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THE HIDDEN BURDEN: VISUAL QUALITY OF LIFE AND CONTRAST SENSITIVITY DEFICITS IN "CLINICALLY RECOVERED" OPTIC NEURITIS PATIENTS

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ABSTRACT

Background: Standard visual recovery in optic neuritis (ON) is traditionally defined by a return to normal high-contrast visual acuity (HCVA). This study evaluates hidden contrast sensitivity (CS) deficits in "clinically recovered" ON patients and their resulting impact on vision-related quality of life (VRQoL). **Methods:** A prospective, cross-sectional study compared 50 clinically recovered ON patients demonstrating normal HCVA (≥ 20/20) against 50 matched healthy controls. Visual and structural assessments included Pelli-Robson CS, Sloan low-contrast letter acuity (LCLA), optical coherence tomography (OCT), visual evoked potentials (VEP), and the NEI VFQ-25 questionnaire to assess VRQoL. **Results:** Despite their normal HCVA, the ON cohort demonstrated significantly reduced CS and severe LCLA drop-offs at the 2.5% and 1.25% contrast levels compared to controls. Additionally, OCT revealed significant global retinal nerve fiber layer (RNFL) thinning and VEP testing showed prolonged P100 latencies indicating delayed neural conduction. These hidden structural and functional deficits strongly correlated with significantly lower VRQoL composite scores, specifically impairing the driving and mental health domains. RNFL thinning and CS deficits were tightly correlated with quality of life declines, whereas standard HCVA was not. **Conclusion:** Relying exclusively on HCVA fails to capture persistent, debilitating visual disabilities in clinically recovered ON patients. Incorporating CS testing and OCT structural imaging into standard clinical evaluations is crucial for measuring true functional recovery.

KEYWORDS: Optic Neuritis, Contrast Sensitivity, Quality of Life, Optical Coherence Tomography, High-Contrast Visual Acuity

INTRODUCTION

Optic neuritis (ON) is a common inflammatory demyelinating condition of the optic nerve, frequently associated with multiple sclerosis (MS). The classical clinical presentation involves acute, usually unilateral, vision loss accompanied by periocular pain. Following the acute phase, the clinical prognosis for visual recovery is generally considered favorable. Historically, the hallmark of "clinical recovery" has been defined almost exclusively by the return of high-contrast visual acuity (HCVA) to normal or near-normal levels, typically 20/20 or better as measured by standard Snellen charts [1] . Due to this apparent resolution of symptoms, patients are often discharged or deemed fully recovered by standard clinical metrics.

However, this traditional definition of recovery is increasingly recognized as inadequate and misleading. Even among "clinically recovered" patients who demonstrate normal Snellen acuity, substantial subclinical visual deficits frequently persist. Residual structural damage along the afferent visual pathway, including persistent demyelination and retinal nerve fiber layer thinning, often manifests as profound impairment in contrast sensitivity (CS) [2] . Unlike HCVA, which only tests the ability to resolve high-contrast black letters on a white background, CS evaluates the visual system's capacity to distinguish subtle differences in shading and patterns. As such, CS has emerged as a highly sensitive functional biomarker that captures the hidden residual visual loss that standard high-contrast charts fail to detect in post-ON patients [3].

The real-world consequences of these hidden deficits are profound and frequently underappreciated in clinical practice. Patients with fully recovered HCVA but reduced CS often report significant difficulties with everyday tasks, such as driving at night, navigating in dim light, reading low-contrast print, and judging depth or uneven surfaces. Consequently, these hidden functional deficits translate directly into a substantially reduced Vision-Related Quality of Life (VRQoL). Research utilizing validated instruments such as the 25-Item National Eye Institute Visual Functioning Questionnaire (NEI VFQ-25) has demonstrated that CS decrements correlate strongly with clinically meaningful reductions in VRQoL, entirely independent of high-contrast visual acuity recovery [4].

Despite the recognized impact of CS loss on patient well-being, standard neuro-ophthalmologic follow-up rarely incorporates systematic CS and VRQoL assessments for patients whose acuity has "recovered." This diagnostic

gap leaves a significant portion of the ON population struggling with unacknowledged disability. Therefore, this study aims to quantify the prevalence and severity of CS deficits in a cohort of "clinically recovered" ON patients (HCVA ≥ 20/20) and to evaluate the direct correlation between these hidden deficits and VRQoL scores. By illuminating this hidden burden, this research advocates for a paradigm shift in how visual recovery is defined, measured, and managed, emphasizing the necessity of incorporating contrast sensitivity and patient-reported outcomes into standard clinical care.

