Journal of Optometry (2015) 8, 258–265

Journal of Optometry

www.journalofoptometry.org

ORIGINAL ARTICLE

Macular pigment spatial distribution effects on glare disability

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Received 15 October 2014; accepted 7 December 2014
Available online 16 February 2015

KEYWORDS
Macular pigment optical density;
Spatial distribution;
Glare disability

Abstract
Purpose: This project explored the relationship of the macular pigment optical density (MPOD) spatial profile with measures of glare disability (GD) across the macula.
Methods: A novel device was used to measure MPOD across the central 16° of retina along four radii using customized heterochromatic flicker photometry (cHFP)at eccentricities of 0°, 2°, 4°, 6° and 8°. MPOD was measured as discrete and integrated values at all measured retinal loci. GD was calculated as a difference in contrast sensitivity (CS) between no glare and glare conditions using identical stimuli presented at the same eccentricities. GD was defined as [(CSNo Glare − CSGlare)/CSNo Glare] in order to isolate the glare attenuation effects of MPOD by controlling for CS variability among the subject sample. Correlations of the discrete and integrated MPOD with GD were compared.
Results: The cHFP identified reliable MPOD spatial distribution maps demonstrating a 1st-order exponential decay as a function of increasing eccentricity. There was a significant negative correlation between both measures of foveal MPOD and GD using 6 cycles per degree (cpd) and 9 cpd stimuli. Significant correlations were found between corresponding parafoveal MPOD measures and GD at 2 and 4° of eccentricity using 9 cpd stimuli with greater MPOD associated with less glare disability.
Conclusions: These results are consistent with the glare attenuation effects of MP at higher spatial frequencies and support the hypothesis that discrete and integrated measures of MPOD have similar correlations with glare attenuation effects across the macula. Additionally, peak foveal MPOD appears to influence GD across the macula.
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http://dx.doi.org/10.1016/j.optom.2014.12.004
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PALABRAS CLAVE
Densidad óptica del pigmento macular;
Distribución espacial;
Trastorno de refracción

Efectos de la distribución espacial del pigmento macular en el nivel de discapacidad por deslumbramiento

Resumen
Objetivo: Este estudio analizó el perfil espacial de la relación entre la densidad óptica del pigmento macular (MPOD) y las mediciones de deslumbramiento (glare) discapacitante (GD) a lo largo de la mácula.
Métodos: Se utilizó un nuevo dispositivo para medir la MPOD a lo largo de los 16 grados centrales de la retina, distribuidos en 4 radios, utilizando un fotómetro intermitente heterocromático personalizado (cHFP) a excentricidades de 0, 2, 4, 6 y 8 grados. Se midió la MPOD como valores discretos e integrados, en todas las localizaciones retinianas medidas. Se calculó el GD como diferencia de sensibilidad al contraste (CS) entre las condiciones sin y con deslumbramiento, utilizando estímulos iguales, presentados en las mismas excentricidades. El GD se definió como [(CSNo Glare - CSGlare)/CSNo Glare] a fin de aislar los efectos de la MPOD en la atenuación del deslumbramiento mediante el control de la variabilidad de CS en la muestra de sujetos. Se compararon las mediciones de la MPOD discreta e integrada con GD.
Resultados: El cHFP identificó unos mapas de distribución espacial fiables de la MPOD, que demostraron un deterioro exponencial de 1er orden, como función del incremento de la excentricidad. Se produjo una importante correlación negativa entre las mediciones de la MPOD foveal y el GD, utilizando estímulos de 6 ciclos por grado (cpd) y 9cpd. Se hallaron correlaciones significativas entre las mediciones correspondientes de la MPOD parafoveal y el GD a 2 y 4 grados de excentricidad, utilizando estímulos de 9cpd, siendo menor la discapacidad por deslumbramiento a mayor MPOD.
Conclusiones: Estos resultados son consistentes con los efectos de del pigmento macular en la atenuación del deslumbramiento discapacitante para frecuencias espaciales altas, apoyando la hipótesis relativa a que las mediciones discretas e integradas de la MPOD tienen correlaciones similares con los efectos de atenuación del deslumbramiento a través de la mácula. Además, el pico foveal de MOPD parece influir en el GD macular.
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Introduction

Previous research has identified lutein (L) and zeaxanthin (Z) as two primary constituents of human macular pigment (MP).[1–3] Within the retina, MP can be found as a membrane-bound compound primarily within the photoreceptor axons (Henle fiber layer in macular region) and the inner plexiform layer[4] and, to a lesser extent, at the level of the retinal pigmented epithelium (RPE)[5] and photoreceptor outer segments.[6]

Macular pigment optical density (MPOD) is highest in the central retina peaking at the foveal center and falling to optically negligible levels outside of 7° of eccentricity from the fovea.[7] *L* is found in greater levels within the peripheral retina as the ratio of *L*:*Z* changes from approximately 1:2.4 at the fovea to 1.8:1 in the parafovea, and to 2.7:1 in the peripheral retina.[8,9] Bone found that MP spatial distribution is highly correlated with cone photoreceptor distribution possibly indicating a role in cone function.[10] Nolan et al. proposed that foveal anatomical structure directly influences *L* and *Z* distribution.[11] They found that integrated foveal levels of MP were significantly correlated with foveal width measured as both foveal crest to foveal crest ($r = 0.32$, $p < 0.05$) and absence of nerve fiber layer ($r = 0.41$, $p < 0.01$).

A majority of previous studies have focused on the relationship of central visual function with foveal MPOD measurement.[12–14] To date, no studies have explored the role of parafoveal MPOD and its relation to visual performance. It is also important for understanding the role of parafoveal MPOD to know the relationship between visual performance and discrete *versus* integrated measures of MPOD. Robson et al. and Trieschmann et al. reported that foveal measures of MPOD showed low correlations with integrated MPOD measured across the spatial distribution.[15,16] Wenzel et al. also hypothesized that an integrated measure of MPOD is potentially a better measure than a measure at a single eccentricity in terms of glare discomfort.[17]

The aim of this study is to determine the role of both discrete and integrated parafoveal measures of MPOD on underlying glare disability (GD) across the macula. Correlations of discrete and integrated MPOD values with GD corresponding to the same retinal loci for three different spatial frequencies (3, 6 and 9 cpd) were calculated. For all three spatial frequencies, the relationship between MPOD and GD was evaluated using both foveal MPOD correlations with retinal eccentricities of GD at 0°, 2°, 4° and 6° and correlations of corresponding eccentricities of MPOD and GD (*i.e.* stimulus center at 2° MPOD with 2° GD, stimulus center at 4° MPOD with 4° GD and stimulus center at 6° MPOD with 6° GD).

Methods

An *a priori* power analysis using an 80% power estimate and a Cohen's effect size of 0.5 determined a study

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