RESEARCH

Effects of Optical Intervention on Balance Following Mild Traumatic Brain Injury: An Exploratory Pre—Post Study of Postural Sway

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ABSTRACT

Background

Optical interventions are increasingly used in clinical practice to address visual and balance disturbances following mild traumatic brain injury (mTBI), and may offer a novel intervention for managing vestibular-ocular complaints. However, empirical evidence with objective balance outcomes remains limited. This exploratory pre—post study examined changes in balance performance following a clinically prescribed optical intervention in a community-based mTBI population.

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Method

Sixty-six adults with clinically-confirmed mTBI underwent objective balance assessment using a force-plate—based measure of postural sway under proprioceptive-led, vestibular-led, and visually-led conditions. All patients received single vision distance prescriptions with a binocular balanced spherical endpoint of 20/25 OU and either base-in or yoked base-down prism, depending on phoric posture. On average, participants wore the lenses for 3.38 weeks (+/— 1.47).

Results

Significant improvements were observed across all three sensory-weighted balance conditions following intervention, with the largest changes observed in vestibular-led balance (Mdiff = 34.45). Results also indicated that baseline balance functioning remained strongly associated with follow-up performance. Overall, balance changes were also not significantly associated with recovery phase, gender, or prior glasses use.

Conclusion

Findings provide preliminary evidence that optical prescription intervention is associated with measurable changes in balance performance following mTBI, highlighting vision as a clinically relevant contributor to postural control. However, given the multicomponent nature of the intervention and the absence of a control condition, individual elements of the optical prescription cannot be independently attributed to the observed outcomes. The findings should be interpreted as reflecting the combined effects of visual modification rather than isolated optical mechanisms. Controlled trials are needed to clarify the specific contributions of individual prescription components and their clinical relevance for mTBI rehabilitation.

Commonly referred to as a "concussion," mild traumatic brain injury (mTBI) results from mechanical forces applied to the head, leading to rapid acceleration or rotational movement of the brain within the skull.[1-4] The consequences of mTBI are multifactorial and frequently give rise to a constellation of symptoms known as persisting post-concussive symptoms (PPCS), which reflect the ongoing nature of post-injury impairment.[5-8] These may include cognitive deficits (e.g., memory and attention difficulties), sensory sensitivities (e.g., photophobia), fatigue, visual disturbances, dizziness, balance problems, and sleep disruption.[9-11] Although symptoms typically resolve within days or weeks for most individuals, a substantial subset (~15–50%) may experience symptoms for months or even years,[12,13] resulting in delayed recovery and reduced quality of life.[14-16]

Oculomotor and vestibular disturbances are among some clinically significant symptom clusters,[17,18] affecting approximately 40% to 60% of patients post-injury.[19-22] Notably, up to 28% of individuals report balance or visual dysfunction persisting one year after mTBI.[23] These symptoms are often linked to binocular vision dysfunction (BVD), a broad term encompassing deficits in the coordination of the eyes during binocular vision.[24-26] BVD may manifest as convergence insufficiency, accommodative dysfunction, smooth pursuit impairment, or vertical heterophoria.[24-29] Vestibulo-ocular dysfunction and BVD are observed across both acute and chronic mTBI phases, with prevalence estimates ranging from 50% to 90%, depending on the stage of recovery.[30-34] In chronic mTBI populations, rates of specific BVD subtypes such as accommodative dysfunction and convergence insufficiency range from 36% to 43%.[35-37] While some of these abnormalities remit within weeks, disorders of ocular alignment and coordination are increasingly recognized as contributing to prolonged recovery trajectories.[22,38]

Given the high prevalence of BVD in mTBI, clinicians have pursued targeted rehabilitation strategies to address persistent vestibular-ocular symptoms.[40-49] Among these, optical interventions, particularly microprism and yoked prism, have garnered interest for their potential to modulate visual processing and enhance postural control.[24,52-54] Microprisms (typically 0.5 to 1.5 prism diopters), have shown promise in alleviating symptoms such as dizziness, light sensitivity, and visual motion hypersensitivity.[30,31,38,52,53] Such interventions propose that subtle ocular misalignment following mTBI may generate persistent sensory conflict through increased extraocular muscle effort and unstable visual input.[24,47] Within this framework, low-magnitude prismatic correction is hypothesized to reduce compensatory oculomotor strain and visual instability, thereby attenuating sensory discrepancies and associated dizziness.[24,47] Although direct experimental evidence for these mechanisms remains limited, studies have nonetheless documented improved quality of life and symptom improvements on standardized clinical measures (Vestibular/Ocular Motor Screener) following microprism prescription.[40,43,51,58]

Yoked prisms, on the other hand, which apply equal power and direction to both eyes to shift the visual field uniformly, are theorized to trigger the recalibration of spatial perception by altering the perceived visual midline.[54,55] These adjustments may promote compensatory postural adaptations and affect proprioceptive feedback, potentially stabilizing balance in individuals with mTBI.[54-58] By reducing extraocular muscle strain related to misalignment, prisms may also mitigate symptoms such as visual motion sensitivity and headache.[56,58-60]

From an empirical standpoint, a scoping review by Simpson-Jones and Hunt[58] reported that 78% of mTBI patients with vision-related complaints showed refractive changes, with 31% reporting near-complete symptom relief following updates to their prescription lenses. Whitney and colleagues[59] similarly observed an 81% improvement in subjective reports of headache and dizziness severity when vertical heterophoria was treated with prism compensation. In another study, Doble et al. 24 found a 71.8% reduction in self-reported symptom burden and a 48.1% improvement in vertical heterophoria status following prismatic intervention. These findings underscore a potential link between BVD and vestibular-ocular symptoms in mTBI, although the directionality of this relationship remains uncertain.