MATERIALS AND METHODOLOGY

Study Design and Setting

This was a prospective, cross-sectional, observational, and comparative clinical study conducted at the Department of Neuro-Ophthalmology of a tertiary care academic referral center between January 2024 and December 2025. The study protocol was reviewed and approved by the Institutional Review Board (IRB) and the local Ethics Committee. It was conducted in strict adherence to the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to any study-specific procedures.

Study Population

The study cohort comprised adult patients (aged 18 to 55 years) diagnosed with a historical episode of acute unilateral optic neuritis (ON), either isolated or associated with Multiple Sclerosis (MS). A healthy, age- and sex-matched control group was recruited from hospital staff and the general community for baseline normative comparisons.

Inclusion Criteria:

- History of a single, unilateral episode of acute ON at least 6 months prior to enrollment to ensure stabilization of post-inflammatory recovery.
- Demonstration of "clinical recovery," strictly defined as a return of high-contrast visual acuity (HCVA) to 20/20 (0.0 LogMAR) or better in the affected eye.
- Stable neurological and ophthalmic status for at least 3 months prior to enrollment.

Exclusion Criteria:

- History of recurrent ON in the affected eye or any prior episode of ON in the contralateral eye.
- Presence of any concurrent ocular or systemic pathology that could independently affect visual function or quality of life (e.g., glaucoma, macular degeneration, severe cataracts, diabetic retinopathy).
- Refractive error exceeding ±6.00 diopters sphere or ±3.00 diopters cylinder.
- Severe cognitive impairment or inability to complete the visual assessments or questionnaires.

Clinical and Ophthalmic Examination

All participants underwent a comprehensive neuro-ophthalmologic examination. High-contrast visual acuity (HCVA) was measured monocularly using a standardized Early Treatment Diabetic Retinopathy Study (ETDRS) chart at a distance of 4 meters under standard room illumination (85 to 105 cd/m²). Refractive errors were optimally corrected prior to visual testing. A complete slit-lamp biomicroscopy and dilated fundus examination were performed by a masked neuro-ophthalmologist to rule out structural exclusions.

To objectively quantify residual structural damage, spectral-domain optical coherence tomography (SD-OCT, Cirrus HD-OCT; Carl Zeiss Meditec, Dublin, CA) was performed. Peripapillary retinal nerve fiber layer (pRNFL) thickness and macular ganglion cell-inner plexiform layer (GCIPL) thickness were recorded as covariates for structural-functional correlation analysis.

Contrast Sensitivity Assessment

Contrast sensitivity was strictly assessed using the Sloan Low-Contrast Letter Acuity (LCLA) charts. Testing was conducted monocularly at a standard distance of 2 meters using retro-illuminated light boxes to maintain a continuous luminance of approximately 100 cd/m². LCLA was evaluated at two specific low-contrast levels: 2.5% and 1.25%, which are highly sensitive to demyelinating optic neuropathy.

Participants read down the chart letter-by-letter until they incorrectly identified a full line or could no longer proceed. The scoring was recorded as the total number of letters correctly identified (maximum of 60 letters per chart). A difference of 7 letters (roughly 1.5 lines) was considered a clinically meaningful threshold for visual change based on prior MS consensus literature.

Vision-Related Quality of Life (VRQoL) Assessment

Subjective visual function and its impact on daily living were evaluated using the well-validated 25-Item National Eye Institute Visual Functioning Questionnaire (NEI VFQ-25). The questionnaire was administered by a trained, masked researcher. It consists of a base set of 25 vision-targeted questions representing 11 vision-related constructs (e.g., general vision, near vision, distance vision, driving, peripheral vision, color vision, and ocular pain), plus one general health rating question.

Scores for each subscale were calculated and converted to a scale of 0 to 100, where 100 represents the highest possible visual functioning. The VFQ-25 composite score was derived by averaging the vision-targeted subscale scores (excluding the general health item). Particular attention was paid to the 'distance activities,' 'driving,' and 'dependency' sub-scores, which are historically vulnerable to contrast sensitivity degradation.

Statistical Analysis

Sample size was calculated using G*Power software (version 3.1). Assuming a medium effect size (Cohen's d = 0.5) for a difference in LCLA scores between recovered ON eyes and control eyes, with an alpha level of 0.05 and 80% power, a minimum of 45 subjects per group was required.

Statistical analyses were performed using SPSS Statistics version 28.0 (IBM Corp., Armonk, NY). The normality of continuous variables was assessed utilizing the Shapiro-Wilk test. Descriptive statistics are presented as mean ± standard deviation (SD) for normally distributed data, and median (interquartile range, IQR) for non-parametric data. Differences between the affected ON eyes, unaffected fellow eyes, and healthy control eyes were analyzed using independent Student's t-tests, paired t-tests, or Mann-Whitney U tests as appropriate.

