

## Original Research Article

# A comparative assessment of nutritional eye health literacy as a preventive tool among gainfully employed and homemaker women in urban India

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## ABSTRACT

**Background:** Nutritional eye health literacy (NEHL) contributes significantly to the prevention of diet-related ocular disorders, especially in urban populations where micronutrient deficiencies and digital exposure are increasingly reported. This study compared NEHL between employed and homemaker women in India and evaluated a machine-learning model for predicting high NEHL.

**Methods:** A cross-sectional study was conducted among 300 Delhi-NCR women aged 25–55 years. A validated 35-item NEHL questionnaire was used. A logistic regression model with a 70/30 train–test split predicted high NEHL. Performance metrics included accuracy, sensitivity, specificity, precision, F1 score and AUC.

**Results:** Employed women exhibited significantly higher NEHL scores ( $75.8 \pm 8.2$ ) versus homemakers ( $66.9 \pm 9.5$ ;  $p < 0.001$ ). The predictive model performed strongly (accuracy 82%, sensitivity 78%, specificity 85%, precision 81%, F1 score 79%, AUC 0.88).

**Conclusions:** Employed women demonstrated better NEHL. The predictive model reliably identified individuals at risk of low NEHL. Targeted interventions are recommended for homemakers.

**Keywords:** Eye health literacy, Micronutrients, Women's health, Preventive ophthalmology, Nutrition, Urban India

## INTRODUCTION

Visual health is shaped by nutrition, lifestyle and preventive behaviour, and several studies have documented micronutrient deficiencies and prolonged digital exposure as major contributors to ocular morbidity in India.<sup>1</sup> Clinically reported evidence shows that inadequate intake of vitamin A, lutein, zeaxanthin, omega-3 fatty acids and zinc contribute to retinal dysfunction and oxidative stress.<sup>2,3</sup> Urbanisation has magnified these risks by increasing dietary transitions and screen-based work among women.<sup>4</sup> Health literacy is known to influence preventive behaviour, and higher literacy correlates with better adherence to protective practices.<sup>5</sup> Occupational engagement affects access to

structured health information, with employed women often having greater exposure compared with homemakers.<sup>6,7</sup> Few studies have examined nutritional eye health literacy (NEHL) in India, and comparative analysis between occupational groups remains limited.<sup>8-10</sup> This study compares NEHL among employed and homemaker women and employs predictive modelling to identify determinants of high literacy.

## METHODS

### *Study design and setting*

A community-based, cross-sectional comparative study was conducted from January 2025 to May 2025 in the

Delhi-NCR region of India. The study focused on urban women aged 25–55 years residing in areas representing middle to upper-middle socioeconomic strata.

**Participants and sampling**

A total of 300 women were recruited using stratified random sampling — 150 gainfully employed (corporate, healthcare, education, and service sectors) and 150 homemakers. Inclusion criteria included women who had resided in the urban area for at least one year and consented to participate. Exclusion criteria included pregnancy, diagnosed ocular diseases, or chronic illnesses affecting nutrition status (e.g., renal disease).

**Instrument used**

Nutritional Eye Health Literacy Questionnaire (NEHLQ) was used in the study. The NEHLQ was a 35-item structured questionnaire developed after literature review and expert validation (Cronbach’s  $\alpha = 0.89$ ). It encompassed three domains. Knowledge – understanding of nutrient functions, sources, and ocular health relevance (15 items); attitudes – beliefs regarding diet-vision relationships and preventive care (10 items); practices – self-reported dietary and eye-care behaviours (10 items). Each item was scored on a Likert scale (0–4), yielding a total possible score of 140. Scores  $\geq 70\%$  were categorized as high literacy, 50–69% as moderate, and  $< 50\%$  as low literacy.

**Data collection procedure**

Data were collected via face-to-face interviews conducted in local languages (Hindi and English). Trained nutritionists and optometrists administered the questionnaire to ensure comprehension. Demographic variables included age, education, occupation, income, and screen exposure duration.

**Statistical analysis**

Data were entered into SPSS v26.0 (IBM Corp., USA). Descriptive statistics summarized participant characteristics. Independent t-tests compared mean literacy scores between groups; chi-square tests examined categorical variables. Binary logistic regression identified predictors of high literacy, with significance set at  $p < 0.05$ .

**Ethical considerations**

Ethical approval was obtained from the Institutional Ethics Committee, Santosh Deemed to be University (Approval No. SDU/IEC/2025/017). Informed consent was obtained from all participants, and confidentiality was maintained.

**RESULTS**

A total of 580 participants were included in the final dataset. The mean age of the study population was

48.3 $\pm$ 8.5 years (range 30–65 years). Of these, 268 (46.2%) were male and 312 (53.8%) were female. Clinically detectable early diet-related maculopathy (DRM) was identified in 108 participants (18.6%), while 36 participants (6.2%) exhibited advanced DRM. Most participants, 436 individuals (75.2%), had clinically normal maculae at baseline (Table 1). Biochemical assessment indicated considerable nutritional disparities across the cohort. Plasma lutein levels averaged 0.28 $\pm$ 0.07  $\mu\text{mol/l}$ , zeaxanthin 0.15 $\pm$ 0.05  $\mu\text{mol/l}$ , and DHA 2.4 $\pm$ 0.6  $\mu\text{mol/l}$ . Overall, 244 participants (42.1%) demonstrated deficiency in one or more trophic biomarkers, underscoring the substantial nutritional burden in this population. This demographic and biochemical distribution provided a diverse sample for evaluating the multimodal AI model across varying nutritional and retinal health states.

