

# Macular Pigment Optical Density in Young Adults of South Asian Origin

Olivia Howells, Frank Eperjesi, and Hannah Bartlett

Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham, United Kingdom

Correspondence: Olivia Howells, Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham, UK; o.howells@aston.ac.uk.

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**PURPOSE.** To assess the range of macular pigment optical density (MPOD) in a healthy group of young adults of South Asian origin; to investigate whether any dietary factors or personal characteristics were related to intersubject variations in MPOD; and to compare the mean MPOD of the South Asian group with the mean MPOD of a white group.

**METHODS.** Heterochromatic flicker photometry was used to measure the macular pigment (MP) levels of 169 healthy volunteers, of which 117 were Asian and 52 were white. In addition, the Asian participants completed a questionnaire pertaining to the various physical, ocular, lifestyle, dietary, and environmental factors that may be associated with MPOD or AMD.

**RESULTS.** The mean MPOD of the Asian subjects was  $0.43 \pm 0.14$ . The male participants had a higher mean MPOD than the females ( $0.47 \pm 0.13$  vs.  $0.41 \pm 0.14$ ,  $P < 0.01$ ). Possible associations also emerged between MPOD and form of refractive correction, and iris color. No MPOD associations were found for the other variables examined in the questionnaire. The mean MPOD of the white subject group was  $0.33 \pm 0.13$ , which was significantly lower than the Asian group ( $P < 0.0005$ ).

**CONCLUSIONS.** This study adds to the currently limited information on MPOD in South Asians, and while a comparison between Asians and Whites was not the main focus here, highly significant differences between these two ethnicities were revealed. This provokes the possibility that South Asian individuals could have a lower risk for AMD, and it warrants further study.

**Keywords:** age-related macular degeneration, heterochromatic flicker photometry, macular pigment, macular pigment optical density

Evidence suggests that ethnicity has a role to play in AMD, with Whites having the highest prevalence and Blacks the lowest.<sup>1-13</sup> The AMD prevalence in East Asians (Chinese/Japanese), Southeast Asians (Malays), Hispanics, and Latinos has mostly been found to be lower than in Whites, but higher than in Blacks.<sup>14-21</sup> Studies on South Asians (Indians/Pakistanis/Bangladeshis/Sri Lankans) have been rare, but reported prevalences in a North and South Indian population were comparable to Western countries.<sup>22-24</sup> Cheung and colleagues determined the prevalence of AMD in Chinese, Malay, and Indian persons in Singapore<sup>25</sup> and found it to be similar between the three groups. Based on pooled data from Kawasaki et al.,<sup>26</sup> they concurred with the previous reports that prevalence is similar to Whites.

Macular pigment (MP) is the collective name for three carotenoids, lutein (L), zeaxanthin (Z), and meso-zeaxanthin (MZ), which are found at high concentrations in the central macula, to the exclusion of other carotenoids.<sup>27</sup> They are only available through dietary/supplement intake.<sup>28,29</sup> MP is a blue light filter; its absorption spectrum peaks around 460 nm.<sup>30-33</sup> It is well placed in the retina to reduce the amount of blue light reaching the photoreceptors; the higher the MP optical density (MPOD), the greater the amount of blue light filtering.<sup>34,35</sup> It is also proposed that MP protects against oxidative stress.<sup>36,37</sup> Since blue light and oxidative stress have been implicated in the

pathogenesis of AMD,<sup>38,39</sup> a high level of MP could reduce the risk for AMD.<sup>40-43</sup>

The relationship between race and MPOD has been rarely examined, largely because the vast majority of participants in MPOD studies have been white. Wolf-Schnurrbusch et al.<sup>44</sup> compared MPOD in a group of 51 African and 67 white non-Hispanic subjects. The mean MPOD for the African subjects was significantly higher than for the white subjects ( $P < 0.0001$ ). Conversely, Iannaccone et al.<sup>45</sup> compared MPOD in a group of 35 black and 148 white subjects, and found it to be significantly higher in the Whites than Blacks ( $P < 0.0005$ ). Nolan et al.<sup>46</sup> compared 18 nonwhite (Indian, "Asian," Hispanic, and black) and 41 white subjects; mean MPOD was significantly higher in the nonwhite group than the white group ( $P < 0.01$ ). Studies that found no statistically significant MPOD ethnicity differences<sup>47,48</sup> had low numbers of nonwhite subjects (7%–8% of total samples) compared with white subjects, so there may have been a lack of statistical power.

Outside of ethnic comparisons and white subject-dominated MP studies, there have been a few MP investigations with East Asian participants,<sup>49-52</sup> and one with South Asian participants.<sup>53</sup>

The aims of the current study were firstly to assess MPOD in a healthy group of young adults of South Asian origin. Secondly, to investigate whether any dietary factors or personal characteristics were related to intersubject variations in MPOD.

