal accommodation behavior; no history of wearing contact lenses within the four weeks preceding the testing period; None of the subjects used any methods of myopia controlling such as peripheral defocus spectacles, low-dose atropine, orthokeratology, etc. that might have affected their accommodation or IOP.

Each included subject underwent a complete ocular examination, such as noncycloplegic subjective refraction, IOP, binocular testing, slit-lamp biomicroscopy of the anterior eye, and a fundus examination was conducted to exclude patients with fundus disease. The best visual acuity was achieved using the principle of maximum plus during subjective refraction. Participants were instructed to wear spectacles with lenses prescribed during the subjective refraction for both the reading tasks and accommodation measurements.

Procedures

The whole experiment lasted for approximately 2 h. After completing a comprehensive eye examination, each participant was asked to perform two reading tasks while seated: reading with the head bowed (neck flexed at a 45° angle) and reading with the head upright (neck in a neutral position). The sequence of these 2 reading tasks was randomized. IOP measurements were conducted using an Icare rebound tonometer (Icare TA01i, Revenio, Finland) for 6 consecutive times, and the average value was recorded. The measurements were taken only from the right eye of each participant.

The refractive state was measured before and after the 30-min reading period using an open-field autorefractor (WAM-5500; Grand Seiko Co., Ltd., Hiroshima, Japan), which has been shown to be reliable for NITM and its decay, as well as accommodative stimulus-response testing in its dynamic mode [31]. According to the manufacturer's manual, the dynamic mode of the autorefractor had a precision of 0.01 D. The dynamic measurements were taken at a rate of approximately 5 Hz (five samples per second). The high-speed measurements were collected by connecting the Grand Seiko WAM-5500 autorefractor to a computer via an RS-232 C cable, and the resulting data output was automatically converted into an Excel spreadsheet [32].

Each participant was instructed to rest with their eyes closed in a completely dark room for 5 min to help alleviate any accommodative spasms. After the resting period, the participants were brought to the experimental room where they were seated in front of the open-field autorefractor, wearing their corrected spectacles, and under natural room light illumination. The autorefractor was used to measure monocular refractive errors of the right eye while the participants viewed the 20/30 Snellen letters at a distance of 6 m, with their corrective spectacles on. A total of 50 measurements were taken at intervals of 0.2 s [33]. The mean SE was computed from this data, which represents the average baseline distance refractive state. Baseline IOP measurements were obtained from the right eye prior to reading.

Next, the subjects began to read the text for 30 min at a distance of 33 cm, while adopting the corresponding body posture in sitting position. Both postures read the same material, consisting of paragraphs of words in 10.5-point Sim Sun Chinese font with darker letters on a lighter background, under an environmental luminance of 100 cd/m^2. Subjects temporarily stopped reading for IOP measurements at 5, 10, 20, and 30 min. The IOP was measured in head upright position of both postures to eliminate the impact of changes in the angle of the tonometer on IOP.

Then, post-task distance refractive state measurements were immediately performed at the end of the half-hour reading session. After the 30-min reading period, the subjects were instructed to shift their focus to the distant Snellen target at 6 m. The autorefractor then continuously obtained distance refraction measurements for a period of 10 s, consisting of 50 measurements in total [33]. The post-task refraction was calculated by averaging the measurements obtained over a 10-s period. Finally, the subjects were asked to close their eyes for a 5-min recovery period, after which another IOP measurement was taken while they remained seated.

After completing one reading task, the participants were required to take a break of at least 30 min in a completely dark room before switching to the other reading task.

Statistical analysis

After the completion of data collection, the SE was calculated as the sum of the sphere power and half of the cylinder power. To determine the magnitude of NITM, the mean spherical equivalent of the distance refraction measurements taken pre-task was subtracted from the mean spherical equivalent of the post-task measurements.

All analyses were carried out using the SPSS software v25. The normal distribution of the variables was confirmed ($P > 0.05$) by the Kolmogorov-Smirnov test, and all data were presented as mean ± standard deviation (SD). To evaluate longitudinal changes in IOP, a repeated measures ANOVA was performed to compare the pre-work value with the value at each subsequent interval. To compare the significance of IOP changes within each posture at different time points, paired t-tests with Bonferroni correction were performed. The paired Student's t-test was conducted to assess the significance of within-subject factors, specifically body postures (head bowed and head upright), on the changes in IOP and initial NITM. A significance level of $P < 0.05$ was used for all statistical analyses.

