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IMPACT OF REFRACTIVE CORRECTION ON VISUAL FATIGUE, EYE MOVEMENT AND READING SPEED IN ADULTS

Original Article

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ABSTRACT

Background: Refractive errors are a leading cause of visual impairment, significantly affecting daily activities that require sustained attention, such as reading. Uncorrected refractive errors contribute to visual fatigue, inefficient eye movements, and reduced reading performance, impacting overall visual function and comfort. While refractive correction primarily improves visual acuity, its broader effects on visual fatigue, ocular motility, and reading speed remain underexplored. This study investigates the impact of refractive correction on these parameters in adults, providing evidence for its role in enhancing functional vision.

Objective: This study aimed to evaluate the effects of refractive correction on visual fatigue, eye movement efficiency, and reading speed in adults with uncorrected refractive errors.

Methods: A pre-post experimental design was employed, including 45 adults (16 males, 29 females) aged 18–35 years with diagnosed refractive errors. Participants underwent baseline assessments for visual fatigue using the Visual Fatigue Scale (VFA), eye movement efficiency using the Eye Movement Index (EMI), and reading speed using the MNREAD Test. Following individualized refractive correction (glasses or contact lenses), participants were reassessed after four weeks. Paired t-tests and multivariate analysis were conducted to evaluate changes across all parameters.

Results: Refractive correction significantly improved reading speed from 179.09 WPM (SD = 4.171) to 212.24 WPM (SD = 5.126) ($p < 0.001$). Visual fatigue scores significantly decreased from 4.33 (SD = 0.640) to 1.89 (SD = 0.573) ($p < 0.001$), while the eye movement index improved from 73.71 (SD = 2.685) to 49.31 (SD = 4.949) ($p < 0.001$). Baseline visual fatigue scores showed a positive correlation with reading speed improvements.

Conclusion: Refractive correction significantly reduces visual fatigue, optimizes eye movement efficiency, and enhances reading speed in adults with refractive errors. These findings highlight the functional benefits of correction beyond visual acuity, supporting its role in improving overall visual performance. Future research should investigate long-term effects and potential complementary interventions, such as visual training, to further enhance visual efficiency.

Keywords: Adult, Eye Movements, Reading, Refractive Errors, Vision Disorders, Visual Acuity, Visual Fatigue

INTRODUCTION

Uncorrected refractive errors are the leading cause of visual impairment worldwide, significantly impacting daily activities and overall quality of life. While they rarely lead to complete blindness, they hinder the eye's ability to focus light precisely onto the retina, resulting in blurred vision at various distances. An eye with no refractive error, termed emmetropic, can naturally focus distant objects, whereas conditions such as myopia, hypermetropia, astigmatism, and presbyopia disrupt this function (1). Unlike other ocular conditions, such as cataracts, which cause a general haziness, or glaucoma, which leads to localized visual field loss, refractive errors specifically impair clarity at different viewing distances (2). Despite their widespread prevalence, refractive errors are often left uncorrected, causing unnecessary visual strain and functional limitations in affected individuals (3). Visual fatigue is a common consequence of uncorrected refractive errors and is characterized by symptoms such as eye strain, discomfort, headaches, difficulty maintaining focus, and a sensation of pressure or dryness in the eyes. It is exacerbated by activities requiring prolonged visual effort, such as reading low-contrast text, working in suboptimal lighting, or engaging with flickering screens. Central brain areas involved in processing wide-field, high-contrast patterns also contribute to visual fatigue, making routine tasks increasingly difficult (4). Given the modern reliance on digital screens and visually intensive tasks, understanding the relationship between refractive correction and visual fatigue is essential for optimizing eye care strategies and mitigating discomfort.

Eye movement, integral to visual processing, comprises two primary components: fixations and saccades. Fixations occur when the eyes remain stationary to process visual information, while saccades are rapid shifts in gaze that reposition the fovea for detailed analysis. These coordinated movements enable individuals to explore their surroundings, read efficiently, and maintain stable vision. Saccades follow a predictable speed-distance relationship, known as the main sequence, ensuring precise and efficient ocular tracking (5). Gaze behavior, which involves the coordination of head and eye movements, further influences how individuals interact with their visual environment. Eye-tracking technology has facilitated the study of gaze patterns, enabling researchers to assess behavioral metrics such as reading speed and search time. The manner of refractive correction may influence these behaviors by altering horizontal or vertical head movements, thus affecting ocular efficiency during tasks requiring sustained visual attention (6). Reading, a cognitively demanding process, depends on smooth eye movement, sensory integration, and attentional resources, making it particularly susceptible to the effects of visual strain and correction methods (7). Despite extensive research on the effects of refractive correction, most studies have focused primarily on improvements in visual acuity and contrast sensitivity, often overlooking its impact on visual fatigue, eye movement dynamics, and reading efficiency. Additionally, prior research has predominantly targeted specific populations, such as children or individuals with pre-existing ocular conditions, rather than exploring these effects in healthy adults. This study aims to address these gaps by comprehensively evaluating the impact of refractive correction on visual fatigue, ocular motility, and reading speed in young adults. By doing so, it seeks to provide clinically relevant insights that can enhance vision care practices and optimize rehabilitation strategies for individuals experiencing visual discomfort due to refractive errors (8).