Thirdly, to compare, for the first time to our knowledge, the mean MPOD of a South Asian group with that of a white group. Hereafter, the term “South Asian” is shortened to “Asian,” and is not intended to encompass any other Asian groups.

## METHODS

### Subjects

Subjects were recruited by email and word of mouth, and consisted mainly of optometry students and staff from Aston University. One hundred and twenty Asian subjects were examined. The majority (104) were British born, 14 were Canadian, and two were African. All were in good health, with an age range of 18 to 30 years (mean  $\pm$  SD: 21.3  $\pm$  2.6 years). MP measurements were also collected on 53 white participants; 47 were British, two were Canadian, and the others Australian, German, Irish, and Polish. All were in good health, with an age range of 18 to 61 years (mean  $\pm$  SD: 27.6  $\pm$  9.3 years). The white subjects were not age-matched to the Asian subjects.

All participants had a habitual visual acuity (VA) of 0.14 logMAR (Snellen 6/7.5<sup>-2</sup>) or better in the eye being tested (the right eye unless it was unsuitable through poor acuity). Exclusion criteria were: age younger than 18 years; VA worse than 0.2 logMAR (Snellen 6/9.5) in the eye being tested; and the presence of any ocular disease in the eye being tested (all subjects were required to have had an eye examination within the last year).

Aston University's ethics committee approved the study. All subjects signed an informed consent form, and all procedures adhered to the tenets of the Declaration of Helsinki.

### Lifestyle Questionnaire

A questionnaire was created for the Asian participants to complete. Questions were focused on the physical, ocular, lifestyle, dietary, and environmental factors that may be associated with MPOD or AMD, for example, height and weight (for body mass index [BMI] calculation), iris color, smoking history, fruit/vegetable consumption, sunlight exposure, and family history of AMD. A copy of the questionnaire is provided as Supplementary Material.

### Macular Pigment Screener (MPS) 9000

Measurements of MPOD were taken using the MPS 9000 (MPS-Tinsley Ophthalmic, Redhill, Surrey, UK), a portable device that employs the heterochromatic flicker photometry (HFP) technique, and which has been described in detail elsewhere.<sup>54</sup> In brief, HFP determines MPOD by presenting a light stimulus of two alternating wavelengths (blue, maximal absorption by MP, and green/yellow, minimal absorption by MP) at the fovea and at a parafoveal or perifoveal area, with the aim of achieving a perception of no or minimal flicker. In traditional HFP the blue-green alternation frequency remains constant, while the radiance of the blue light is increased/decreased until minimal flicker is reported. The procedure is carried out with the subject looking directly at the stimulus (central/foveal measure), and then away from the stimulus (peripheral measure, where MP is assumed to be negligible). The presence of MP in the fovea (with subsequent absorption of some of the blue light before it reaches the photoreceptors) means that a greater radiance of blue light is required here for minimal flicker than at the eccentric point. The log ratio of the two values gives a measure of MPOD. The MPS uses the same HFP principle, but instead of responding to minimal flicker, subjects respond to the appearance of flicker as the blue-green

alternation frequency decreases automatically.<sup>54</sup> Rather than the radiance of the blue wavelength light being adjusted by the subject until minimal flicker, the subject registers their first perception of flicker throughout a series of blue-green ratios. Over the course of the test their responses create two V-shaped curves that are visible on a computer screen. One curve represents central viewing of a 1° circular stimulus, and the other peripheral viewing (8° eccentricity). An internal algorithm calculates the MPOD using the difference between the central and peripheral minima (the larger the difference, the higher the MPOD), but this can also be calculated manually.

An explanation of how to perform the MPS test was read by the investigator from an instruction sheet. Subjects wore their habitual distance correction, if appropriate, and the eye not being measured was occluded. Each subject performed two central and peripheral tests (a short practice was completed before the first of each). Because the MPS generates a visible curve as subjects respond to flicker, it provides a way for the operator to assess whether the curve adheres to the expected V-shape, giving an indication as to the accuracy of the MPOD value produced. The results were, therefore, screened at the time of data collection, and if a poor curve was obtained, or if there was a considerable difference between equivalent minimum readings (central or peripheral), then a third central and/or peripheral test was completed. The averages of the central minima and peripheral minima were used to calculate MPOD. Any poor quality curves were not included in the MPOD calculation. This method has been shown to provide excellent repeatability in subjects of similar ages to this study.<sup>55</sup> Total testing time was 10 to 20 minutes per subject.