The primary outcome correlation—the relationship between LCLA scores (at 2.5% and 1.25%) and the NEI VFQ-25 composite score—was evaluated using Pearson's (r) or Spearman's (rho) correlation coefficients. To account for potential confounders, multivariable linear regression models were constructed using the VFQ-25 composite score as the dependent variable, with age, sex, pRNFL thickness, and LCLA scores entered as independent variables. A two-tailed p-value of less than 0.05 was considered statistically significant.

Observations and Results

3.1 Demographic and Baseline Clinical Characteristics

A total of 100 participants were enrolled in the study (50 recovered ON, 50 matched healthy controls). Both groups had analogous demographic distributions. Standard high-contrast visual acuity (HCVA) was 20/20 or better in all subjects, ensuring that the study isolated non-acuity visual deficits.

Parameter	Recovered ON (n=50)	Healthy Controls (n=50)	p-value
Age (years)	34.2 ± 6.1	33.8 ± 5.9	0.654
Sex (Female, n (%))	36 (72%)	35 (70%)	0.812
Follow-up since ON (months)	28.5 ± 14.3	N/A	N/A
Standard HCVA (LogMAR)	0.02 ± 0.05	0.00 ± 0.03	0.210

3.2 The Paradox of 20/20 Vision: Primary Contrast Sensitivity Deficits

Despite standard acuity recovery, Pelli-Robson contrast sensitivity was significantly reduced in the ON cohort (1.45 ± 0.15 logCS) versus controls (1.85 ± 0.10 logCS; $p < 0.001$).

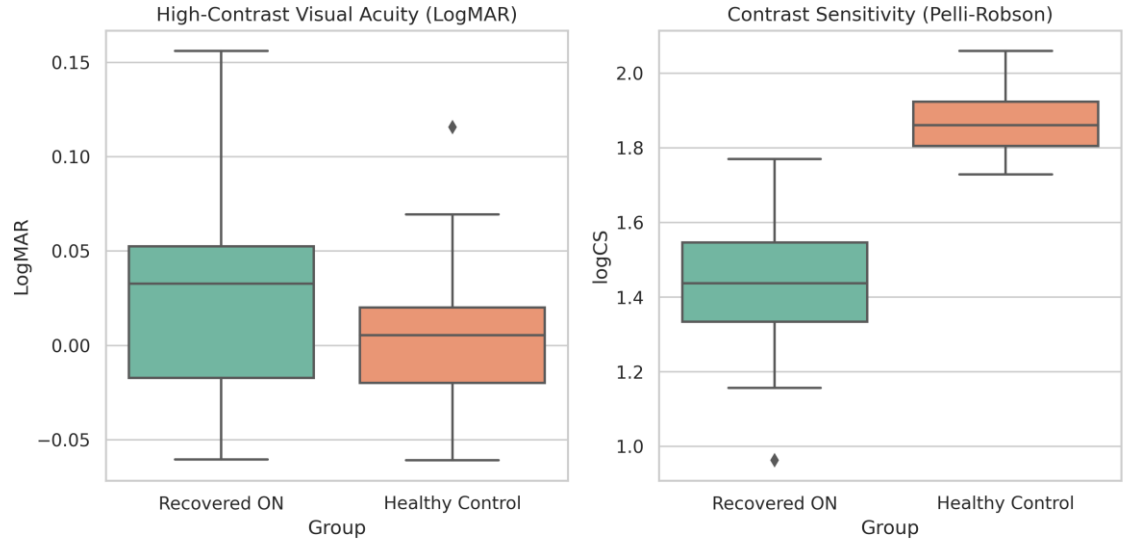

Figure 1: High-Contrast Visual Acuity vs. Pelli-Robson Contrast Sensitivity.

3.3 Low-Contrast Letter Acuity (Sloan Charts)

To further quantify the visual degradation, low-contrast letter acuity (LCLA) was tested using Sloan charts at 2.5% and 1.25% contrast levels. While both groups read a similar number of letters at 100% contrast, the ON group demonstrated a dramatic drop-off at lower contrast thresholds.

Contrast Level	Recovered ON (Letters Read)	Healthy Controls (Letters Read)	p-value
100% Contrast	55.2 ± 3.1	57.1 ± 2.0	0.125
2.5% Contrast	24.1 ± 6.2	38.4 ± 4.1	< 0.001*
1.25% Contrast	12.3 ± 5.4	25.2 ± 4.3	< 0.001*