Results

Table 1 describes the subjects' demographic and baseline clinical data. The study comprised 60 children, each contributing their right eye, resulting in a total of 60 eyes included. The subjects had an average SE of -2.36 ± 1.54D, with a range between −0.50 and −5.93D. Figure 1A and B show the effects of head bowed and head upright postures during reading at the different points of intraocular pressure measurement. Among the head bowed posture, pre-work average IOP was 16.13 ± 2.47 mmHg. After 5 min of reading while head bowed caused a significant

Table 1 Demographic and clinical characteristics of subjects

	Subjects
Cases (eyes)	60
Age (years)	10.63 ± 2.53
Gender (F/M)	26/34
Spherical equivalent (D)	-2.36 ± 1.54
Baseline IOP (Head down posture vs. Head upright posture, mmHg)	16.13 ± 2.47 vs. 16.72 ± 2.41, P = 0.180

Values are mean ± SD

F, female; M, male; D, diopters

increase in IOP (17.17 ± 2.97 mmHg; +1.03 ± 2.29 mmHg; p = 0.014). After reading task for 10 min, we found a significant elevation in the mean IOP (17.18 ± 2.93 mm Hg; +1.05 ± 2.61 mmHg; p = 0.043), which continued to increase throughout the 20-min observation period (17.87 ± 2.90 mmHg; +1.73 ± 2.58 mmHg; $p < 0.001$) and persisted for 30 min (17.57 ± 3.46 mmHg; +1.43 ± 2.66 mmHg; p = 0.002). The IOP returned to the pre-reading level within 5 min after the reading task was stopped (16.68 ± 3.33 mmHg; +0.55 ± 2.65 mmHg; p = 1.000).

In the head upright posture, the average pre-work IOP was 16.72 ± 2.41 mmHg. After 5-min work, the IOP value was comparable to the baseline measurement (16.83 ± 2.47 mmHg; +0.12 ± 1.84 mmHg; p = 1.000). However, over the course of 10 min, we found that the IOP value dropped to 16.68 ± 2.69 mmHg, which was lower than the baseline IOP but not statistically significant (-0.03 ± 2.21 mmHg; p = 1.000). During the 20 and 30 min of reading, we observed that the IOP values were slightly higher (16.92 ± 2.64 mmHg; +0.20 ± 2.43 mmHg; p = 1.000 and 16.95 ± 3.05 mmHg; +0.23 ± 2.68 mmHg; p = 1.000) when compared with baseline IOP, but remained statistically insignificant. The mean IOP decreased below the pre-work level (16.32 ± 2.78 mmHg; -0.40 ± 2.58 mmHg; p = 1.000) at 5 min after stopping the task. The IOP values at different measurement points were all not significantly different when compared to the baseline measurement (all p = 1.000) in the head upright posture.

As for pre-work IOP, it was not significantly different between the two postures (head bowed: 16.13 ± 2.47 mmHg; head upright: 16.72 ± 2.41 mmHg; p = 0.180). Figure 2 displays the IOP changes during and after the reading tasks between the two different postures. After 5 min of reading task, we compared the change in IOP values between the two postures and found that the head bowed posture had a significantly higher increase of 1.03 ± 2.29 mmHg compared to the head upright posture, which had an increase of 0.12 ± 1.84 mmHg (p = 0.020). After 10 min of work, the head bowed posture showed an increase in IOP of 1.05 ± 2.61 mmHg, while the head upright posture demonstrated a decrease of 0.03 ± 2.21 mmHg, the difference between the two postures was statistically significant (p = 0.016). After the 20 min of work, the head bowed posture demonstrated a significantly greater increase in IOP of 1.73 ± 2.58 mmHg than the head upright posture which had a much smaller increase of 0.20 ± 2.43 mmHg (p = 0.002). After 30 min of work, the head bowed posture exhibited a statistically significant increase in IOP of 1.43 ± 2.66 mmHg compared to the baseline, which was significantly greater than the increase of 0.23 ± 2.68 mmHg observed in the head upright posture (p = 0.017). Five minutes after the cessation of work, the mean increase in IOP for the head bowed posture was 0.55 ± 2.65 mmHg, while the head upright posture exhibited a decrease in IOP of 0.40 ± 2.58 mmHg compared to the pre-work level. However, the difference in IOP change between the two postures was not statistically significant (p = 0.060).