The main focus of this study was to examine an Asian subject group, and the numbers recruited were in line with several other MPOD studies that each examined a host of variables and their possible associations with MPOD.<sup>44,56-58</sup> In addition, power calculations, using G\*Power (version 3.1; Heinrich-Heine University, Düsseldorf, Germany), indicated that for an estimated significant mean difference in MPOD of 0.1 (with group SDs of 0.14), a sample size of 64, with 32 subjects per group, was required for 80% power at the 5% alpha significance level.

### Statistics

SPSS (version 18.0; IBM, Portsmouth, UK) was used for data analysis. Mean values were mainly compared using two-tailed independent-samples *t*-tests or its nonparametric equivalent (the Mann-Whitney *U* test), as appropriate in terms of normality. Pearson's *r* or Spearman's rho correlations were used to quantify associations between continuous variables. A *P* value of less than 0.05 was considered statistically significant.

## RESULTS

### Lifestyle Questionnaire

Data from three Asian subjects were removed from the analyses due to inability to complete the MPS test. Of the remaining 117 participants with successful MPOD measurements, 100 fully completed the lifestyle questionnaire, and one subject partially completed it. Only limited information was available for the 16 other subjects. See Table 1 for descriptive statistics of the Asian group.

The mean MPOD of 117 Asian subjects was 0.43  $\pm$  0.14. Other mean MPOD values on which statistical analyses were conducted are summarized in Table 1. Some variables were not analyzed because of the very low subject numbers in one or more of the groups involved. These included: Asian back-

**TABLE 1.** A Summary of the Physical, Ocular, Lifestyle, Dietary, and Environmental Data Collected on the Asian group, Along With the Corresponding MPOD

Variable	Value	MPOD
All, <i>n</i>	117	0.43 ± 0.14
Age, <i>y</i>	21.3 ± 2.6	N/A
Sex, <i>n</i>		
Male	44 (38%)	0.47 ± 0.13
Female	73 (62%)	0.41 ± 0.14*
BMI		
All	21.9 ± 4.0 ( <i>n</i> = 100)	N/A
Male	23.8 ± 4.6 ( <i>n</i> = 38)	N/A
Female	20.8 ± 3.1 ( <i>n</i> = 62)	N/A
South Asian origin, <i>n</i>		
Indian	75 (71%)	0.44 ± 0.15
Pakistani	22 (21%)	0.42 ± 0.12
Bangladeshi	3 (3%)	N/A
Sri Lankan	4 (4%)	N/A
Other	2 (2%)	N/A
Iris color, <i>n</i>		
Dark brown	61 (58%)	0.46 ± 0.15
Brown	37 (35%)	0.42 ± 0.14
Light brown	1 (1%)	N/A
Hazel	5 (5%)	N/A
Green	2 (2%)	N/A
Brown + light brown + hazel + green	45 (42%)	0.41 ± 0.13
Smoking status, <i>n</i>		
Current	6 (6%)	N/A
Former	3 (3%)	N/A
Never	92 (91%)	N/A
Dietary background, <i>n</i>		
Meat eater	72 (71%)	0.43 ± 0.13
Part vegetarian†	8 (8%)	N/A
Vegetarian	21 (21%)	0.46 ± 0.16
Vegetable servings per wk	7.0 ± 5.2 ( <i>n</i> = 100)	N/A
Fruit servings per wk	6.6 ± 5.8 ( <i>n</i> = 100)	N/A
Eggs (including yolks) per wk	1.8 ± 2.1 ( <i>n</i> = 100)	N/A
≤15 vegetable + fruit + egg servings per wk	59 (59%)	0.44 ± 0.13
>15 vegetable + fruit + egg servings per wk	41 (41%)	0.44 ± 0.15
Oily fish servings per wk	0.7 ± 1.1 ( <i>n</i> = 101)	N/A
Alcohol units per wk	3.8 ± 8.2 ( <i>n</i> = 101)	N/A
Regular exercise, <i>n</i>		
Yes	44 (44%)	0.43 ± 0.13
No	57 (56%)	0.44 ± 0.15
Time spent outside per wk, <i>h</i>		
Autumn/winter	8.7 ± 5.8 ( <i>n</i> = 100)	N/A
Spring/summer	17.0 ± 10.0 ( <i>n</i> = 100)	N/A
Autumn/winter daylight exposure ≤ 7 h	56 (56%)	0.43 ± 0.14
Autumn/winter daylight exposure > 7 h	44 (44%)	0.44 ± 0.15
Spring/summer daylight exposure ≤ 15 h	52 (52%)	0.43 ± 0.13
Spring/summer daylight exposure > 15 h	48 (48%)	0.44 ± 0.15
Regular strong sunlight exposure, <i>n</i>		
Yes	24 (24%)	0.43 ± 0.13
No	77 (76%)	0.44 ± 0.15