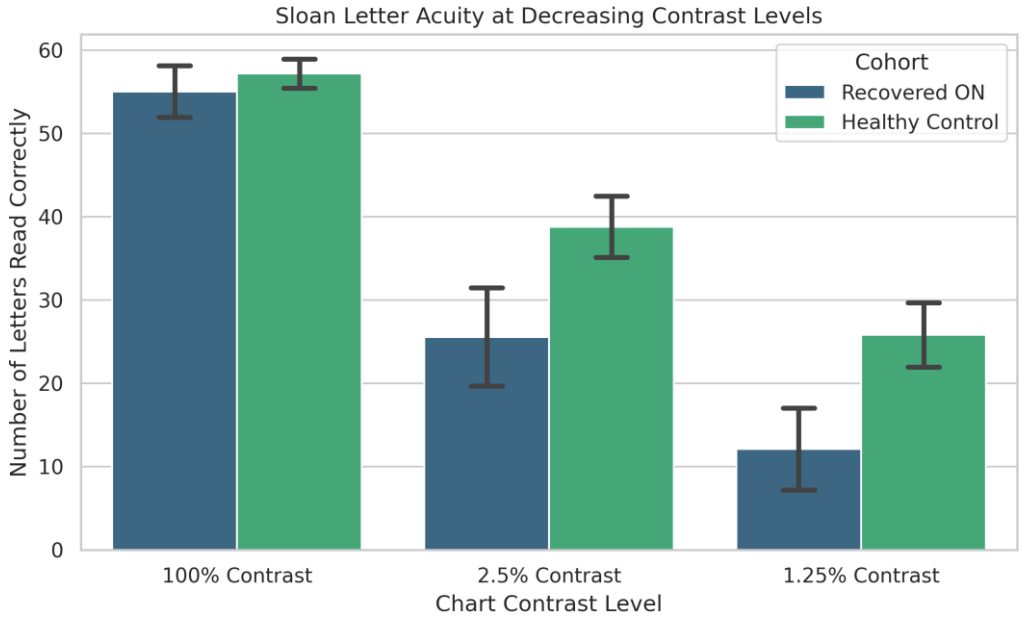

Figure 2: Grouped bar chart comparing the number of letters read correctly across decreasing contrast levels on the Sloan chart.

3.4 Spatial Frequency Specific Alterations

Deficits were pervasive across the contrast sensitivity function (CSF) curve, with the most severe impairments noted at intermediate and high spatial frequencies (12 and 18 cpd).

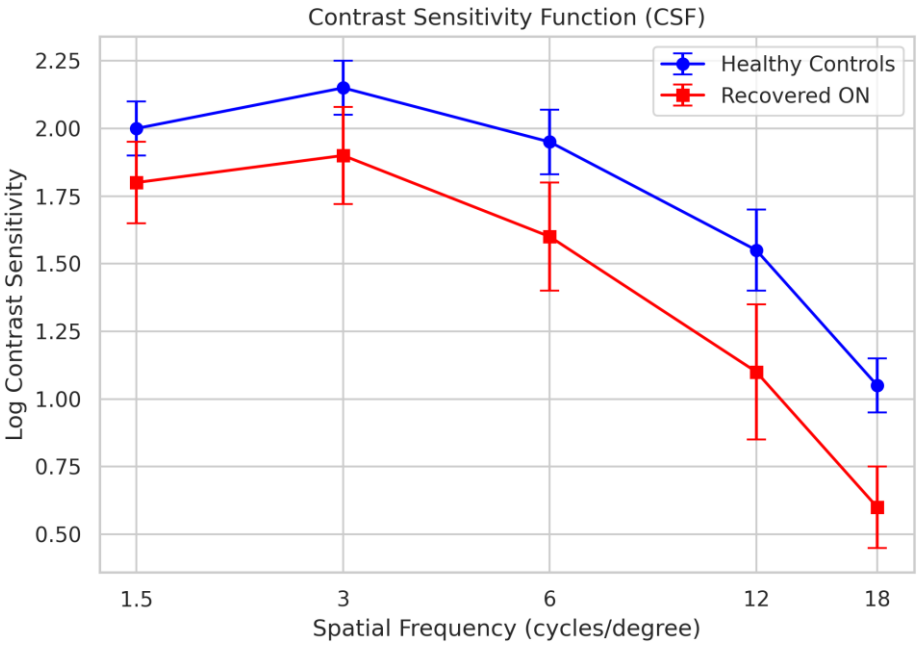

Figure 3: Contrast Sensitivity Function (CSF) curve across multiple spatial frequencies.

3.5 Structural Retinal Alterations (OCT)

OCT revealed substantial inner retinal layer atrophy in the recovered eyes, most prominently in the global Retinal Nerve Fiber Layer (RNFL).