Despite encouraging clinical reports, evidence for the efficacy of optical intervention remains mixed.[45] While some studies suggest yoked

Table 1
Demographic Information

Variables	Total Sample	Subacute Phase	Chronic Phase
Sample Size	66	18.18% (*N* = 12)	51.51% (*N* = 54)
Proportion Female	68% (*N* = 45)	75% (*N* = 9)	66.67% (*N* = 36)
Proportion Male	31% (*N* = 21)	25% (*N* = 3)	33.33% (*N* = 18)
Mean Age (SD)	44.62 (16.26)	49.08 (16.83)	43.63 (16.12)
Previous Glasses Hx			
Yes	48.48% (*N* = 32)	58.33% (*N* = 7)	46.30% (*N* = 25)
No	51.51% (*N* = 34)	41.67% (*N* = 5)	53.70% (*N* = 29)
Months Since mTBI (SD)	12.17 (12.89)	2.50 (0.67)	14.31 (13.34)
Weeks with Glasses (SD)	3.38 (1.47)	3.08 (1.08)	3.44 (1.54)
T1 Proprioceptive (SD)	35.18 (30.85)	36.58 (33.27)	34.87 (30.61)
T1 Visual (SD)	28.08 (24.50)	26.00 (20.51)	28.54 (25.44)
T1 Vestibular (SD)	20.76 (20.09)	25.33 (21.93)	19.74 (19.74)
T1 Cumulative (SD)	22.44 (20.57)	24.67 (20.25)	21.94 (20.80)
T2 Proprioceptive (SD)	50.79 (31.44)	58.58 (37.17)	49.05 (30.15)
T2 Visual (SD)	50.21 (24.49)	49.50 (22.08)	50.37 (25.18)
T2 Vestibular (SD)	55.21 (26.03)	60.67 (25.26)	54.00 (26.29)
T2 Cumulative (SD)	51.71 (25.73)	58.42 (28.45)	50.22 (25.12)

Note. T1 = Time 1 measurements pre-intervention; T2 = Time 2 measurements post-intervention; Previous Glasses Hx = History of previous glasses use; mTBI = Mild Traumatic Brain Injury. Table represents demographic information for entire collected sample and for data stratified by subacute and chronic recovery phases. Balance indicator means and standard deviations are represented as percentile ranks.

prisms can induce immediate postural shifts, controlled trials demonstrating improvements in real-world functioning (e.g., fall risk reduction) are scarce.[41,54,57] It also remains unclear whether prismatic lenses are more effective for patients with pre-existing BVD revealed by mTBI or those who acquire visual dysfunction as a direct consequence of injury.[24,50] Clarifying this distinction will be essential for guiding appropriate patient selection and tailoring effective interventions in future research.

Present Study

Despite growing interest in optical interventions for managing BVD, dizziness, and balance complaints following mTBI, evidence supporting their efficacy remains mixed and limited.[30,31,38,52,53] Accordingly, as an exploratory analysis, the primary aim of this study was to examine changes in balance functioning following an optical prescription intervention in a community-based mTBI population. A secondary aim was to investigate whether changes in balance performance differed across recovery phase (subacute, chronic) and selected demographic characteristics (e.g., gender, prior glasses use). By integrating both vision-based and balance-related assessments with clinically prescribed optical intervention, this study seeks to contribute to a more precise understanding of the role of vision in postural control following mTBI.

METHOD

Sample

The study sample consisted of 66 participants (21 M, 45 F) who were referred to an outpatient rehabilitation clinic for optometric vision therapy services following their mTBI diagnosis. Patient data was collected from July 1 to November 30th, 2022, and consisted of a series of force plate balance indicators to measure vestibular-ocular functioning, including proprioceptive led balance, vestibular led balance, and visually led balance; all participants provided their expressed consent prior to initiating their treatment protocol and had

Table 2
Spearman's r Correlation Matrix — Balance Indicators Pre-Post Intervention

Variables	Proprioceptive (T1)	Visual (T1)	Vestibular (T1)	Cumulative (T1)	Proprioceptive (T2)	Visual (T2)	Vestibular (T2)	Cumulative (T2)
Proprioceptive (T1)	—							
Visual (T1)	.50***	—						
Vestibular (T1)	.53***	.58***	—					
Cumulative (T1)	.75***	.75***	.91***	—				
Proprioceptive (T2)	.76***	.40***	.45**	.61***	—			
Visual (T2)	.37**	.77***	.56***	.64***	.31*	—		
Vestibular (T2)	.25*	.41***	.61***	.57***	.32**	.42***	—	
Cumulative (T2)	.61***	.67***	.74***	.82***	.71***	.65***	.80***	—

Note. T1 = Time 1 measurements pre-intervention; T2 = Time 2 measurements post-intervention. Table represents Spearman's *r* correlations between balance indicators pre-post intervention. * = $p < .05$; ** = $p < .005$; *** = $p < .001$.

self-indicated balance or vision concerns following their mTBI at the time of their assessment. Ethics approval for this study was obtained from the University of British Columbia, Okanagan.

The mean age of the patient group was 44.62 +/— 16.26 years, with an indicated average time since injury of 12.17 +/— 12.90 months. Approximately half of the sample (N = 32; 48%) had a pre-existing glasses prescription at the time of assessment, while the remaining sample (N = 34; 52%) did not wear a glasses prescription prior to their injury. Based on previous literature,10 participants were categorized into recovery phases based on time elapsed since injury, including a subacute phase (< 3 months) and a chronic phase (> 3 months). The majority of participants were classified into the chronic phase (n = 54; 82%), with the remaining 18% classified into the subacute phase (n = 12).

