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Macular Pigment Optical Density and Ocular Pulse Amplitude in Subjects with Different Axial Lengths and Refractive Errors

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEF 1 **Maciej Czepita**
AD 1 **Danuta Karczewicz**
C 2 **Krzysztof Safranow**
AD 1 **Damian Czepita**

1 Department of Ophthalmology, Pomeranian Medical University, Szczecin, Poland
2 Department of Biochemistry and Medical Chemistry, Pomeranian Medical University, Szczecin, Poland

Corresponding Author: Damian Czepita, e-mail: czepita@pro.onet.pl
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Background: The purpose of our study was to: (1) investigate the macular pigment optical density (MPOD) and ocular pulse amplitude (OPA) in subjects with different axial lengths (AL) and refractive errors (RE); (2) determine if there is a correlation between MPOD and OPA; and (3) evaluate whether MPOD and OPA depend on intraocular pressure (IOP).

Material/Methods: This study included 140 eyes of 70 subjects – 17 men and 53 women, aged 18 to 29 years (mean: 22.5 years; SD=2.8). Every examined person underwent a thorough eye examination including: visual acuity, anterior segment and fundus examination, keratometry, auto-refractometry, and MPOD, OPA, AL, and IOP measurements. The obtained results were analyzed statistically using Statistica 10 software. P values of <0.05 were considered statistically significant.

Results: The following refractive errors were selected: emmetropia (34 eyes), hyperopia (18 eyes), low myopia (60 eyes), medium myopia (19 eyes), and high myopia (9 eyes). It has been established that the OPA increases with the rise in the spherical equivalents (SE) (Rs=+0.38, P<0.001), while the increase in AL correlates with the decrease of OPA (Rs=–0.40, P<0.001). The increase in IOP correlates with the rise in the OPA (Rs=+0.20, P<0.05). There were no significant correlations between IOP and SE or AL.

Conclusions: (1) MPOD is not correlated with the OPA in subjects with different AL and RE; (2) OPA decreases with the rise of AL; (3) OPA decreases with the fall of the SE; and (4) OPA increases with the rise in IOP.

MeSH Keywords: **Axial Length, Eye • Macula Lutea • Refractive Errors**

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Background

In the 20th century a significant increase in the prevalence of refractive errors influenced by genetic and environmental factors has been noted. Refractive errors occur in more than half of the world's population. They are a serious social problem as uncorrected refractive errors can lead to serious impairment of vision [1–5].

At the time being there is considerable demand for clinical and experimental studies, which can explain the pathogenesis of degenerative changes in the course of myopia such as macular pigment optical density (MPOD) and ocular pulse amplitude (OPA).

Ocular pulse amplitude is the intraocular pressure fluctuation originating from the pulsatile ocular blood flow connected with the systolic and diastolic phases of the heartbeat. The principle of this concept is that when a bolus of fluid enters the eye during systole, the eye will expand by the volume of the bolus associated with an increase in the intraocular pressure. When the bolus leaves the eye during the diastole, a decrease in eye volume occurs [6].

OPA is an indirect measurement of choroidal perfusion. It is influenced by various local and systemic factors and is manifested as an ocular pressure pulse. Ocular pulse amplitude is not affected by changes in non pulsatile venous flow. OPA reflects the total pulsatile ocular blood flow. The contribution of choroidal perfusion on the total pulsatile ocular blood flow is the highest and stands at around 85%. The remainder comes from the ciliary body, retina and iris [7].

Investigations into MPOD and OPA are clinically significant because they provide insights to the changes occurring in the macula and into the ocular blood flow, which can lead to different ocular disorders. To the best of our knowledge, no studies evaluating the role of macular pigment optical density and ocular pulse amplitude have been carried out so far.

A number of methods of measuring MPOD have been devised. Heterochromatic flicker photometry (HFP) has so far proven to be the most popular clinical method. The main advantage is that it does not require dilating the pupils and the results are repeatable [8–12].

At the time being one of the most precise methods of measuring OPA is dynamic contour tonometry (DCT). The obtained results are accurate and reliable. The central corneal thickness and the rigidity of the eyeball do not interfere with the result of the measured intraocular pressure and ocular pulse amplitude [13–16].

Therefore, the aim of this paper was:

1. To study the macular pigment optical density and ocular pulse amplitude in subjects with different axial length and refractive error.
2. To examine whether a correlation between MPOD and OPA does exist.
3. To evaluate whether macular pigment optical density and ocular pulse amplitude depend on intraocular pressure (IOP).