**TABLE 1.** Continued

Variable	Value	MPOD
Sunbed use, <i>n</i>		
Yes	1 (1%)	N/A
No	100 (99%)	N/A
Skin sensitivity to sunlight, <i>n</i>		
Yes	12 (12%)	0.46 ± 0.11
No	89 (88%)	0.43 ± 0.14
Sunglasses use in bright conditions, <i>n</i>		
Always/most of the time	19 (19%)	0.40 ± 0.16
Sometimes/occasionally	39 (39%)	0.43 ± 0.13
Very rarely/never	43 (43%)	0.45 ± 0.14
Spectacle prescription		
- best vision sphere, DS	-2.08 ± 2.82 ( <i>n</i> = 110)	N/A
Refractive correction, <i>n</i>		
Spectacles and/or UV-blocking contact lenses	39 (37%)	0.47 ± 0.15
None or non-UV-blocking contact lenses	62 (59%)	0.42 ± 0.14
Mixture	4 (4%)	N/A
Family history of AMD, <i>n</i>		
Yes	2 (2%)	N/A
No	99 (98%)	N/A

Note: Information on vitamin and supplement use was also acquired from the questionnaire, but it is not included here as very few subjects took either, and of those that did, no vitamins/supplements included lutein or zeaxanthin. N/A, not applicable.

\*  $P < 0.01$  (i.e., male MPOD significantly higher than female MPOD).

† Part vegetarian refers to someone who eats one form of meat only (e.g., fish).

grounds other than Indian and Pakistani, smoking status, sunbed use, and family history of AMD. For the same reason, some variables were modified: iris colors other than dark brown were combined to make a larger group that could then be compared with dark brown; part vegetarians were excluded from the dietary background analysis; and the 'mixture' group was excluded from the refractive correction analysis.

Of the variables examined, only sex demonstrated a statistically significant difference in MPOD, with the males having a higher average MPOD than the females ( $P = 0.008$ ). Figure 1 shows the frequency distribution of MPOD for both groups.

Aside from sex, another variable that approached significance ( $P = 0.059$ ) was refractive correction; individuals who wore spectacles (which absorb some or all UV light) or UV-filtering contact lenses (CLs) full time had a higher mean MPOD than those who wore no spectacles or non-UV-filtering CLs (Table 1). There was also a possible trend for iris color; subjects with dark brown eyes had a higher mean MPOD than subjects with lighter ("other") eyes ( $P = 0.078$ ). The spread of MPOD in these two groups is shown in Figure 2. Table 2 shows the individual MPOD breakdown of the more unusual iris colors in the non-dark brown category (unusual, that is, for an Asian population), so brown irides, which accounted for the largest percentage eye color in this group, have been omitted. All but one MPOD value was below the overall average of  $0.43 \pm 0.14$  and below the "other" iris color group's average of  $0.41 \pm 0.13$ .

In addition to looking for differences in mean MPOD between the various groups, the possibility of any MPOD associations was explored for the continuous data. Using Pearson's  $r$  or Spearman's rho (dependent on normality), and

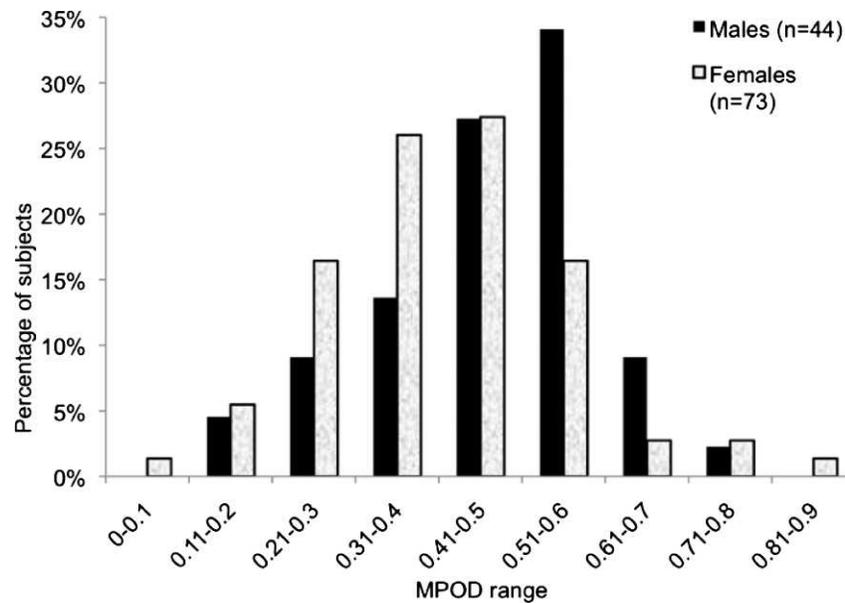


FIGURE 1. The frequency distribution of MPOD for males and females in the Asian group.