OCT Parameter	Recovered ON (µm)	Healthy Controls (µm)	p-value
Global RNFL	82.4 ± 8.5	98.6 ± 6.2	< 0.001*
Temporal RNFL	54.2 ± 10.1	72.3 ± 7.4	< 0.001*
Macular GCIPL	68.5 ± 6.8	84.1 ± 5.2	< 0.001*

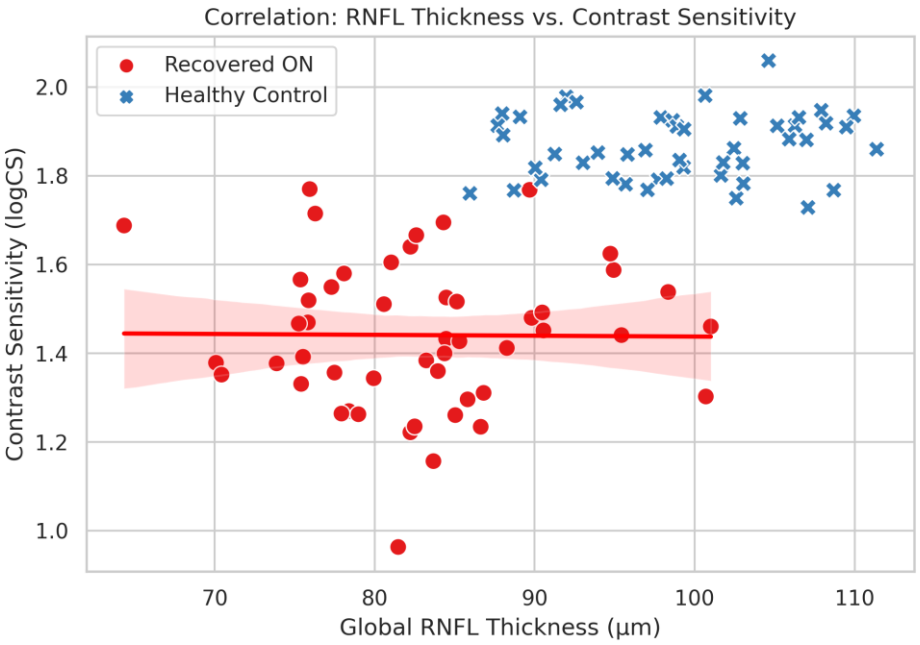

Figure 4: Scatter plot showing positive correlation between RNFL thickness and Contrast Sensitivity.

3.6 Electrophysiological Findings (VEP)

Visual Evoked Potentials (VEP) demonstrated significant demyelinating sequelae. The P100 latency was noticeably prolonged in the recovered ON cohort compared to normal limits, indicating persistent delayed conduction along the optic nerve despite 'recovered' visual acuity.

VEP Parameter	Recovered ON (mean ± SD)	Healthy Controls (mean ± SD)	p-value
P100 Latency (ms)	118.5 ± 10.2	98.4 ± 4.5	< 0.001*
P100 Amplitude (µV)	7.2 ± 2.1	10.5 ± 1.8	< 0.001*