Material and Methods

One hundred and forty eyes of 70 subjects – 17 men and 53 women, aged 18 to 29 years (mean: 22.5 years; SD=2.8) – were included in this study, most of them recruited from Szczecin, Poland. All subjects recruited were healthy and had no ocular abnormalities other than refractive errors.

This study adhered to the guidelines of the Declaration of Helsinki for research in human subjects and was approved by the ethics committee of the Pomeranian Medical University. Written informed consent was obtained from each volunteer prior to measurements.

Every examined person underwent a thorough eye examination including: visual acuity, anterior segment and fundus examination, keratometry, auto-refractometry, MPOD, OPA, axial length, and IOP measurements.

Uncorrected and best corrected distance visual acuity was examined with Snellen chart at a distance of 5 meters. Anterior segment examination was performed with a slit lamp and fundus examination with an ophthalmoscope or non-contact slit lamp lens after administration of 1% Tropicamide.

Keratometry and auto-refractometry was done after cycloplegia with 1% Tropicamide using an ACCUREF-K9001 autorefractometer (Shin-Nippon, 2002).

Macular pigment optical density was examined by heterochromatic flicker photometry using the MacuScope (MacuCheck, 2010).

Ocular pulse amplitude and intraocular pressure was measured by dynamic contour tonometry – PASCAL (Ziemer Ophthalmic Systems AG, 2008).

Axial length (AL) was measured by partial coherence interferometry using the IOL Master (Carl Zeiss Jena, 2006).

The refractive errors were described as spherical equivalents (SE). Hyperopia was defined to be spherical equivalent higher than +0.5 D and emmetropia to be higher than –0.5 and

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Table 1. Refractive state, spherical equivalent (SE), and axial length (AL).

Refractive state		*n*	SE (D) Mean	SE (D) SD	AL (mm) Mean	AL (mm) SD
Hyperopia		18	2.20	1.37	22.43	0.61
Emmetropia		34	–0.21	0.25	23.19	0.73
Myopia	Low	60	–1.96	1.02	23.86	1.06
	Medium	19	–6.45	1.13	25.48	1.04
	High	9	–10.09	2.01	26.78	0.65

Table 2. Refractive state, macular pigment optical density (MPOD), ocular pulse amplitude (OPA), and intraocular pressure (IOP).

Refractive state		MPOD (log units) Mean	MPOD (log units) SD	OPA (mmHg) Mean	OPA (mmHg) SD	IOP (mmHg) Mean	IOP (mmHg) SD
Hyperopia		0.49	0.21	2.79	0.82	14.52	2.07
Emmetropia		0.49	0.21	2.64	0.72	14.89	2.13
Myopia	Low	0.55	0.25	2.33	0.79	14.21	2.64
	Medium	0.53	0.23	2.05	0.67	15.50	3.77
	High	0.50	0.21	1.86	0.46	17.12	2.03

lower than +0.5 D. Myopia was defined to be an SE lower than –0.5 D. High myopia was defined as spherical equivalent lower than –8, medium myopia in the range from –8 to –4, and low myopia lower than –0.5 and higher than –4 D.

The obtained results were entered into an EXCEL spreadsheet and analyzed statistically using Statistica 10 software. The Kruskal-Wallis test followed by Mann-Whitney U test was used to compare variable values between the groups, and the Spearman rank correlation coefficient (Rs) was used to evaluate the strength of correlation between these variables. P values of <0.05 were considered statistically significant.

Results

The study population consisted of 140 eyes for which the population characteristics are shown in Table 1. Three groups were selected based on the refractive error. The first group consisted of emmetropes (34 eyes), the second consisted of hyperopes (18 eyes), and the third included low-myopia (60 eyes), medium-myopia (19 eyes), and high-myopia (9 eyes). The spherical equivalent in emmetropic eyes was –0.21±0.25, in hyperopic eyes 2.20±1.37, with low myopia –1.96±1.02, medium myopia –6.45±1.13, and with high myopia –10.09±2.01 D. The axial length in the emmetropic group was 23.19±0.73 mm and in the hyperopic group 22.43±0.61, while in low myopia it was 23.86±1.06, in medium myopia 25.48±1.04, and in high myopia 26.78±0.95 mm (Table 1).