Procedure

Participants had all been referred to the clinic, with a confirmed mTBI diagnosis made by their physician. After an mTBI history was identified, participants' proprioceptive, vestibular, and visually-led balance were assessed to obtain pre-intervention measurements (Time 1) of relative functioning using the modified Clinical Test of Sensory Integration and Balance (mCTSIB). Participants' refractions were then determined by a registered optometrist, with final prescriptions modified to meet the study design's prescribing protocol.

Each participant received single vision distance prescriptions, with a binocular balanced spherical endpoint of 20/25 OU. The endpoint of 20/20 was deliberately avoided to prevent over-minusing and increased accommodative demand. Cycloplegic refractions were not performed due to the primarily non-pediatric age of the patient population. For participants showing any degree of exophoria at distance on von Graefe measurement, a prismatic component of 0.5 base-in (BI) was applied OU. For participants with orthophoria or any degree of esophoria at distance on von Graefe measurement, a prismatic component of 1 base-down (BD) was applied OU. This method of prescribing prism is commonly used within the optometric rehabilitation field.[39,52,61-64] Participants with vertical phoria exceeding 1 prism diopter were not included in this study, as this presentation may necessitate different treatment strategies.

Near prescriptions were provided to those who normally required bifocal or multifocal prescriptions, though these were not used while assessing balance. Participants were asked to wear their prismatic lenses for at least four hours a day throughout their treatment protocol. Time 1 balance testing was conducted before participants received their prescribed prism lenses. Time 2 testing was performed with prism in place to evaluate intervention effects.

No treatment protocols were advised outside of the wear of the prismatic glasses. Following wear of the prismatic glasses, secondary mCTSIB measurements (Time 2) were made for all three balance indicators to observe changes in vestibular-ocular functioning. On average, participants wore their lenses for 3.38 weeks (SD = 1.47), with exceptional cases (N = 5) wearing for five or more weeks. Compliance was monitored through self-reported daily lens wear time, but individual deviations were not recorded beyond the provided mean wear time. The removal of prism was not indicated for any of the participants at Time 2.

Measures

Postural sway was measured using the Balance Tracking System (BTrackS), an evidence-based tool for postural stability assessment.[65,66] The BTrackS utilizes a force plate system to quantify Center of Pressure (COP) movement, providing objective metrics for postural stability across three key sensory conditions—proprioceptive-led, vestibular-led, and visually-led balance—each reflecting a predominant reliance on a specific sensory system.[65-69] Postural sway across all three balance conditions was quantified using total COP path length. The system recorded COP movement at 25 Hz, generating 500 data points per 20-second trial. The total COP path length was then calculated by summing the path lengths across all test conditions. Percentile scores were determined by comparing individual sway values to a normative dataset from healthy young adults,[65] with lower percentiles indicating increased postural sway (poorer balance control) and higher percentiles suggesting greater postural stability.

Visually-led balance refers to a compensatory reliance on visual input to maintain spatial orientation, often emerging when vestibular or proprioceptive systems are compromised. While visual cues are critical for balance, excessive dependence on them may impair stability in visually complex environments, contributing to motion sensitivity and dizziness. To assess visually-led balance, participants stood on a compliant foam surface with eyes open over the BTrackS force plate sensor. This condition isolates visual contributions to postural control, with center of pressure (COP) movement recorded to generate percentile scores reflecting visual reliance.

Vestibular-led balance reflects greater dependence on the vestibular system, which integrates spatial orientation and motion cues from the inner ear and contributes to functions such as gaze stabilization, head positioning, and postural regulation. This was assessed by having participants stand on a compliant foam surface with eyes closed, thereby eliminating visual input and minimizing proprioceptive cues. The BTrackS system captured COP sway in this condition, producing percentile scores indicative of vestibular system contribution to balance control.

Proprioceptive-led balance occurs when individuals primarily rely on sensory feedback from muscles, joints, and skin. To isolate proprioceptive input, participants stood on a firm surface with eyes closed, thereby reducing reliance on visual and vestibular inputs. COP displacement was measured to evaluate postural control in this condition, and percentile scores were calculated relative to normative data to quantify proprioceptive functioning. In addition to obtaining percentile score values for all three balance indicators, cumulative percentile ranks were also recorded for each assessment (Time 1, Time 2) from the BTrackS software.

Statistical Plan

Given the exploratory nature of this study, an a priori power analysis was conducted using JASP, indicating that a sample size of 66 would yield a power of 0.485 to detect small effects (Cohen's d = 0.2) with a one-sided $\alpha = 0.05$. While the study is adequately powered for detecting moderate to large effects, it may have reduced sensitivity to detect smaller effects. Prior to hypothesis testing, data were evaluated for assumptions of normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test). The assumption checks revealed significant violations across multiple balance measures, particularly at Time 1, indicating skewed distributions and heteroscedasticity. Given that normality violations can lead to inflated Type I errors or biased estimates, and that Levene's test suggested unequal variance across groups, non-parametric analyses were deemed most appropriate for statistical inference.

To explore preliminary relationships between demographic variables and balance indicators, Spearman's rank correlations were employed, which is more robust to violations of normality and outliers than Pearson's r. To address the first research question, Wilcoxon signed-rank tests were conducted to examine whether postural sway significantly differed between baseline (Time 1) and post-treatment (Time 2). The use of Wilcoxon tests was warranted given the non-normality of postural sway distributions and the paired nature of the data. For the second research question, Mann-Whitney tests were used to evaluate whether pre—post changes in postural sway differed across demographic variables (e.g., gender, mTBI recovery phase, prior glasses use). Given the presence of multiple comparisons, results were interpreted with adjusted significance thresholds using the Benjamini-Hochberg False Discovery Rate calculation to mitigate the risk of Type I error inflation.