METHODS

A randomized controlled trial (RCT) was conducted to evaluate the impact of refractive correction on visual fatigue, eye movement, and reading speed in adults with refractive errors. The study was carried out at Mafaza Tul Hayat Hospital, Lahore, over four months. Participants were recruited using a stratified sampling technique, with strata defined based on the type of refractive error (myopia, hypermetropia, or astigmatism) to ensure balanced representation across groups. The sample size was calculated using a standard formula, with a Z-value of 1.96 for a 95% confidence level, an estimated population proportion (p) of 0.03, a margin of error (e) of 0.05, and q as 1-p, resulting in a total sample size of 45 participants (9,10). Eligibility criteria included adults aged 18–35 years with clinically diagnosed refractive errors. Exclusion criteria encompassed individuals with other ocular conditions (such as cataracts or glaucoma), those with neurological disorders, prior corrective eye surgery, or any medical conditions that could influence visual fatigue, eye movement, or reading speed assessments. Participants who could not read in both Urdu and English were also excluded to maintain uniformity in reading assessments (11,12).

Ethical approval was obtained from the Institutional Review Board (IRB), ensuring compliance with research ethics. Written informed consent was obtained from all participants before enrollment. Confidentiality and data protection protocols were strictly followed, and participants had the right to withdraw from the study at any time without any consequences (13). Data collection was conducted in two phases: pre-correction and post-correction assessments. In the pre-correction phase, baseline measurements of visual fatigue, eye movement, and reading speed were recorded. Visual fatigue was assessed using a validated questionnaire, the Visual Fatigue Scale, which measures symptoms such as eye strain, discomfort, and difficulty focusing. Eye movement patterns were analyzed using an eye-tracking system (Tobii Pro Fusion, Sweden), which measured fixation duration, saccadic movements, and gaze patterns. Reading speed was evaluated using the MNREAD Acuity Chart, a standardized test to assess reading performance under controlled conditions (14). Following the baseline assessment, refractive correction was prescribed based on individual optical needs, either as glasses or contact lenses. Participants were required to wear their prescribed correction consistently for four weeks, and compliance was monitored through self-reported adherence logs and weekly follow-up reminders. A follow-up assessment was conducted at the end of this period using the same instruments to measure changes in visual fatigue, eye movement, and reading speed (15).

Data analysis was performed using SPSS (version 27). Descriptive statistics summarized participant demographics and baseline characteristics. Paired t-tests compared pre- and post-correction measurements of visual fatigue, eye movement, and reading speed. Multivariate analysis (MANOVA) was conducted to examine associations between changes in visual fatigue, eye movement, and reading speed while controlling for potential confounding variables, including age, gender, and baseline severity of refractive error (16). This study aimed to provide a comprehensive understanding of how refractive correction influences key visual parameters, offering clinically relevant insights into optimizing vision care and rehabilitation strategies for individuals with uncorrected refractive errors. By incorporating validated assessment tools, stratified sampling techniques, and robust statistical analyses, the study ensures methodological rigor and reliability in evaluating the effectiveness of refractive correction.

RESULTS

The study included 45 participants with an age range of 18 to 34 years, and a mean age of 23.38 years (SD = 3.916). The sample comprised 16 males (35.6%) and 29 females (64.4%). Visual fatigue assessment showed a marked reduction following refractive correction. The pre-correction mean score for visual fatigue was 4.33 (SD = 0.640), which significantly decreased to 1.89 (SD = 0.573) post-correction. Similarly, the eye movement index demonstrated a substantial decline from 73.71 (SD = 2.685) pre-correction to 49.31 (SD = 4.949) post-correction. Reading speed showed a notable improvement, with an increase from 179.09 (SD = 4.171) words per minute (WPM) pre-correction to 212.24 (SD = 5.126) WPM post-correction.