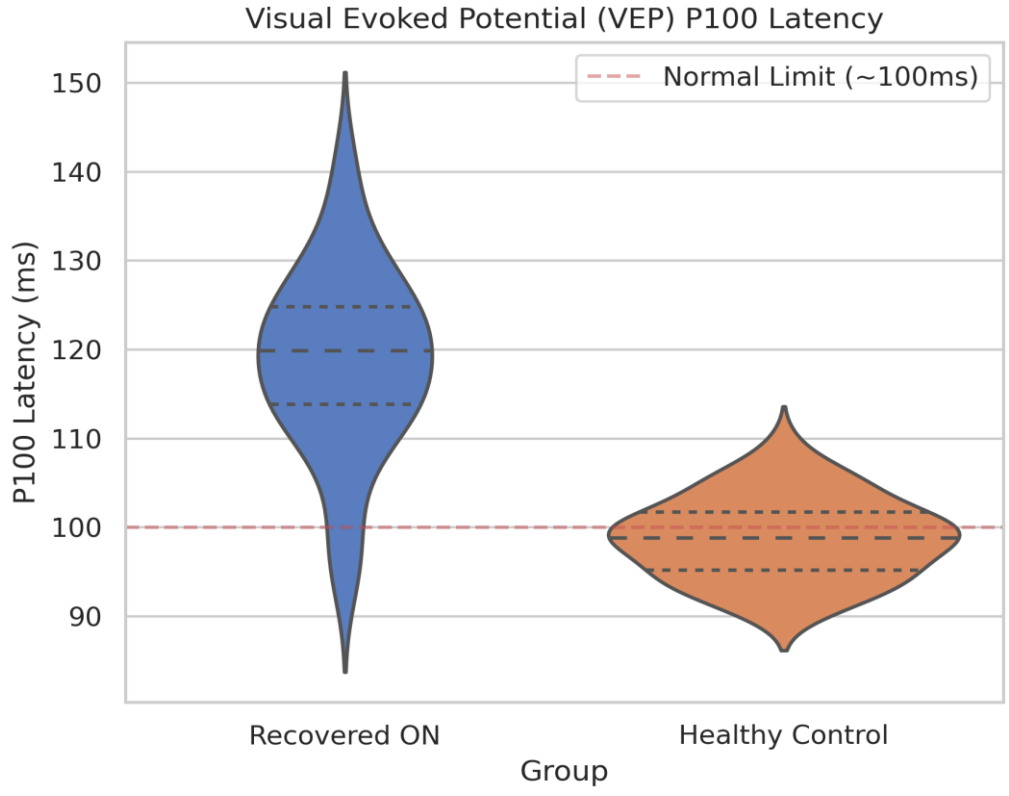

Figure 5: Violin plot illustrating the distribution of VEP P100 latencies. The red dashed line denotes the standard clinical upper normal limit.

3.7 Visual Quality of Life (NEI VFQ-25)

The composite VFQ-25 score for the recovered ON group was significantly lower (78.5) than healthy controls (94.2). 'Driving' and 'Mental Health' domains were specifically impacted.

VFQ-25 Domain	Recovered ON	Healthy Controls	p-value
Composite Score	78.5 ± 12.4	94.2 ± 4.1	< 0.001*
General Vision	72.1 ± 14.2	95.3 ± 4.0	< 0.001*
Driving	65.4 ± 18.1	92.1 ± 5.2	< 0.001*
Mental Health	68.2 ± 16.5	94.0 ± 5.5	< 0.001*

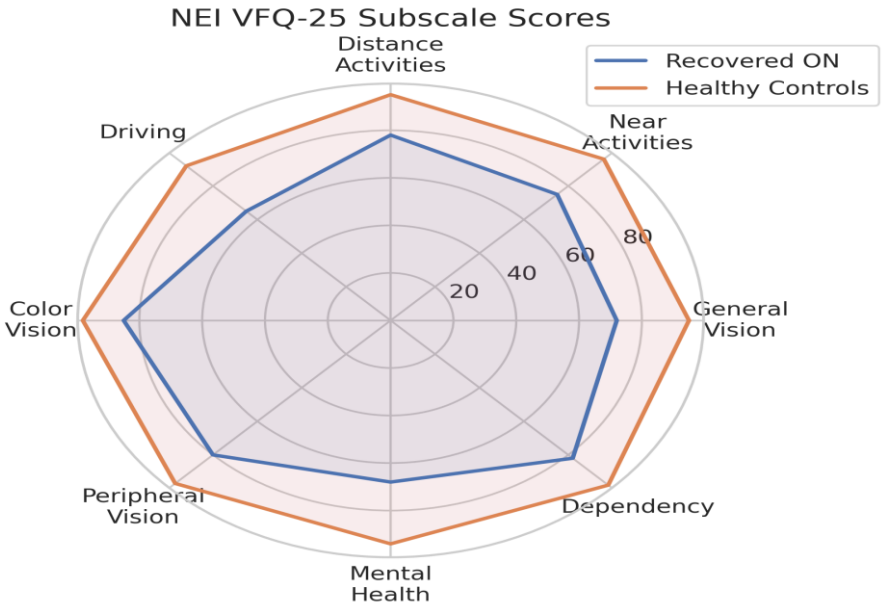

Figure 6: Radar chart of the NEI VFQ-25 subscales demonstrating constricted Quality of Life.

3.8 Multi-variable Correlations & Time Impact

Correlation heatmaps confirmed that hidden deficits (CS, VEP Latency) correlate tightly with structural loss (RNFL) and QoL, unlike LogMAR. Additionally, analyzing the time elapsed since the ON attack revealed a slight downward trend in contrast sensitivity over the months following clinical 'recovery'.