RESULTS

Descriptive Statistics

Overall, all three independent balance indicators had notable mean improvements in percentile scores from Time 1 to Time 2 (see Table 1). The largest mean improvement between Time 1 and Time 2 was observed in vestibular-led balance (Mdiff = 0.35), followed by visually-led balance (Mdiff = 0.22) and proprioceptive-led balance functioning (Mdiff = 0.16). Total cumulative balance similarly showed noteworthy improvements, with a mean change of Mdiff = 0.29. Results of the Spearman's rank correlation matrix identified several statistically significant correlations (see Table 2). Of note, all Time 1 balance scores displayed significant positive correlations with all Time 2 Cumulative balance scores (see Table 2).

With respect to relevant demographic variables, age appeared to be negatively correlated with Time 1 cumulative balance percentile scores ($r = -0.40$, $p < .005$) and Time 1 vestibular balance percentile scores ($r = -0.39$, $p < .005$). Time since injury (measured in months) or weeks with glasses did not appear to significantly correlate with any variables of interest (see Tables 3 & 4).

Inferential Statistics

Results indicated that participants demonstrated higher cumulative balance scores at Time 2 ($M = 0.52$, $SD = 0.26$) compared to Time 1 ($M = 0.22$, $SD = 0.21$), on average; this difference was statistically significant ($W = 0.00$, $p < .001$, $z = -7.06$). Similarly, participants appeared to also have significantly higher scores on all three independent balance indicators at Time 2 compared to Time 1 (see Table 5 & Figure 3).

There were no statistically-significant demographic effects of gender, mTBI phase, or pre-existing glasses use on Time 1 or Time 2 balance scores after correcting for multiple comparisons. The reader is referred to Table 6 for a detailed overview of the results for differences in balance scores among several demographic variables.

DISCUSSION

The present study aimed to contribute to the growing body of literature by examining the effects of an optical prescription intervention on postural control and balance functioning in a community-

Table 5

Wilcoxon Signed Rank Measurement Differences Pre-Post Intervention

Variable Comparisons	W	Z	r_{rb}	[CI]	p
Proprioceptive (T1) - Proprioceptive (T2)	137.00	-5.73	-0.85	[-0.91, -0.75]	< .001
Visual (T1) - Visual (T2)	0.00	-6.91	-1.00	[-1.00, -1.00]	< .001
Vestibular (T1) - Vestibular (T2)	0.00	-7.06	-1.00	[-1.00, -1.00]	< .001
Cumulative (T1) - Cumulative (T2)	0.00	-7.06	-1.00	[-1.00, -1.00]	< .001

Note. T1 = Time 1 measurements pre-intervention; T2 = Time 2 measurements post-intervention. Table represents Wilcoxon signed rank measurement differences between balance indicators pre-post intervention.

based mTBI population with PPCS. Overall, participants demonstrated significant improvements in balance performance across all three sensory-weighted domains (vestibular-led, visually-led, and proprioceptive-led balance) following intervention, as indexed by objective postural sway measures. Improvements were most pronounced in vestibular-led balance, followed by visually-led and proprioceptive-led balance, respectively. This pattern is noteworthy given the established contribution of vestibular and visual disturbances to balance impairment following mTBI[72] and the central role of multisensory integration in postural control.[71-78] While the specific mechanisms underlying these changes cannot be isolated within the present study design, the findings provide preliminary evidence that optical intervention is associated with measurable changes in balance performance in individuals with mTBI.

These findings are broadly consistent with prior work highlighting the clinical utility of optical adaptation on balance and spatial orientation following neurological injury.[50,52,75,76,77] Previous studies examining optometrically-based interventions have reported changes in postural sway and stability, suggesting that visual input can meaningfully influence postural control under certain conditions.[40,41,43,51,54-58,75,76,78,79] While several theoretical accounts have proposed that prism lenses may affect processes such as visual—vestibular interaction or postural adaptation,[43,51,54] the present findings should not be interpreted as evidence for any specific underlying mechanism. Rather, the current results extend this literature by demonstrating that clinically prescribed visual intervention is associated with objective changes in balance performance in individuals with mTBI, reinforcing the relevance of vision as a modifiable component of postural control.

Another important finding was the strong association between pre- and post-intervention balance scores, indicating that balance outcomes at follow-up (Time 2) were closely related to Time 1 balance scores. This pattern may suggest that individuals who exhibited greater balance dysfunction at the initial assessment tended to show residual deficits at follow-up. This finding is consistent with the heterogeneity of recovery trajectories following mTBI, as individuals with severe vestibular-ocular dysfunction typically require additional rehabilitation beyond optical intervention alone.[32,82] Furthermore, the lack of significant correlations between time since injury and balance improvements highlights the potential benefits of optical intervention across both subacute and chronic recovery phases. This suggests that even individuals with longstanding symptoms may experience meaningful postural improvements with optical application, reinforcing the clinical relevance of vision-based intervention in persistent mTBI cases.

Despite significant balance improvements at the group level, few demographic variables appeared to statistically influence post-intervention outcomes. Notably, age was negatively correlated with visual and vestibular balance scores, particularly at baseline, suggesting that older participants exhibited greater postural instability prior to the intervention. This finding aligns with previous research indicating that age-related changes in sensory integration, proprioceptive feedback, and vestibular function may exacerbate balance impairments following mTBI.[13,17,59] However, possible accompanying factors, such as age-related muscle degeneration (i.e., sarcopenia), reduced neuromuscular coordination, decline in the efficiency of sensorimotor reflexes (e.g., VOR), changes in central nervous system processing and integration of sensory inputs, or degeneration within specific sensory organs themselves (e.g., otoliths), may also contribute to lower initial balance scores.[81,83-86] While older individuals continued to exhibit slightly lower visual balance scores post-treatment, they nonetheless demonstrated significant improvements following the intervention. This suggests that optical intervention may offer benefits across a wide age range, though younger adults may experience greater relative gains in balance function.