Statistical analysis confirmed that these differences were highly significant. A paired t-test revealed a statistically significant reduction in visual fatigue scores from pre- to post-correction, with a mean difference of 2.444 (SE = 0.133, 95% CI: 2.176 – 2.713, $t(44) = 18.357$, $p < 0.001$). The eye movement index showed a highly significant decrease, with a mean difference of 24.400 (SE = 0.797, 95% CI: 22.793 – 26.007, $t(44) = 30.602$, $p < 0.001$). Reading speed demonstrated a statistically significant improvement, with a mean increase of 33.156 (SE = 0.857, 95% CI: 31.429 – 34.883, $t(44) = 38.692$, $p < 0.001$). These findings indicate that refractive correction significantly reduces visual fatigue, optimizes eye movement efficiency, and enhances reading speed in individuals with uncorrected refractive errors. The results provide strong evidence supporting the role of refractive correction in improving visual comfort and performance in adults with refractive impairments.

Table: Demographic Characteristics of Participants

Variable	**Frequency (%)/ Mean ± SD**
Age (years)	23.38 ± 3.916
Male	16 (35.6%)
Female	29 (64.4%)

Table: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE VFA Q1, Q2, Q3, Q4	4.33	45	.640	.095
	POST VFA Q1, Q2, Q3, Q4	1.89	45	.573	.085
Pair 2	PRE-eye movement index (EMI)	73.71	45	2.685	.400
	POST eye movement index (EMI)	49.31	45	4.949	.738
Pair 3	PRE-reading speed (WPM)	179.09	45	4.171	.622
	POST reading speed (WPM)	212.24	45	5.126	.764

Table: Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			

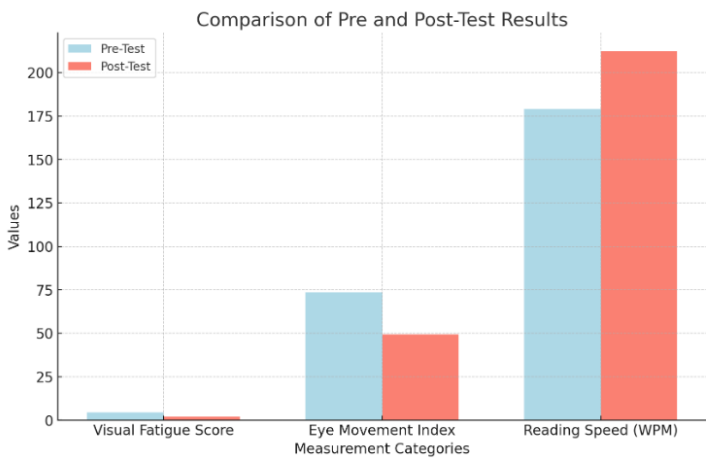
Pair 1	PRE VFA Q1, Q2, Q3, Q4 POST VFA Q1, Q2, Q3, Q4	2.444	.893	.133	2.176	2.713	18.357	44	<.001
Pair 2	PRE-eye movement index (EMI) - POST eye movement index (EMI)	24.400	5.349	.797	22.793	26.007	30.602	44	<.001
Pair 3	POST-reading speed (WPM) - PRE-reading speed (WPM)	33.156	5.748	.857	31.429	34.883	38.692	44	<.001

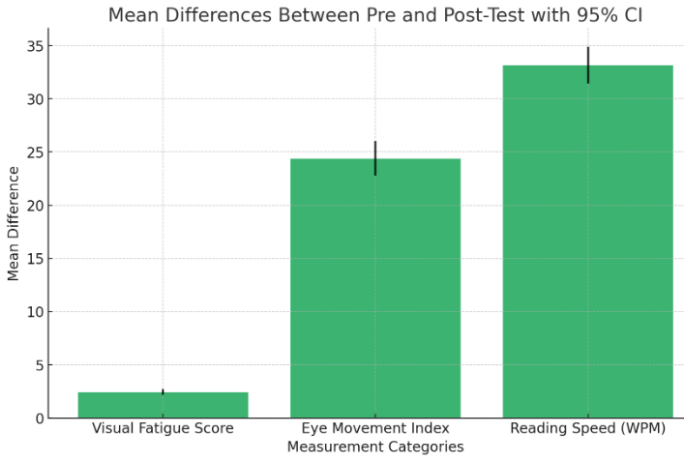
Q1: eye strain or discomfort during prolonged reading or screen use