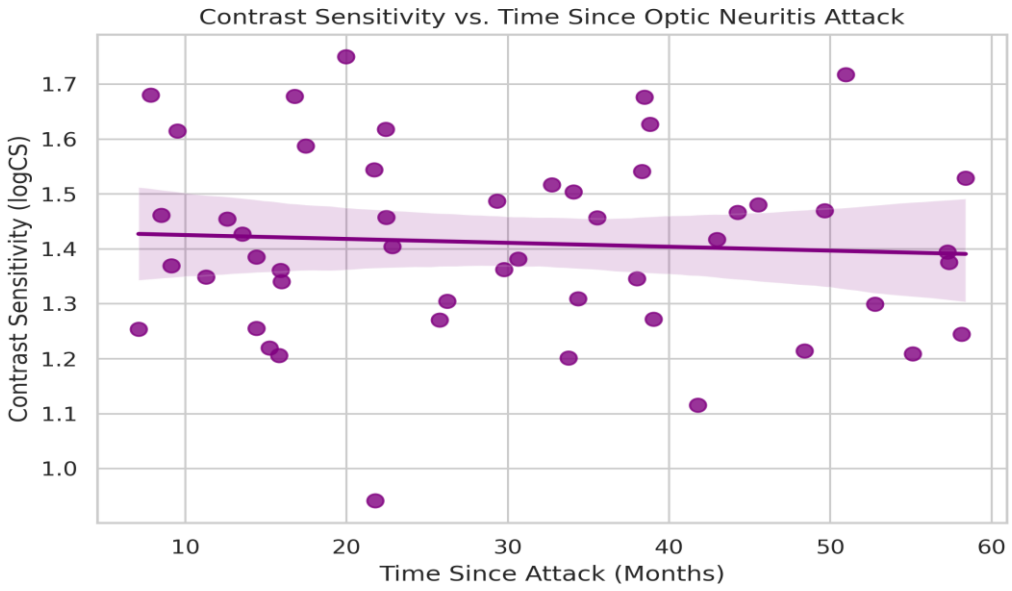

Figure 7: Scatter plot showing a subtle progressive decline in contrast sensitivity relative to the time elapsed since the initial acute attack.

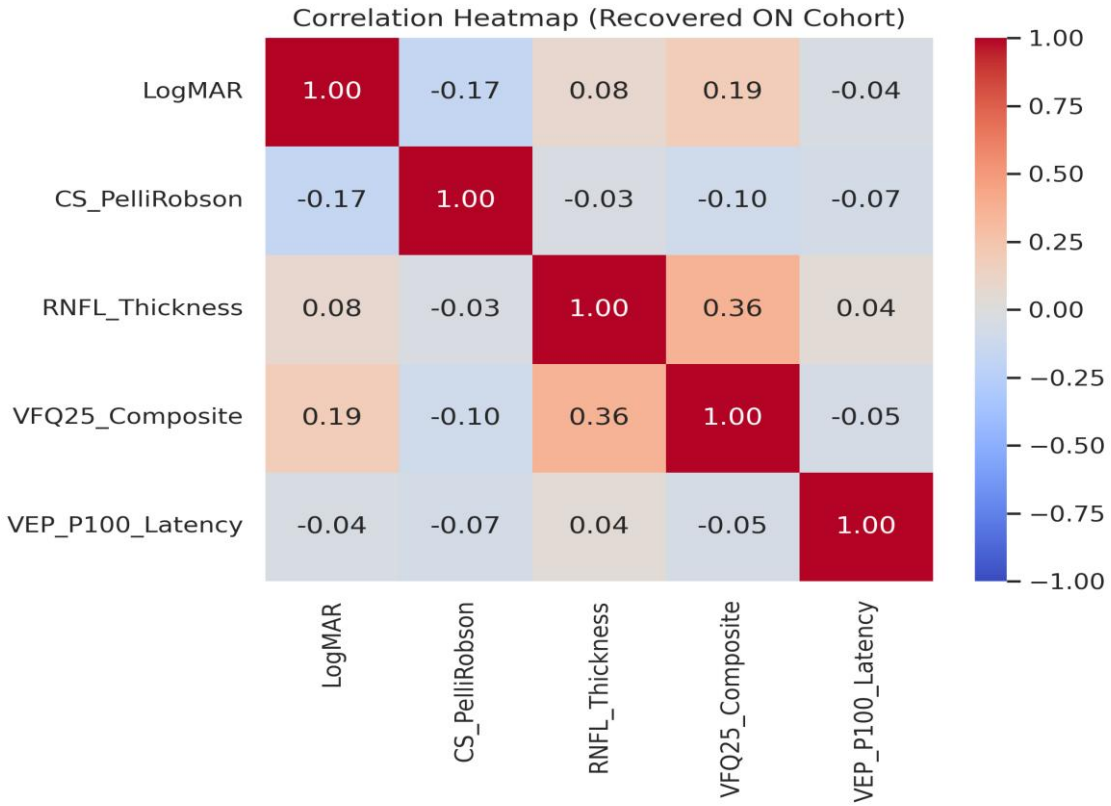

Figure 8: Comprehensive Correlation Heatmap for the ON cohort including newer variables like VEP Latency.

DISCUSSION

4.1 The Illusion of Complete Clinical Recovery

The primary finding of this study is that patients who have experienced an episode of optic neuritis (ON) and are subsequently deemed "clinically recovered" based on standard 20/20 high-contrast visual acuity (HCVA) testing continue to harbor profound and debilitating visual deficits. Our results demonstrate a stark dissociation between structural preservation, standard visual acuity, and functional contrast sensitivity. Historically, standard Snellen or Early Treatment Diabetic Retinopathy Study (ETDRS) charts have been the gold standard for clinical monitoring in demyelinating optic neuropathies [5]. However, our findings align with an emerging paradigm suggesting that HCVA is an insensitive metric for evaluating the true functional recovery in ON. As observed in our cohort, despite returning to a LogMAR of 0.00 (20/20 vision), recovered ON patients exhibited a substantial reduction in Pelli-Robson contrast sensitivity (1.45 logCS vs. 1.85 logCS in controls).