scatter graph observations, virtually no significant correlations between MPOD and any variable (age, BMI, vegetable intake, fruit intake, vegetables/fruits combined, egg intake, vegetables/fruits/eggs combined, oily fish intake, alcohol intake, hours spent outside, and best vision sphere) were found, even when analyzing males and females separately (in view of the MPOD sex difference). The only significant correlation to emerge was a positive association between MPOD and alcohol intake ( $\rho = 0.229$ ,  $P = 0.021$ ). This association remained significant for females ( $\rho = 0.330$ ,  $P = 0.009$ ), but not for males ( $\rho = 0.108$ ,  $P = 0.511$ ). However, observation of the scatter graphs indicated that the large proportion of subjects who did not drink alcohol (61%) might have influenced the correlations. Indeed, separating the group as a whole into drinkers of

alcohol and nondrinkers resulted in no relationship for alcohol units and MPOD ( $\rho = 0.045$ ,  $P = 0.782$ ).

#### Asian Versus White MPOD Comparisons

Data from one white subject was removed from the analyses due to inability to complete the MPS test. The total number of Whites was 52 (15 males, 37 females), and their mean MPOD was  $0.33 \pm 0.13$ , compared with  $0.43 \pm 0.14$  for the 117 Asian subjects. These means are significantly different ( $P < 0.0005$ ), as demonstrated in Table 3. Figure 3 is a frequency distribution of MPOD for each group. The white group was older than the Asian group, on average, and a significant decline in MPOD with age was present in this particular sample (Fig. 4), which could therefore be the cause of the differing MPOD means

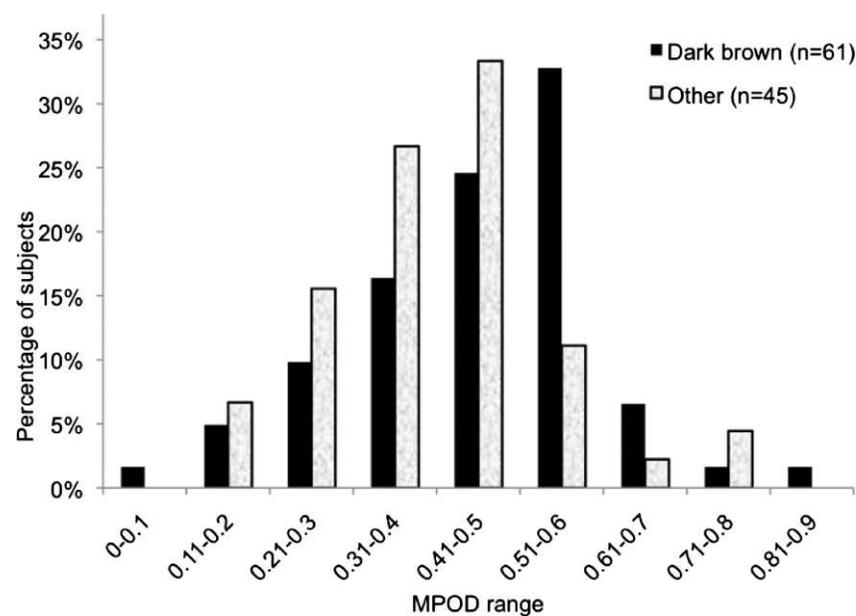


FIGURE 2. The frequency distribution of MPOD for individuals with dark brown eyes and other colored eyes (brown, light brown, hazel, green) in the Asian group.

**TABLE 2.** The Individual MPOD Values of the Eight Asian Subjects With Iris Colors Other Than Dark Brown or Brown

Iris Color	MPOD	Sex
Light brown	0.36	Male
Hazel	0.58	Male
Hazel	0.26	Female
Hazel	0.30	Female
Hazel	0.35	Female
Hazel	0.38	Female
Green	0.31	Female
Green	0.36	Female

between the two races. Although there was still a difference in the mean ages ( $P = 0.01$ ), limiting the white subjects to the same age range as the Asian subjects (18–30 years,  $n = 39$  Whites) removed the MPOD age correlation ( $\rho = -0.135$ ,  $P = 0.413$ ), but a statistically significant difference between the two MPOD means ( $P = 0.002$ ) was maintained. Finally, MPOD in the white group was examined for any sex differences. In contrast to the Asians, the mean MPOD in males ( $0.30 \pm 0.14$ ) was lower than the mean MPOD in females ( $0.34 \pm 0.13$ ), but this difference was not statistically significant ( $P = 0.385$ ).