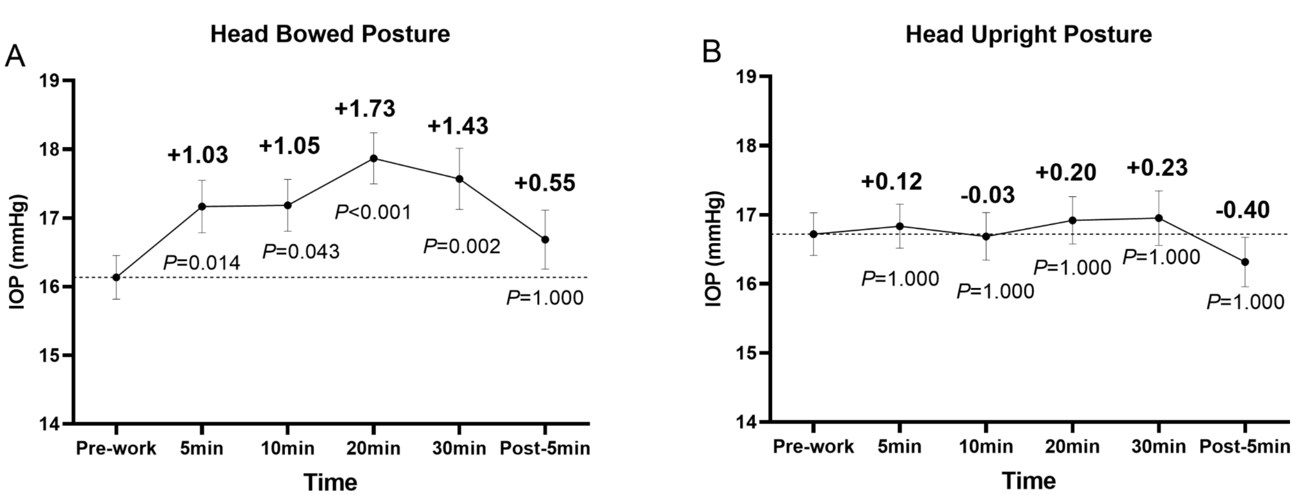

Fig. 1 The graph illustrating the mean IOP values, along with the standard error of the mean represented by the Y error bar, for 60 eyes during and after near work in both head bowed (**A**) and head upright (**B**) postures