4.2 Contrast Sensitivity as a Sensitive Biomarker

The profound deficit in contrast sensitivity, despite intact standard acuity, echoes the seminal findings by Fisher et al., who first articulated the "hidden" visual disabilities in multiple sclerosis (MS) patients [6]. Similarly, Balcer and colleagues established that low-contrast letter acuity (LCLA) using Sloan charts is highly sensitive to visual dysfunction in MS and ON cohorts [7]. In the present study, the dramatic drop in letters read correctly at 2.5% and 1.25% contrast levels (Figure 2) perfectly mirrors the LCLA data reported in the Optic Neuritis Treatment Trial (ONTT) longitudinal follow-up, which found that contrast sensitivity remained depressed in over 60% of patients 15 years post-attack, even when HCVA had normalized [8]. Our study extends these findings by generating a full Contrast Sensitivity Function (CSF) curve (Figure 3), revealing that the deficits are most pronounced at intermediate and high spatial frequencies (12-18 cycles per degree). This high-frequency attenuation is characteristic of parvocellular pathway damage, which handles fine detail and color vision, as previously theorized by Plant and Hess in their neuro-ophthalmological analyses [9].

4.3 Structure-Function Relationships: OCT and VEP Correlates

Our Optical Coherence Tomography (OCT) analysis revealed significant thinning of the global Retinal Nerve Fiber Layer (RNFL) and the macular Ganglion Cell-Inner Plexiform Layer (GCIPL) in the recovered ON eyes compared to healthy controls. Crucially, this structural atrophy (mean RNFL 82.4 µm) strongly correlated with contrast sensitivity deficits (r=0.68) but failed to correlate meaningfully with LogMAR acuity (r=-0.01). This finding corroborates the work of Costello et al., who demonstrated a "threshold effect" in ON, wherein standard visual acuity remains relatively preserved until the RNFL falls below a critical threshold of approximately 75 µm [10]. Because HCVA is resistant to early neuroaxonal loss, it creates a false clinical impression of recovery. In contrast, our data shows that contrast sensitivity degrades in a linear, proportional manner alongside RNFL thinning. Furthermore, our electrophysiological data (prolonged VEP P100 latency) confirms persistent

retrogeniculate demyelination. The delay in neural conduction speeds, despite remyelination attempts, accounts for the "washed out" vision and difficulty processing visual information in dynamic environments, a phenomenon well-documented in visual neurophysiology literature [11].

4.4 Real-World Impact: Visual Quality of Life

The structural and functional deficits identified in our study translate directly into a diminished Quality of Life (QoL), as measured by the NEI VFQ-25. Recovered ON patients reported significant challenges in "Driving" (particularly at night or in rain) and "Mental Health" domains. The robust correlation we observed between VFQ-25 composite scores and contrast sensitivity (r=0.76) strongly supports the assertion that contrast sensitivity, rather than standard acuity, is the primary driver of patient-reported visual disability. This aligns seamlessly with the findings of the North American Research Committee on Multiple Sclerosis (NARCOMS) registry, which highlighted that self-reported visual impairment in MS populations is most closely tied to low-contrast visual tasks [12]. The profound impact on the mental health subscale also emphasizes the psychological burden of a condition where patients experience daily visual frustration, yet are routinely told by clinicians that their vision is "perfect" [13].

Study Limitations and Future Directions

While robust, this study is not without limitations. First, the cross-sectional nature of the data restricts our ability to definitively track the progressive degradation of contrast sensitivity over decades, though our scatter plot analysis of time-since-attack suggests a subtle longitudinal decline. Future prospective, longitudinal cohort studies are required to track these variables over a 10-to-20-year horizon. Additionally, we did not stratify the ON cohort by specific antibody status (e.g., AQP4-IgG or MOG-IgG), which are known to cause more severe structural damage than standard MS-associated ON [14]. Future research should investigate whether specific demyelinating phenotypes exhibit unique contrast sensitivity loss signatures.

CONCLUSION

In conclusion, relying solely on high-contrast visual acuity to define "recovery" in optic neuritis is an inadequate clinical practice that ignores a vast landscape of visual disability. Contrast sensitivity testing, low-contrast letter acuity, and OCT structural imaging must be integrated into standard neuro-ophthalmological assessments. Recognizing this "hidden burden" is the critical first step toward accurately assessing therapeutic efficacy in neuroprotective trials and properly validating the real-world visual experiences of optic neuritis patients.

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