## DISCUSSION

The present investigation aimed to determine the range of MPOD in a healthy group of young adults of South Asian origin, to investigate whether any dietary factors or personal characteristics were related to intersubject variations in MPOD, and to compare the mean MPOD of a South Asian group with that of a white group.

The mean MPOD of the Asian subjects was higher than most previously published MPS-based averages,<sup>54,59–64</sup> the exceptions being the MPOD means reported by Qin et al.<sup>65</sup> and Tsika et al.<sup>66</sup> (0.47 and 0.52, respectively). While not being directly comparable (because of the different HFP instruments used), Raman et al. also reported a high MPOD mean of  $0.50 \pm 0.21$  at 0.5° in their group of South Asian subjects.<sup>53</sup> It therefore seems very likely that South Asians have higher MP levels, on average, than other, predominantly white, subjects, although we recognize that none of our particular population sample were born in Asia, and so may not be representative of South Asians in general. However, it is still useful to know if people of South Asian origin living in developed countries have higher MPOD, as they may have less chance of AMD, which is important in terms of AMD screening in developed countries, and also in terms of planning public health expenditure.

We found Asian males averaged a statistically significant higher mean MPOD than females. This finding is in common with several other studies,<sup>34,43,56,61,67–72</sup> while the converse has been rarely reported.<sup>58</sup> Nevertheless, the majority of studies have not found any sex differences, and in the present study the effect size ( $r = 0.25$ ) was only small to medium. Of

note, Raman et al., in their MPOD study of South Asians, reported higher MPOD in males ( $0.54 \pm 0.14$ ,  $n = 30$ ) than females ( $0.47 \pm 0.18$ ,  $n = 30$ ) in their participant age group (20–29) similar to the present study, but this difference was not statistically significant ( $P = 0.087$ ).<sup>53</sup>

Aside from the male/female difference, MPOD in the present study was unrelated to virtually all the physical, ocular, lifestyle, dietary, and environmental factors determined from the questionnaire. In some cases this could, in part, be the result of too small a sample size, such as the limited number of vegetarians compared with meat eaters. It may also be due to problems inherent in our data collection methods, such as relying on self-reported height and weight to calculate BMI.

There was an almost significant MPOD difference between individuals who wore spectacles or UV-filtering CLs full time and those who wore no spectacles or non-UV-filtering CLs. These differences were not attributable to greater numbers of males in the spectacle/UV CL group (36% males/64% females) compared with the no spectacles/non-UV CL group (42% males/58% females). We previously reported significantly greater MPOD ( $P = 0.014$ ) in eyes that had worn UV-blocking CLs ( $0.41 \pm 0.13$ ) compared with eyes that had worn non-UV-blocking CLs ( $0.33 \pm 0.15$ ) for the previous 5 years.<sup>97</sup> Light exposure, particularly UV and blue light, is damaging to the retina,<sup>73–76</sup> and it has been shown to cause the production of free radicals, leading to oxidative stress and possibly AMD.<sup>39</sup> From population-based studies, there is some evidence to suggest that chronic light exposure is a risk factor for AMD.<sup>77–79</sup> With less UV light reaching the retina as a result of absorption by spectacles or UV CLs, there may be less light-induced oxidative stress in the retina, thus, permitting an augmentation of MP by reducing its antioxidant-function workload. Interestingly, there was no MPOD relationship with questionnaire-reported sunglasses use or light exposure. This could be because sunglasses are mostly worn in bright conditions (and the questionnaire only asked about their use in bright conditions), so the UV protection is intermittent. Spectacles and CLs would be worn more often, out of necessity to see clearly (and the questionnaire asked specifically about the frequency of spectacle/CL wear and their use in public), so chronic exposure to UV light would be less than with sunglasses. Furthermore, it has been documented that high MPODs are associated with better glare resistance.<sup>80–83</sup> As a result, those with higher MPOD may feel less inclined to wear sunglasses. Although not reaching statistical significance, this could explain the higher MPOD means in those subjects reporting very little sunglasses use compared with those reporting frequent use (Table 1). For light exposure, the questions on time spent outdoors were far and above the ones that participants struggled with the most, so the lack of any significant correlation may in part be a reflection of the overall difficulties in establishing an individual's light exposure.