The macular pigment optical density in emmetropic eyes was observed to be 0.49±0.21 log units and did not differ significantly in groups with hyperopia (0.49±0.21), low myopia (0.55±0.25), medium (0.53±0.23) or high myopia (0.50±0.21). No correlation between MPOD and OPA or AL was observed. Additionally, no correlation between MPOD and SE or IOP was observed. The ocular pulse amplitude was found to be 2.64±0.72 mmHg in emmetropic eyes. This value is higher in hyperopic eyes (2.79±0.82) (P<0.05), but lower than in eyes with medium myopia (2.05±0.67) (P<0.05) or with high myopia (1.86±0.46) (P<0.05) (Table 2).

It has been established that the OPA increases with the rise in the SE (Rs=+0.38, P<0.001) (Figure 1), while the increase in axial length correlates with the decrease of ocular pulse amplitude (Rs=–0.40, P<0.001) (Figure 2).

The increase in IOP correlates with the rise in the OPA (Rs=+0.20, P<0.05) (Figure 3).

The intraocular pressure in the examined subjects was found to be 14.78±2.69 mmHg. In emmetropic eyes IOP was 14.89±2.13 mmHg. In the hyperopic group the intraocular pressure was found to be 14.52±2.07 mmHg. Participants of this study with low myopia had IOP of 14.21±2.64 mmHg. Intraocular pressure in the medium myopia group was 15.50±3.77 mmHg, while participants with high myopia had IOP of 17.12±2.03 mmHg. This shows that intraocular pressure of the examined groups was within normal limits, but it was significantly higher

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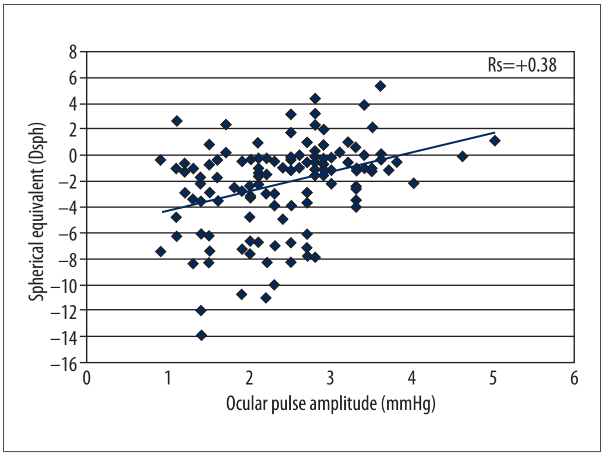

Figure 1. Ocular pulse amplitude and spherical equivalent.

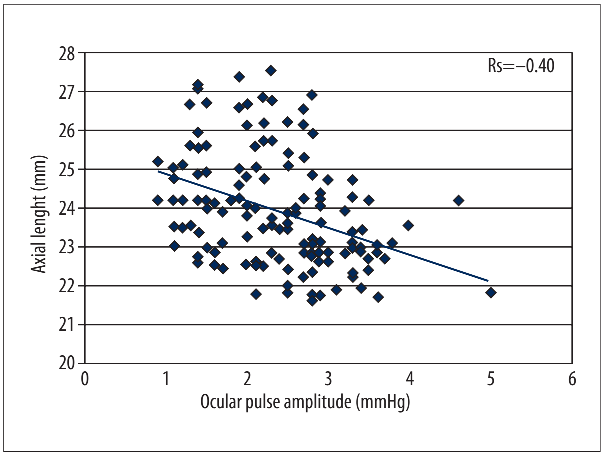

Figure 2. Ocular pulse amplitude and axial length.

in participants with high myopia when compared to emmetropic ones (P<0.01).

There were no significant correlations between IOP and SE or AL.

Discussion

To date only 4 papers have been published in which macular pigment optical density has been described in subjects with different axial lengths and refractive errors. It was expected that a relationship between MPOD and AL or SE exists, but obtained results proved otherwise [9,11,12].

The first paper on this subject was published in 2006 by Liew et al. [10]. The authors examined 322 women (612 eyes) aged younger than 50 years. The examined patients were twins, who had taken part in the TwinsUK project carried out by Saint Thomas Hospital in London. Every patient had undergone optical coherence tomography (OCT) and MPOD examination by means of heterochromatic flicker photometry. A