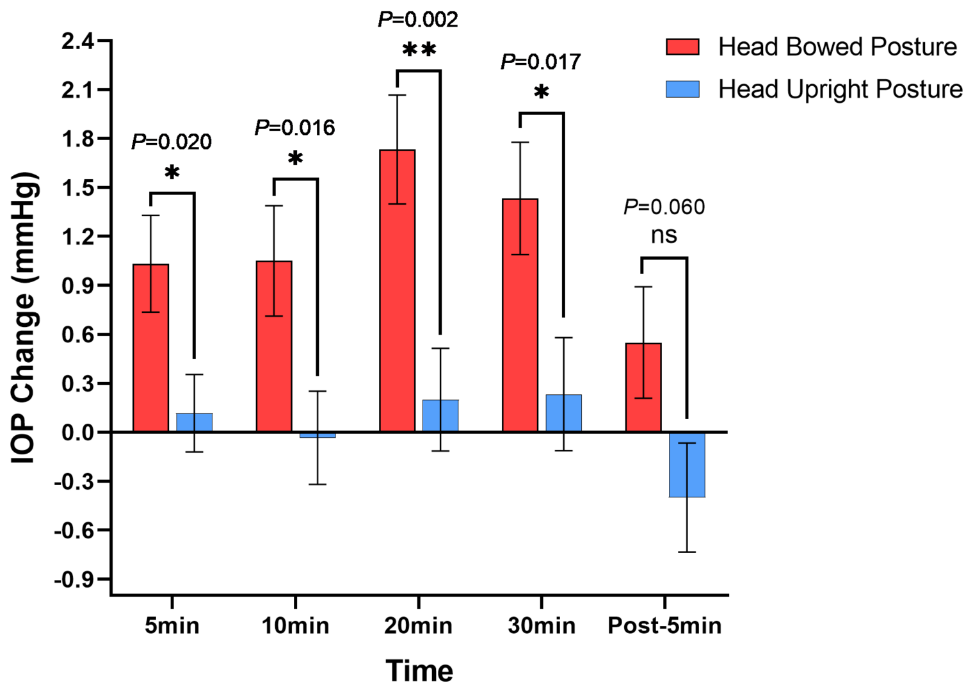

Fig. 2 The graph showing the difference between pre-work IOP and IOP at various measure points for both the head bowed and head upright postures. The IOP changes in the head bowed posture are represented by the red bars, while the IOP changes in the head upright posture are represented by the blue bars. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, ns = no significance. The Y error bar indicates the standard error of the mean

In addition, we also observed that after 30 min of near-work, the NITM was higher for the head bowed posture (-0.24±0.53 D) compared to the head upright posture (-0.12±0.47 D), and the difference between the two postures was statistically significant ($p = 0.038$). Figure 3 displays the mean initial NITM values along with their respective SDs for each reading posture.

Discussion

This paper was inspired by recent research revealing that, in children with myopia, reading-associated IOP changes are contingent upon bodily position. The present data indicated that there was a significant increase in IOP when reading in a head-bowed posture, whereas it remained stable when reading with an upright head posture. Additionally, we observed that adopting a head-bowed posture resulted in greater increases in IOP compared to maintaining an upright head posture. Consequently, it was also found that reading with a head-bowed posture leads to a greater NITM compared to reading with an upright head posture. Based on these findings, reading with an upright head posture may be a better choice, as this can help to prevent increases or fluctuations in both IOP and NITM, while its long-term impact on myopia progression is needed to further study. Adopting an upright head posture during reading has the potential to be a convenient and cost-effective behavioral intervention for controlling the progression of myopia. This study has important implications for eye care specialists who are involved in the prevention and management of myopia.

Our findings confirmed the impact of reading posture on IOP, demonstrating a greater increase in IOP when reading with a head-bowed posture compared to an upright head posture. It is proven that maintaining a sustained neck flexion posture while reading can lead to an increase in IOP. And there is convincing evidence about the fact that IOP is sensitive to changes in body and head positions [27, 29]. Malihi et al. reported that IOP levels could be modulated by the head and neck postures, with IOP being significantly higher in neck flexion compared to neck extension or neutral neck positions (all $p < 0.0001$) [29]. These findings were consistent with our results, as IOP also had a significantly greater increase during neck flexion than neutral neck position. In addition, similar results were found in Ha's study [34], which reported that using a smartphone while adopting a neck flexion angle of 33–45° from the vertical can lead to a transient increase in IOP. Ha's study also observed a strong positive correlation between the degree of neck flexion and the magnitude of the IOP increment. Additionally, a previous study by Leydolt [23] demonstrated that short-term fluctuations in IOP could lead to a significant increase in AL. Thus, we hypothesize that sustained