Contrary to expectations, there were no statistical effects of gender, pre-existing glasses use, or mTBI phase on balance outcomes. However, due to the relatively small sample size in this study, these findings should be interpreted with caution, as larger-scale studies with greater statistical power may be required to detect more nuanced demographic interactions.

Limitations and Future Research

A primary limitation of this study is the absence of a control or comparison condition. The visual prescription implemented in this study involved multiple concurrent optical adjustments, including use of single vision glasses, binocular balancing to a 20/25 OU endpoint, relative plus power at distance resulting in central defocus, and low-magnitude prismatic correction. Each of these elements represents a meaningful alteration of visual input and spatial processing, and their effects cannot be disentangled within the present design. As such, it is not possible to determine whether observed changes in balance performance were attributable to prismatic components, central defocus associated with over-plussing, single vision lens design, or their combined influence. Non-specific factors such as expectancy effects, adaptation to new lenses, or spontaneous recovery may also have contributed to observed changes.

A second limitation is the absence of comparison to habitual correction, plano lenses, or trial framing without optical modification. Inclusion of such comparison conditions would allow future studies to more precisely isolate the relative contribution of specific visual manipulations, including compensatory prism for binocular misalignment and spatial effects associated with base-in or yoked prism application. Randomized or counterbalanced designs incorporating these conditions would be necessary to establish specificity of effect.

Another limitation is the absence of subjective symptom ratings before and after the intervention. Although this study focused on objective balance assessments, incorporating self-reported measures of vestibular-ocular symptoms would provide valuable insight into patient-perceived improvements. Given the heterogeneity of PPCS, tracking symptoms such as dizziness, motion sensitivity, and visual discomfort could help clarify whether observed balance improvements align with meaningful clinical change. Future studies should include validated symptom inventories alongside objective measures to more fully capture the impact of optical correction on functional recovery.

Importantly, visual prescriptions in this study were determined clinically and applied as a multi-component intervention, precluding examination of differential effects across individual optical elements or patient subgroups. Future research employing dismantling approaches, including systematic manipulation of refractive correction, central defocus, and prismatic configuration, may help clarify which visual factors are most strongly associated with balance change following mTBI. Lastly, it remains unclear whether prismatic interventions are more effective for individuals with pre-existing BVD unmasked by mTBI, or for those who develop vision dysfunction as a direct consequence of injury.[24,59]

CONCLUSION

Collectively, the present findings provide preliminary evidence that optical intervention is associated with measurable changes in balance performance among individuals with mTBI and PPCS. Improvements in postural sway were observed across multiple sensory-weighted balance conditions and demographic subgroups, supporting the broader premise that vision represents a modifiable contributor to postural control following mTBI. However, as the optical prescription was implemented as an integrated clinical intervention, the present findings reflect the effects of combined visual modification on balance performance rather than isolated optical mechanisms. Future research should prioritize randomized controlled trials incorporating placebo lenses, as well as investigations into dose—response relationships and the durability of vision-related balance changes over time.

Despite these limitations, this study contributes objective data to a growing literature examining the role of vision in balance functioning and rehabilitation following mTBI. The findings underscore the need for future controlled and randomized study designs that systematically isolate individual components of visual prescription, incorporate subjective symptom outcomes, and evaluate the persistence of balance changes over time. Future clarification into how different forms of visual interventions influence postural control will be essential for refining clinical decision-making and optimizing vision-based rehabilitation strategies following mTBI.

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APPENDIX A: STUDY TABLES

Table 3

Spearman's r Correlation Matrix — Demographic Variables and Balance Indicators Pre-Intervention (Time 1)

Variables	*Age*	*Months Since TBI*	*Weeks with Glasses*	*Proprioceptive (T1)*	*Visual (T1)*	*Vestibular (T1)*	*Cumulative (T1)*
Age	—						
Months since TBI	.16						
Weeks with Glasses	.21	.26	—				
Proprioceptive (T1)	-.23	.06	-.09	—			
Visual (T1)	-.26	.05	-.12	.50**	—		
Vestibular (T1)	-.39**	-.03	-.25	.53***	.58***	—	
Cumulative (T1)	-.40**	.05	-.18	.75***	.75***	.91***	—

Note. T1 = Time 1 measurements pre-intervention. Table represents Spearman's *r* correlations between balance indicators pre-intervention and demographic variables. * = $p < .05$; ** = $p < .005$; *** = $p < .001$.

Table 4

Spearman's r Correlation Matrix — Demographic Variables and Balance Indicators Post-Intervention (Time 2)

Variables	*Age*	*Months Since TBI*	*Weeks with Glasses*	*Proprioceptive (T2)*	*Visual (T2)*	*Vestibular (T2)*	*Cumulative (T2)*
Age	—						
Months since TBI	.16						
Weeks with Glasses	.21	.26	—				
Proprioceptive (T2)	-.04	.07	.04	—			
Visual (T2)	-.29	.08	-.09	.31*	—		
Vestibular (T2)	-.13	.08	-.19	.32*	.42**	—	
Cumulative (T2)	-.24	.08	-.17	.71***	.65***	.80***	—

Note. T2 = Time 2 measurements post-intervention. Table represents Spearman's *r* correlations between balance indicators pre-intervention and demographic variables. * = $p < .05$; ** = $p < .005$; *** = $p < .001$.