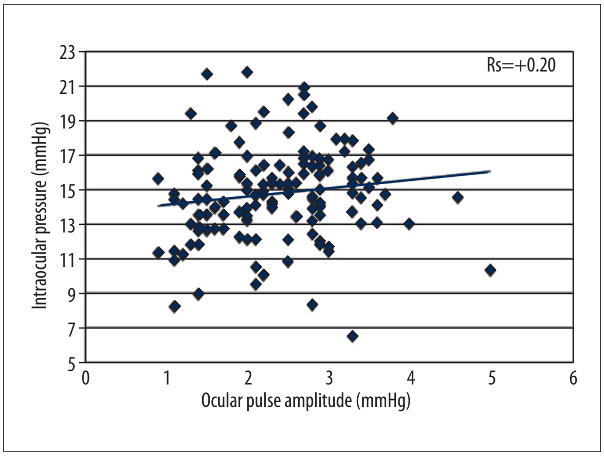

Figure 3. Ocular pulse amplitude and intraocular pressure.

positive correlation between macular pigment optical density and central macular retinal thickness (<1 deg.) was described. No correlation between MPOD and paracentral macular thickness (1–2 deg.) was observed.

In the same year, Neelam et al. [11] published results of their examinations of 180 healthy adults. In each person, ultrasound A scan and macular pigment optical density examination using heterochromatic flicker photometry were conducted. No relationship between MPOD and AL, anterior chamber depth, or vitreous chamber depth was observed. A negative relationship between macular pigment optical density and crystalline lens thickness was described. However, after accounting for age and height, this relationship disappeared.

Another paper dealing with MPOD in people with different AL and refractive error was published by Jongenelen et al. [9]. The authors examined 75 healthy people (150 eyes) aged 12 to 81 years. The participants were examined by psychophysical methods for straylight. No correlation was observed for macular pigment optical density and dispersed light by the crystalline lens, proving that light dispersed by the crystalline lens does not affect MPOD.

The latest paper on macular pigment optical density and different axial length and refractive error was published by Zheng et al. [12]. The authors examined 94 children aged 6–12 years. In each participant, an optical coherence tomography examination, non-contact tonometry, and MPOD by means of HFP were conducted. In children with low, medium, and high myopia a positive correlation between macular pigment optical density and central foveal thickness (CFT) was described as well as a negative correlation between MPOD and minimum foveal thickness (MFT). In children without a refractive error, no relationship was observed between macular pigment optical density and sex as well as body mass index, intraocular pressure, and spherical equivalent and central foveal thickness. The

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obtained results suggest that in the course of low and medium myopia, the retinal thickness in the fovea increases, while the thickness in the parafoveal region decreases.

The results of our study point to the lack of a relationship between MPOD and the SE, AL, IOP, and OPA.

In the world literature, only 3 papers have been published on ocular pulse amplitude measured with dynamic contour tonometry in subjects with different axial lengths and refractive errors.

Kaufmann et al. [16] examined 148 subjects (223 eyes) aged 16 to 61 years, with mean age 34 years. In the examined participants, DCT, Goldmann applanation tonometry, and partial coherent interferometry using an IOL Master were performed.

Similar examinations including dynamic contour tonometry, Goldmann applanation tonometry, and autorefractometry were carried out by Erickson et al. [14] on 115 subjects (115 right eyes) aged 26.4±4.4 years. The following year Erickson et al. [13] supplemented their study with ultrasound A scan biometry.

The latest publication dealing with the subject was published by Ishi et al. [15]. The study included 43 subjects (86 eyes) aged 49±15.9 years. In all the patients, DCT, Goldmann applanation tonometry, OCT, pachymetry, and corneal radius, as well as ultrasound A scan biometry, were conducted.

In all the above-mentioned papers [13,14,16] a negative correlation between axial length and ocular pulse amplitude was proven, as well as a positive correlation between intraocular pressure and OPA. This means that with the increase in intraocular pressure, the ocular pulse amplitude also rises.

The results obtained by us show that with the increase in axial length, a reduction in OPA occurs. We also concluded that in myopia, the ocular pulse amplitude is reduced, while intraocular pressure is increased but is still within normal values. In hyperopia, OPA and IOP are normal. These findings are consistent with the results of Kaufmann et al. [13–16].

To the best of our knowledge, the present study if the first to investigate the relationship between ocular pulse amplitude and macular pigment optical density. Choroidal blood perfusion, as measured in our study by ocular pulse amplitude, does not seem to influence the amount and distribution of macular pigments in the retina in healthy young subjects.

Conclusions

In the present study, we established that:

1. Macular pigment optical density does not correlate with the ocular pulse amplitude in subjects with different axial length refractive errors.
2. OPA decreases with the rise of AL.
3. Ocular pulse amplitude decreases with reduced spherical equivalent.
4. OPA increases with the rise in IOP.

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