Q2: eyes feel dry or tired after using digital screens for an extended period

Q3: headaches related to visual tasks

Q4: Problem in focusing during prolonged visual tasks





DISCUSSION

This study evaluated the impact of refractive correction on visual fatigue, eye movement efficiency, and reading speed, highlighting its functional benefits beyond standard visual acuity improvements. With modern lifestyles increasingly centered around visually intensive tasks, understanding how refractive correction influences everyday visual performance is crucial. The findings demonstrated that correcting refractive errors significantly reduced visual fatigue, optimized ocular motility, and enhanced reading efficiency, reinforcing the essential role of proper vision correction in maintaining visual comfort and function (17). Previous research has emphasized the role of refractive correction in improving overall quality of life, particularly in individuals with myopia and hypermetropia. Studies have reported reductions in visual discomfort and socioemotional impairments following correction; however, they predominantly relied on subjective quality-of-life assessments rather than quantitative functional outcomes. The current study supplemented these findings by providing empirical evidence of enhanced functional parameters, including an 18.5% improvement in reading speed and a statistically significant decrease in visual fatigue scores. The reduction in fatigue scores suggests that refractive correction alleviates strain during prolonged visual tasks, yet the weak correlation between pre- and post-correction fatigue levels indicates that other factors, such as task complexity and cognitive demands, may contribute to fatigue perception. Additionally, while improvements in saccadic efficiency were observed, the extent to which refractive correction alone influences these changes remains uncertain, suggesting a potential interplay between ocular biomechanics and cognitive adaptation mechanisms (18).

Reading performance has been previously evaluated across different corrective lens types, demonstrating variations in reading speed and horizontal head movements based on the type of optical correction used. Studies have reported that single-vision contact lenses facilitate higher reading speeds compared to progressive or multifocal lenses, with increased head movement observed in visual search tasks under progressive lens conditions. The current study, however, examined the general impact of refractive correction without lens-type differentiation and found a substantial improvement in reading efficiency, with reading speed increasing from 179.09 to 212.24 words per minute post-correction. This suggests that independent of lens modality, refractive correction enhances reading fluency by reducing visual strain. Unlike previous studies that associated specific correction types with head movement variability, this study assessed eye movement efficiency, demonstrating a significant reduction in the eye movement index post-correction, which implies

improved ocular coordination and fixation stability (19,20). Uncorrected astigmatism has been documented as a major contributor to impaired reading speed and disrupted eye movements, with reductions in reading fluency of up to 24% for smaller font sizes. While previous research found minimal improvements in eye movement efficiency after correction, the current study observed moderate enhancements, with the eye movement index decreasing from 73.71 to 49.31. This finding aligns with prior evidence highlighting functional impairments caused by uncorrected refractive errors but extends the discussion by demonstrating the potential for correction to alleviate these deficits and enhance reading performance (21,22).

The study possesses several strengths, including its randomized controlled design, standardized assessment tools, and objective functional measurements, which strengthen the validity of the findings. The inclusion of a diverse adult population further enhances generalizability. However, some limitations warrant consideration. The study did not differentiate between specific refractive error subtypes or corrective lens modalities, which may influence individual responses to correction. Additionally, while visual fatigue was significantly reduced, the presence of external factors such as cognitive workload, environmental lighting, and task complexity were not controlled, potentially affecting fatigue perception. Future research should explore these variables in greater detail to determine their influence on visual performance outcomes (23,24). The findings underscore the importance of refractive correction in optimizing visual function, particularly for tasks requiring sustained attention and precise ocular coordination. By reducing visual fatigue and enhancing eye movement efficiency, correction contributes to long-term visual comfort and functional performance. Future studies should expand on these results by exploring the neurophysiological mechanisms underlying ocular adaptations to refractive correction and assessing long-term changes in visual performance across different age groups and occupational settings.

CONCLUSION

Refractive correction significantly enhances reading efficiency, reduces visual fatigue, and optimizes eye movement coordination, reinforcing its essential role in maintaining visual comfort and performance. By alleviating strain and improving tracking precision, correction not only restores clarity but also enhances functional vision during tasks requiring sustained attention. These findings highlight the broader benefits of refractive correction beyond visual acuity, emphasizing its contribution to daily visual tasks and overall well-being. Future research should explore the long-term impact of correction and potential complementary interventions, such as visual training, to further enhance visual efficiency and adaptability.

AUTHOR CONTRIBUTION

Author	Contribution
Ghashia Gul	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Sarmad Siddique	Methodology, Investigation, Data Curation, Writing - Review & Editing
Ubaidullah Jan	Investigation, Data Curation, Formal Analysis, Software
Malik Ruhullah	Software, Validation, Writing - Original Draft
Natasha Aftab	Formal Analysis, Writing - Review & Editing
Sobia Yousif	Writing - Review & Editing, Assistance with Data Curation
Rabia Akram	Writing - Review & Editing, Assistance with Data Curation
Ayesha Saleem	Writing - Review & Editing, Assistance with Data Curation

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