A comparison between Asians and Whites was not the main focus of this study, and, therefore, the data interpretation is limited in this respect. It is interesting, nonetheless, that in comparing the Asian MPOD mean with the white MPOD mean, highly significant differences were revealed (Asian MPOD higher than white MPOD), regardless of age restrictions (Table 3). Even though there was still some MP overlap between the two groups (Fig. 3), and a lot of variation left unexplained (the effect size,  $r$ , was 0.35, i.e., a medium effect), the difference was clear. The low fruit and vegetable consumption of the Asian group suggests that this difference is unlikely to be the result of dietary factors, although without such data available for the white subjects, this clearly cannot be confirmed. It also seems unlikely that sex differences between the groups would be a factor, because the ratio of males to females in each group

**TABLE 3.** MPOD Comparisons Between the Asian and White Groups

Variable	Asian Group	White Group
MPOD	$0.43 \pm 0.14$ ( $n = 117$ )	$0.33 \pm 0.13$ ( $n = 52$ )*
Age, y	$21.3 \pm 2.6$ ( $n = 117$ )	$27.6 \pm 9.3$ ( $n = 52$ )*
Age, 18 to 30 y	$21.3 \pm 2.6$ ( $n = 117$ )	$23.2 \pm 3.6$ ( $n = 39$ )†
MPOD, 18 to 30 y	$0.43 \pm 0.14$ ( $n = 117$ )	$0.35 \pm 0.14$ ( $n = 39$ )‡

\*  $P < 0.0005$ .

†  $P < 0.01$ .

‡  $P < 0.005$ .

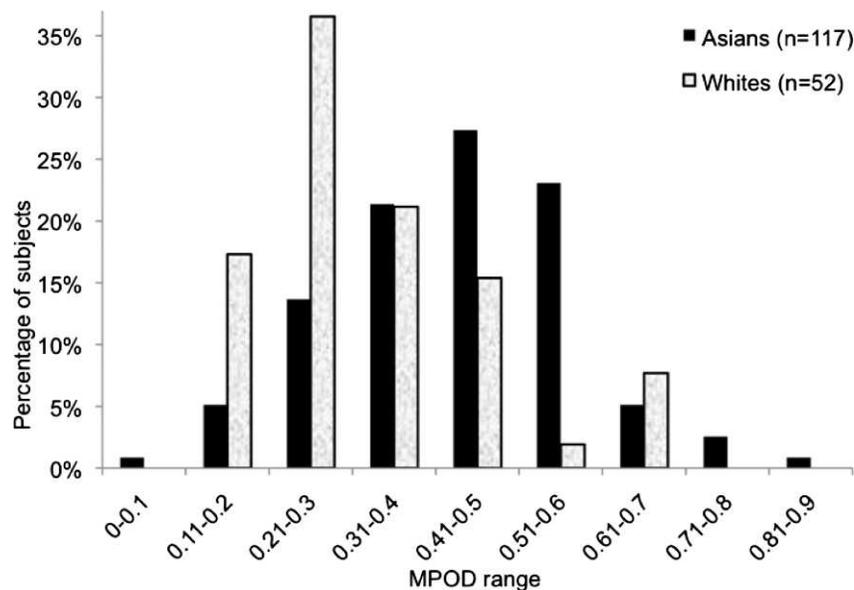


FIGURE 3. The frequency distribution of MPOD in the Asian and white subjects.

was similar, and comparison tests demonstrated significant MPOD differences even when each sex was considered separately ( $P < 0.0005$  for males,  $P < 0.005$  for females). It, therefore, seems reasonable to assume that the cause lies elsewhere.

Firstly, various aspects of foveal architecture have been associated with MPOD. For instance, Nolan et al.<sup>46</sup> found MPOD to be positively and significantly correlated with foveal width ( $r = 0.41$ ,  $P = 0.001$ ), and moreover, that the foveas of non-Whites (Indian/Asian/Hispanic/black) were significantly wider than the foveas of Whites ( $P < 0.05$ ). Consequently, it is possible that ethnic variations in foveal architecture could be a reason for the disparity in MPOD, at least in part. From this point of view, it would have been useful to know the spatial profile of MP for the study participants, but we could not measure this with the MPS.

Secondly, iris color, or more specifically melanin, could account for the differences in MPOD between the two groups. Like MP, melanin absorbs short-wavelength light (mainly UV)