Table 5

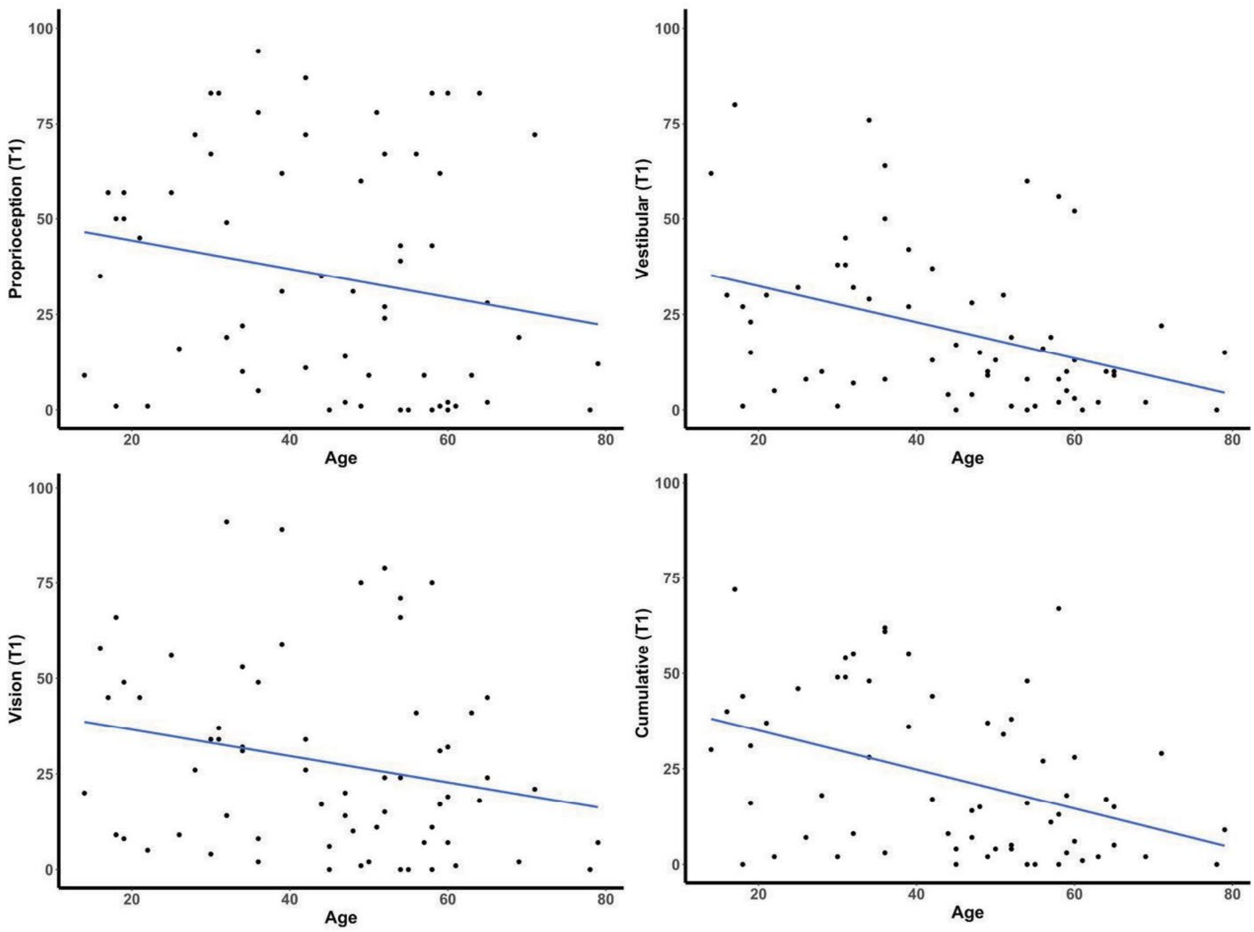
Table 6
Mann-Whitney U Test Measurement Differences Among Gender, Previous Glasses Use, & Recovery Phase