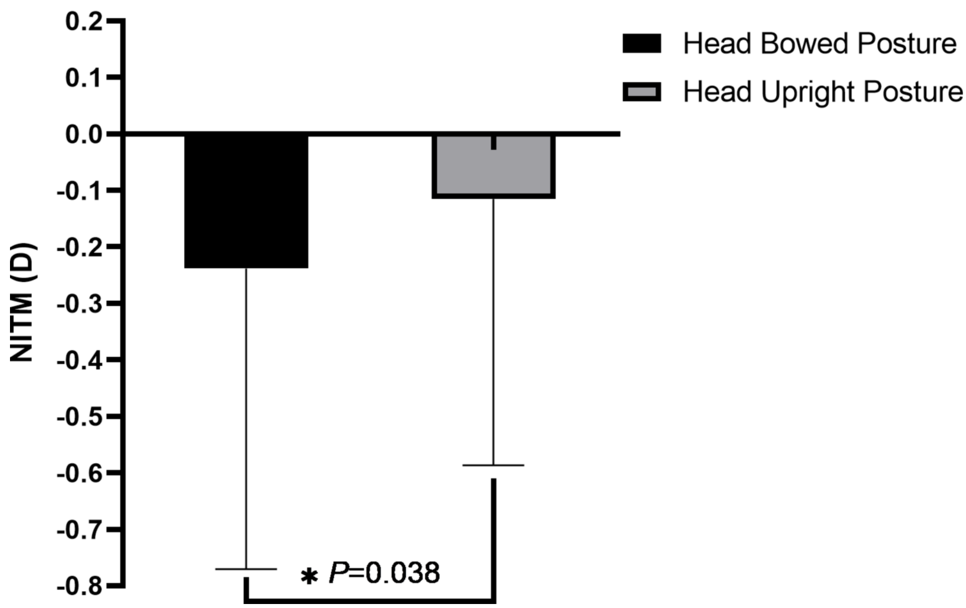

Fig. 3 Effects of two reading postures on the initial NITM values. All values are shown as mean ± SD

increases in IOP while reading with a head-bowed posture may contribute to the elongation of AL and the development of refractive errors in humans. However, the mechanisms underlying changes in IOP with changes in body posture are not yet fully understood. It is believed that the increase in IOP observed when transitioning from a neutral neck position to a flexed neck position is likely due to greater venous compression and an increase in episcleral venous pressure (EVP) [29, 35]. The elevation of IOP observed during neck flexion may be attributed to hydrostatic pressure effects and increases in EVP resulting from the eyes being in a head-bowed posture. Studies have shown that for every 0.83 mm Hg increase in EVP, there is a corresponding increase of 1 mm Hg in IOP [35]. Another possible mechanism underlying the changes in IOP is choroidal vascular engorgement caused by the redistribution of body fluids when transitioning from a neutral neck position [36]. This phenomenon has been associated with the cephalad fluid shift that occurs during head tilt, which is a result of a gravity-induced, orthostatic venous pressure gradient.

In the upright position, there was no significant change in IOP during a 30-min reading task compared to the baseline. It has been reported a slight decrease in IOP during 3D and 6D accommodation [10, 37]. However, it should be mentioned that the most of these findings were based on studies conducted on emmetropic subjects. In myopic subjects, Read et al. [38] also found that IOP decreased significantly after 2 min of near fixation (3D accommodation) with neutral neck posture in young adults, and the SE of all subjects was -3.74 ± 1.88 D. The reduction in IOP during 3D and 6D accommodation is believed to be caused by the contraction of the ciliary muscle. This contraction puts pressure on the trabecular meshwork, leading to the opening of Schlemm's canal. The increased outflow facility associated with accommodation is thought to be greater than any increase in aqueous inflow, which results in a net reduction in IOP. Our study produced results that were not entirely consistent with the above-mentioned studies, as we found that IOP remained unchanged during a head upright posture. This discrepancy in results may be attributed to differences in the age of participants and variations in the duration of the reading task. Previous studies have found a decrease in IOP after two minutes of reading in head upright posture. But in our study, the first IOP measurement time was at 5 min after reading and we found that the IOP remained stable with baseline. Thus, we speculate that IOP may decrease at the beginning of reading, and gradually return to baseline as reading time increases. In future study, we should shorten the time interval for IOP measuring to confirm the hypothesis. However, both our study and Read's study all confirmed that the IOP was not increased when reading with the head upright. However, it should be noted that there is a study by Yan et al. [10] which reported an increase in IOP during accommodation with the head upright posture in myopic individuals. They observed a rise of 0.80 ± 2.28 mm Hg in the IOP of progressing myopes when 3D accommodation was induced for 3 min with neutral neck posture. This finding suggests that the effect of accommodation on IOP may differ depending on factors such as refractive error and the rate of myopia progression. Specifically, our study included subjects with a mean spherical equivalent of -2.36D, whereas their study consisted of subjects with a mean spherical equivalent of -6.58D. It is well-established that individuals with higher levels of myopia may have altered ocular biomechanics and differences in IOP regulation, which could potentially affect the impact of accommodation on IOP. As a result, the increase in IOP during accommodation observed in their study may be specific to individuals with high myopia who are more likely to experience progression even when adopting a head upright posture. In contrast, in individuals with emmetropia or mild to moderate myopia, the effect of accommodation on IOP may result in a decrease or no change in IOP. Other factors that could potentially influence IOP changes associated with near-work and accommodation include lighting conditions, screen brightness, distance to the screen, and the type of reading material used. These factors may affect the amount of accommodation required and the associated changes in IOP. Therefore, we need more researches to confirm that. Moreover, our study only used the book text as reading material, however, many school or office-based work are shifting to computer screens which mainly adopted head upright posture nowadays. Therefore, we should explore the differences of reading with computer screens and book text on IOP in head upright posture in further studies.