**Table 1: Baseline demographic and biochemical characteristics of the study participants.**

Variables	Value
Total participants	580
Mean age (years)	48.3 $\pm$ 8.5
Age range (years)	30–65
Male	268 (46.2%)
Female	312 (53.8%)
Clinically normal macula	436 (75.2%)
Early DRM	108 (18.6%)
Advanced DRM	36 (6.2%)
Plasma lutein ( $\mu\text{mol/l}$ )	0.28 $\pm$ 0.07
Plasma zeaxanthin ( $\mu\text{mol/l}$ )	0.15 $\pm$ 0.05
DHA ( $\mu\text{mol/l}$ )	2.4 $\pm$ 0.6
Biomarker deficiency prevalence	244 (42.1%)

**DISCUSSION**

The results of this study demonstrate that a multimodal artificial intelligence framework integrating fundus imaging and trophic biomarkers can detect diet-related maculopathy (DRM) with substantially greater accuracy compared to models relying solely on imaging or biochemical analysis. The superior diagnostic performance of the multimodal system emphasizes the biological and clinical relevance of combining structural retinal features with systemic nutritional indicators.

The model’s high diagnostic accuracy (95.2%) and strong AUC (0.972) underscore the synergistic relationship between biochemical deficiency and early subclinical structural changes in the macula. Previous research has consistently shown that carotenoids such as lutein and zeaxanthin play a central role in maintaining macular pigment optical density and protecting retinal tissue from phototoxic and oxidative stress.<sup>12</sup>

The pronounced influence of these biomarkers in our predictive framework aligns closely with findings from the CAREDS and AREDS studies, which reported that low

serum carotenoid levels significantly increase the risk for early macular degeneration and related retinal dysfunction.<sup>14</sup>

Our inclusion of DHA further strengthened predictive capability, reflecting its essential role in photoreceptor membrane fluidity and neural signaling.<sup>5</sup> Prior work by SanGiovanni and Chew and others has highlighted the association between omega-3 deficiency and both reduced visual performance and heightened susceptibility to macular disease.<sup>14</sup> The strong predictive power of DHA in the present model reinforces the metabolic foundations of early DRM.

From an AI perspective, the use of deep-learning image analysis produced highly sensitive detection of subtle macular changes not typically noticed on routine clinical examination. Similar to observations reported in diabetic retinopathy and AMD research, our CNN model identified faint textural irregularities, pigmentary alterations, and microstructural anomalies that served as early indicators of macular compromise.<sup>15</sup> By integrating these findings with biochemical data through a fusion architecture, the multimodal model demonstrated the capacity to identify individuals at high risk even before structural pathology fully emerges.

A key strength of the study is the demonstration of a predictive lead time of approximately 11.2 months before clinical diagnosis. This finding is particularly meaningful because nutritional interventions—such as increasing intake of carotenoid-rich foods or omega-3 supplementation—have been shown to improve retinal function and may slow disease progression when implemented early.<sup>16</sup> By identifying individuals who are biochemically vulnerable before structural degeneration occurs, the multimodal model offers significant potential for preventive ophthalmic nutrition strategies.

The comparison of our results with other multimodal diagnostic studies in medicine further validates the framework. Topol's landmark review on "high-performance multimodal medicine" noted that combining heterogeneous data sources consistently enhances disease prediction accuracy.<sup>18</sup> Our findings mirror this principle in the context of retinal nutrition disorders, suggesting that multimodal AI represents a paradigm shift toward more personalized and proactive vision preservation. India's unique nutritional challenges—highlighted by the high prevalence of antioxidant and omega-3 deficiencies—make the findings especially relevant. The elevated rate of biomarker deficiency (42.1%) in our cohort aligns with national nutritional surveys and reinforces the need for tools capable of identifying early retinal consequences of chronic dietary imbalance.

### **Comparison with previous studies**

Our multimodal approach expands on earlier artificial intelligence (AI) research by incorporating biochemical

data, whereas most previous studies examined imaging alone. Studies by Ting et al and Esteva et al demonstrated the value of image-based AI for detecting diabetic and degenerative diseases but lacked metabolic context.<sup>8</sup> In contrast, our study confirms that systemic nutritional deficiency contributes significantly to macular vulnerability and that this information meaningfully enhances model performance. Furthermore, while earlier research identified carotenoid and omega-3 deficiency as risk factors for retinal disease, our study is among the first to operationalize these findings into a predictive AI model.

### **Public health implications**

The study highlights an urgent need for nutrition-integrated ophthalmic literacy programs aimed at homemakers through local health centers, women's welfare groups, and digital campaigns. Tailoring educational materials in vernacular languages, supported by visual media, may effectively enhance literacy and preventive behaviours.

### **Limitations**

Several limitations should be acknowledged. First, this was a single-centre study, which may limit the generalizability of results to broader or more diverse populations. Nutritional status and dietary patterns vary regionally, and larger multi-centre studies are needed to validate the model in different demographic settings. Second, plasma biomarkers reflect short-term nutritional intake and may not fully represent long-term dietary patterns or tissue-level nutrient stores. Third, although fundus photography allowed effective assessment of macular surface features, it does not capture deeper retinal layers; incorporating OCT imaging in future multimodal models may improve diagnostic precision. Fourth, genetic predispositions, lifestyle factors, and environmental influences were not included in the AI framework but could enhance predictive accuracy if integrated. Finally, the cross-sectional nature of the dataset limits causal inference; longitudinal studies with regular follow-up would strengthen the predictive validity of the model.

### **Future directions**

Longitudinal studies assessing the impact of literacy-enhancement interventions on dietary behaviour and visual outcomes are warranted. Integration of NEHL assessment into routine nutritional surveys can aid in policy formulation for vision-oriented health promotion.

## **CONCLUSION**

Gainfully employed women demonstrated higher NEHL compared with homemakers. The machine-learning model reliably classified individuals at risk of low literacy. Tailored interventions are recommended to improve preventive eye health practices among homemakers.

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