Variables	Grand Median	Mean Rank (N_1)	Mean Rank (N_2)	*U*	*p*	r_{rb}	95% CI
Gender (F, M)							
Proprioceptive (T1)	29.50	34.97 (45)	30.36 (21)	538.50	.687	.14	[-.16, .42]
Visual (T1)	22.50	30.98 (45)	38.90 (21)	359.00	.533	-.24	[-.50, .06]
Vestibular (T1)	14.00	32.07 (45)	36.57 (21)	408.00	.687	-.14	[-.41, .16]
Cumulative (T1)	16.00	32.06 (45)	36.60 (21)	407.50	.687	.14	[-.41, .16]
Proprioceptive (T2)	52.00	35.56 (45)	29.10 (21)	565.00	.683	-.20	[-.10, .46]
Visual (T2)	53.00	30.89 (45)	39.10 (21)	355.00	.533	-.25	[-.50, .05]
Vestibular (T2)	57.70	31.18 (45)	38.48 (21)	368.00	.608	-.22	[-.48, .08]
Cumulative (T2)	50.00	32.86 (45)	34.88 (21)	443.50	.916	-.06	[-.35, 24]
Total Proprioceptive Δ	13.00	33.07 (45)	34.43 (21)	454.00	.919	-.04	[-.33, .26]
Total Visual Δ	19.00	32.58 (45)	35.48 (21)	433.00	.876	-.08	[-.37, .21]
Total Vestibular Δ	29.50	32.90 (45)	34.79 (21)	445.50	.916	-.06	[-.34, .24]
Total Cumulative Δ	26.00	35.22 (45)	29.81 (21)	550.00	.687	.02	[-.14, .44]
Hx Glasses (N, Y)							
Proprioceptive (T1)	29.50	28.88 (34)	38.41 (32)	387.00	.268	-.29	[-.52, -.02]
Visual (T1)	22.50	34.35 (34)	32.59 (32)	573.00	.916	.05	[-.22, .32]
Vestibular (T1)	14.00	33.76 (34)	33.22 (32)	553.00	.936	.02	[-.26, .29]
Cumulative (T1)	16.00	33.18 (34)	33.84 (32)	533.00	.936	-.02	[-.29, .26]
Proprioceptive (T2)	52.00	27.57 (34)	39.80 (32)	342.00	.080	-.37	[-.59, -.11]
Visual (T2)	53.00	32.88 (34)	34.16 (32)	523.00	.919	-.04	[-.31, .24]
Vestibular (T2)	57.50	32.84 (34)	34.20 (32)	521.50	.919	-.04	[-.31, .24]
Total Proprioceptive Δ	13.00	31.34 (34)	35.80 (32)	470.50	.687	-.14	[-.39, .14]
Total Visual Δ	19.00	31.35 (34)	35.78 (32)	471.50	.687	-.13	[-39, .15]
Total Vestibular Δ	29.50	30.87 (34)	36.30 (32)	454.50	.687	-.17	[-.42, .11]
Total Cumulative Δ	26.00	28.93 (34)	38.36 (32)	388.50	.269	-.29	[-.52, -.01]
Recovery Phase (Sa, Ch)							
Proprioceptive (T1)	29.50	36.60 (12)	34.90 (54)	315.00	.936	-.03	[-.37, .32]
Visual (T1)	22.50	26.00 (12)	28.50 (54)	326.00	.980	.01	[-.34, .35]
Vestibular (T1)	14.00	25.30 (12)	19.70 (54)	276.00	.715	-.15	[-.47, .21]
Cumulative (T1)	16.00	24.70 (12)	21.90 (54)	303.00	.916	-.07	[-.40, .29]
Proprioceptive (T2)	52.00	58.60 (12)	49.10 (54)	265.00	.687	-.18	[-.50, -.18]
Visual (T2)	53.00	49.50 (12)	50.40 (54)	336.00	.936	.04	[-.32, .38]
Vestibular (T2)	57.50	60.70 (12)	54.00 (54)	278.50	.726	-.14	[-.47, .22]
Cumulative (T2)	50.00	58.40 (12)	50.20 (54)	266.00	.687	-.18	[-.50, .18]
Total Proprioceptive Δ	13.00	22.00 (12)	14.20 (54)	284.00	.786	-.12	[-.45, .24]
Total Visual Δ	19.00	23.50 (12)	21.80 (54)	273.00	.697	-.16	[-.48, .20]
Total Vestibular Δ	29.50	35.30 (12)	34.30 (54)	296.50	.916	-.09	[-.42, .27]
Total Cumulative Δ	26.00	33.70 (12)	28.30 (54)	259.00	.687	-.20	[-.51, -.16]

Note. T1 = Time 1 measurements pre-intervention; T2 = Time 2 measurements post-intervention; Δ = change score between pre- and post-intervention; Gender Group 1 = Females; Gender Group 2 = Males; Hx Glasses Group 1 = no previous glasses use history; Hx Glasses Group 2 = yes previous glasses use history. Recovery Phase Group 1 = subacute patient population; Recovery Phase Group 2 = chronic patient population. Table represents Mann-Whitney U test for measurement differences between balance indicators pre-post intervention and total change scores. Values in bold represent statistically significant differences.