Initial NITM magnitude is defined as the dioptric difference between the immediate pre- and immediate post-near task distance refractive state. It refers to the small and transient myopic shift in the far point of the eye found after a period of sustained near-work. Initial NITM was calculated during the first 10-second interval. Our study revealed an intriguing phenomenon where the initial NITM was smaller in the head upright posture than in the head bowed posture. One possible explanation for this observation is that neck flexion may cause interaction between the parasympathetic and sympathetic nervous system, which in turn affects NITM magnitude [39]. More indicators should be measured in future study such as blood pressure, pupil size, heart rate, etc. to confirm this explanation. Another explanation is that visual fatigue may have been greater in the head bowed posture, which affects the NITM value. However, further research is needed to determine the exact mechanism underlying this finding.

The current study presents evidence on the impact of body posture during reading on IOP, indicating that the head bowed posture should be avoided if maintaining a stable IOP level is desired. Nevertheless, it is important to acknowledge several limitations in this study. First, previous research has shown that IOP changes related to near-work are dependent on refractive error [10, 11], but this study only included subjects with mild to moderate myopia, which may limit the generalizability of our findings to other refractive errors. Future studies should explore the impact of refractive error on IOP changes during reading in different body postures to gain a more comprehensive understanding of this phenomenon. Second, we only examined the impact of a 45° neck flexion angle and neutral neck posture on IOP in subjects with mild to moderate myopia. Future research should explore the correlation between different neck-flexion angles during near work and their association with IOP changes and myopia progression in individuals with myopia. Lastly, it is important to note that all subjects in our study were of East Asian ethnicity. Therefore, our results may not be directly applicable to individuals of other ethnicities, and further research is needed to determine whether the findings of our study hold promise in other populations.

Conclusions

Our study found that IOP increases associated with reading are greater when performed in a head bowed position compared to a head upright posture. Additionally, the initial NITM was smaller in the head upright posture than in the head bowed posture. These findings suggest that reading with a head upright posture should be encouraged in individuals to avoid IOP and NITM fluctuations or increments.

Abbreviations

IOP	Intraocular pressure
NITM	Near work-induced transient myopia
AL	Axial length
SD	Standard deviation
EVP	Episcleral venous pressure

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Author contributions

Xintong Liang and Shengjun Zhao wrote the main manuscript text; Shifei Wei, Shi-Ming Li and Ningli Wang revised the manuscript for important intellectual content; conception and design of the study: Xintong Liang, Yinghan Zhang and Ningli Wang; data acquisition, analysis or interpretation of data: Xintong Liang, Shifei Wei, Shi-Ming Li, Shengjun Zhao and Yinghan Zhang; approval of the final manuscript to be published: Xintong Liang, Shifei Wei, Shi-Ming Li, Shengjun Zhao, Yinghan Zhang and Ningli Wang. Xintong Liang prepared Figs. 1, 2 and 3; Table 1. All authors reviewed and approved the final manuscript.

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Data availability

All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate

This research followed the tenets of the Declaration of Helsinki and was approved by Beijing Tongren Hospital Ethical Committee. Written informed consent was obtained from at least one of each child's parents or guardians, while verbal consent was provided by all the participants.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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