and has antioxidant properties. In the iris its function is predominantly the former, and in the retinal pigment epithelium and choroid its function is predominantly the latter.<sup>84</sup> Light irides, which contain less melanin than dark irides, have been identified as a risk factor for AMD,<sup>4,85-89</sup> and a risk factor for low MP,<sup>34,47,56,68,83,90-92</sup> so in an ethnic group where the majority of irides are dark, it seems logical that they might have higher levels of MP (and a lower risk for AMD) than an ethnic group with a mixture of light and dark iris colors. On account of the expected high propensity of dark irides in the Asian subjects, an eye color related MPOD difference within this group was not anticipated, but it was split into a “dark brown” and an “other” category, and although not reaching statistical significance, there did appear to be a trend towards the darker brown eyes having higher MPOD. Iris color in this study, as in others,<sup>34,56,90</sup> was self-reported and not verified, so the fact that a difference may exist between two such subtle iris color groups lends support to the theory of melanin being involved with MPOD differences between racial groups. In order to rule out the possibility of a greater male dominance in the dark brown than the “other” iris group (with subsequent higher MPOD being the result of sex rather than eye color), the means were compared separately. For males, the difference became more insignificant, dark brown mean ( $n = 24$ ):  $0.47 \pm 0.12$ , “other” mean ( $n = 16$ ):  $0.48 \pm 0.13$  ( $P = 0.707$ ). For females, however, the difference became statistically significant, dark brown mean ( $n = 37$ ):  $0.45 \pm 0.16$ , “other” mean ( $n = 29$ ):  $0.37 \pm 0.12$  ( $P = 0.021$ ). After exploring this further, by examining the individual MPODs of those subjects with more unusual iris colors, it was striking that all but one MPOD value was well below the overall Asian MPOD average and below the “other” iris color group’s MPOD average. It, therefore, seems highly plausible that iris color is a cause of the racial differences in mean MPOD observed in this study. By filtering out more light than lighter colored eyes, dark eyes could reduce the amount of harmful wavelengths reaching the retina,<sup>47,84</sup> and as a result, there might be a lowering of oxidative stress and less depletion of MP than in lighter eyes. Another possibility, as suggested by Hammond et al.,<sup>47</sup> is that melanin and MP deposition are co-inherited traits.

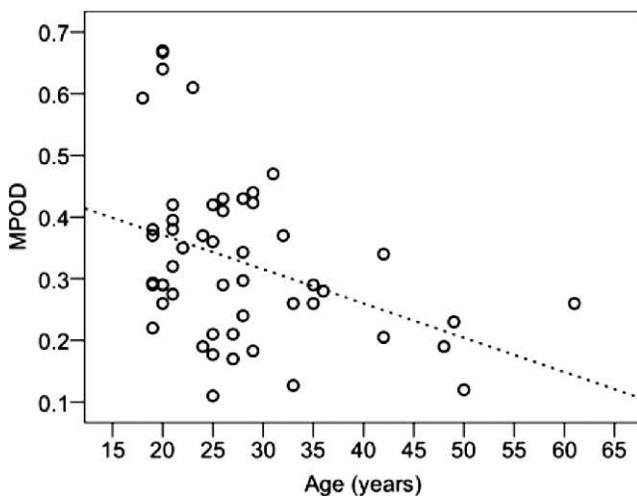


FIGURE 4. The relationship between age and MPOD for the white subjects (Spearman’s rho =  $-0.357$ ,  $P = 0.009$ ).

A final rationale for racial differences in MPOD could lie in ethnicity-variant genetics besides melanin, but the possibilities in this respect are highly diverse. For example, there might be ethnic variations in how effectively L and Z are absorbed, transported or deposited, or there could be specific genes/alleles that lead to higher or lower MPOD, or indeed the first example could be the result of the second. Twin studies on MPOD have demonstrated that there is definitely a genetic component involved,<sup>93,94</sup> and a spousal-based MPOD study appeared to confirm this also; despite statistically significant correlations for dietary and blood serum levels of L and Z between married couples, MPOD between husbands and wives was not correlated at all.<sup>95</sup> Recently a specific gene and its respective genotypes were examined as part of an MPOD study; Loane et al.<sup>96</sup> compared MPOD in three different genotype groups of the apolipoprotein E gene, a gene that codes for lipoproteins that may carry L and Z in serum. It was found that subjects in one of the genotype groups, which contained at least one specific allele, had significantly higher MPOD than subjects in the other two groups, which were both without the specific allele. (As described by Loane et al., the allele in question, Apo ε4, has also been shown to reduce the risk for AMD). This confirms again the genetic aspect of MP, which is not unexpected given the still large amount of unexplained intersubject MPOD variation in the current study and many previous ones.

In conclusion, MPOD in this group of young adults of South Asian origin was largely unrelated to any physical, ocular, lifestyle, dietary, or environmental factors. Males and females, however, did have significantly different MPOD levels, and compared with a group of Whites, MPOD was significantly higher in the Asians, which in turn could mean a decreased risk for AMD. As demonstrated in the introduction, though, current information on AMD prevalence in South Asians, particularly with respect to comparisons with Whites, is limited. Future research will hopefully address this, and wider scale studies examining and comparing MPOD in different racial groups, including South Asians, would be desirable.

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