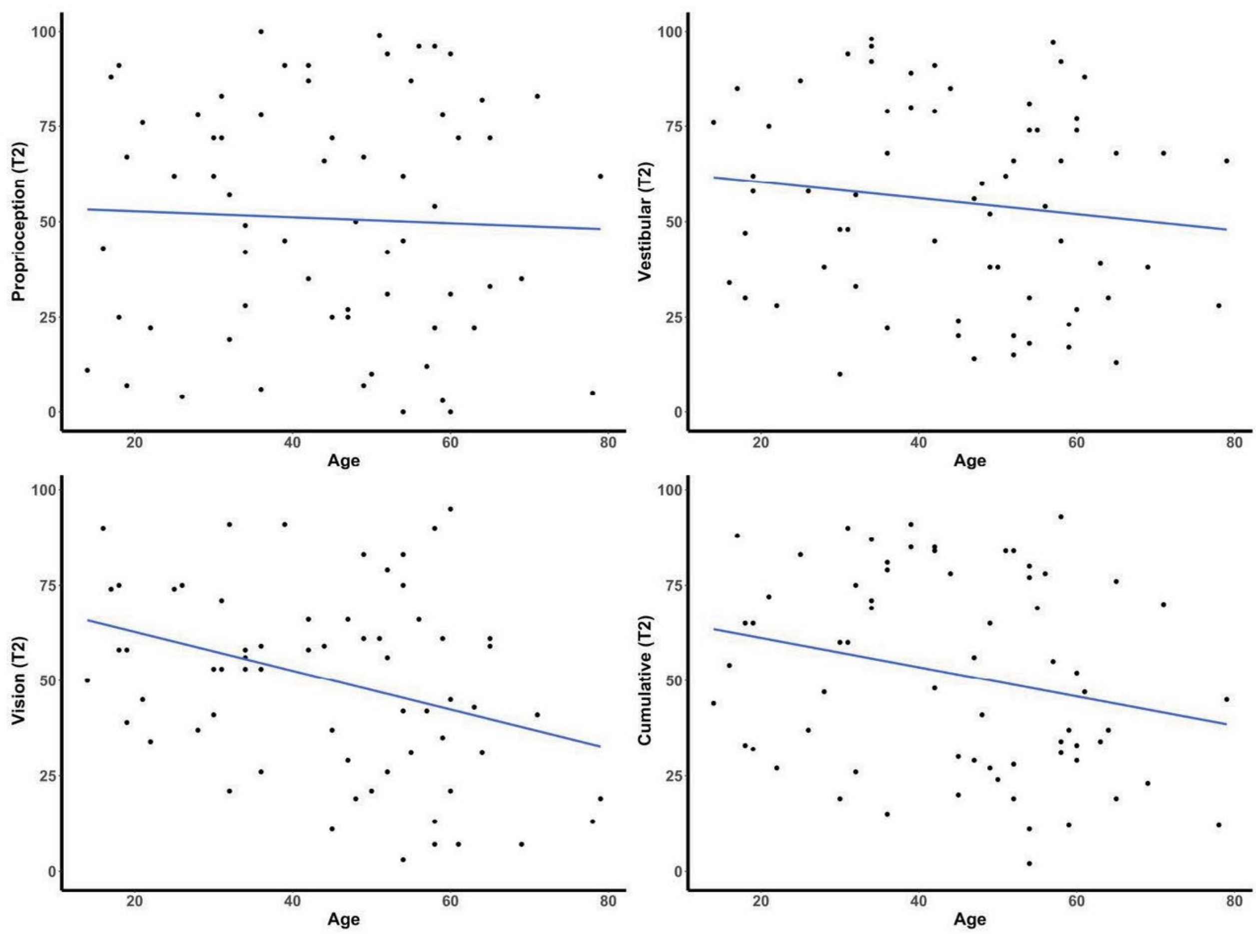
APPENDIX B: STUDY FIGURES

Figure 1. Spearman's r Correlations between Age and Pre-Intervention Balance Indicators



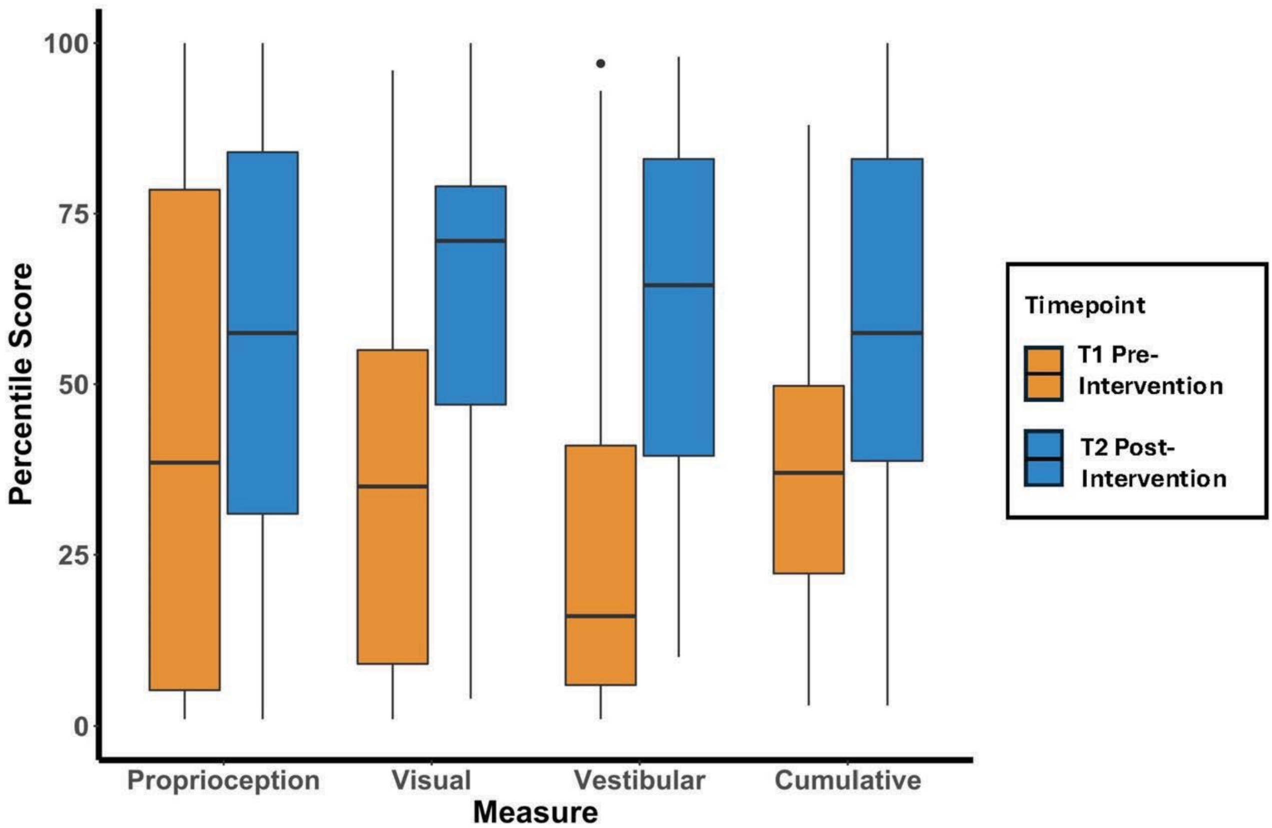
Abbreviations: T1, time 1 measurements pre-intervention.
[a] Balance indicator scores represented as percentile ranks.

Figure 2. Spearman's r Correlations between Age and Post-Intervention Balance Indicators



Abbreviations: T2, time 2 measurements post-intervention.
[a] Balance indicator scores are represented as percentile ranks.

Figure 3. Pre- and Post-Intervention Group Scores by Balance Indicator



Abbreviations: T1, time 1 measurements pre-intervention; T2, time 2 measurements post-intervention.
[a] Balance indicator group means and standard deviations are represented as percentile rank.