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Research Article

The Association of Ocular Rigidity with Axial Length and Intraocular Pressure in Healthy Myopic Adults

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Abstract

Aim: To determine the possible correlation between ocular rigidity and other ocular parameters, such as refractive error, axial length, and intraocular pressure, in healthy adults with myopia.

Methods: Ten healthy adults with myopia recruited to participate in the study. The subjects had a refractive error ranging from −2.00 D to −4.50 D. None of the subjects had astigmatism greater than −1.25 D. The age of the participants ranged between 18 and 28 years. Refractive error was measured using a Nidek auto-refractometer. Axial length was measured using IOL Master. Intraocular pressure was measured using a Schiotz tonometer.

Results: Ocular rigidity and refractive error were significantly positively correlated ($t = 12.130$, $df = 9$, $p = 0.000$). Ocular rigidity and axial length were significantly negatively correlated ($t = -106.203$, $df = 9$, $p = 0.000$). Similarly, refractive error and axial length were significantly negatively correlated ($t = -60.268$, $df = 9$, $p = 0.000$). Furthermore, a significant positive correlation was found between ocular rigidity and intraocular pressure ($t = -44.630$, $df = 9$, $p = 0.000$).

Conclusion: Refractive error, axial length, and intraocular pressure are determinates of scleral elasticity and showed a significant correlation with ocular rigidity. This suggests that the structural characteristics of the scleral shell are important factors in determining these ocular parameters. To confirm our findings, a future study with a larger sample size is recommended. Inclusion of other parameters, such as corneal thickness, might also be useful.

Keywords: Myopia, Ocular rigidity, Axial length, Intraocular pressure

Abbreviations: OR: Ocular rigidity; IOP: Intraocular pressure; AL: Axial length; MSE: Mean spherical equivalent

Introduction

Ocular rigidity (OR) has been defined as "a measurable physical parameter of the eye that expresses the elastic properties of the globe" [1]. According to *Dastiridou, et al.*, OR has been used in the literature as a clinical concept characterizing the biomechanical properties of the ocular coats. It measures the extensibility of the ocular wall as the relationship between a change in intraocular pressure (IOP) and a change in intraocular volume [2].

It is well-established that variations in axial length (AL) contribute to the development of refractive error such that long AL leads to myopia [3-6] and short AL leads to hyperopia [6,7], wherein the ocular size is increased in myopic eyes [8].

Several reports have mentioned that OR is lower in myopic eyes than in emmetropic eyes [1,9-12] and hyperopic eyes [1,2,9,10]. The reason for the lower OR observed in myopic eyes is the reduced tensile strength of the scleral coat resulting from the thinning of the collagen bundle and the reduction in the volume of the individual collagen fibers [1,13-15].

Moreover, prior research has demonstrated that myopic eyes can expanded in all three dimensions [5], with the axial dimension being larger than the vertical or horizontal dimension [16]. Although high myopia are usually associated with increased eyeball size, it is not associated with a larger orbit size [17]. This suggests that compared with emmetropic or hyperopic eyes, the movement of myopic eyes is constrained by the limited size of the orbital cavity. Previous research has investigated the relationship between scleral rigidity and some ocular characteristics, including saccadic eye movement, refractive error, and IOP.

One study was conducted to determine whether a normal population variation in OR can affect the characteristics of saccadic eye movements in both myopic and hyperopic eyes. The authors of that study found a significant negative correlation between OR and AL, in which eyes with short AL showed high rigidity and eyes with long AL showed lower rigidity. Furthermore, increased AL been shown to be associated with decreased scleral thickness [18]. Their findings were also comparable with earlier work [1,2,9].

The same study also reported a significant positive correlation between OR and spherical equivalent refraction, in which myopic eyes were found to have lower OR. They also found that OR influenced the transmission of the force generated by the extraocular muscles to the ocular globe [18].

Another study examined the relationship between OR and several factors, such as age, corneal thickness, AL, and pathological conditions. They reported a significant positive correlation between OR and age ($r = 0.27$, $p = 0.02$). Eyes with smaller AL had higher OR ($r = 0.24$, $p = 0.09$). In addition, myopic eyes had lower rigidity than hyperopic eyes, although this difference was not statistically significant. On the other hand, no correlation was found between OR and corneal thickness, age-related macular degeneration, hypertension, or diabetes [1].

Sergienko and Shargorogska investigated the scleral rigidity of eyes with different refractions. Using A-scan ultrasound biometry, they measured AL before and during the application of external pressure on the eye. The external pressure artificially induced using a metal tube device weighing 30 g with an inner aperture diameter of 13 mm [19]. The difference between the two mean AL measurements considered as the degree of change in AL. The findings of that study indicated that compared with myopes, emmetropes and hyperopes have stiff eyeballs. Moreover, mean AL measurements significantly increased in the myopia group ($p < 0.05$), in which high myopic eyes showed lower rigidity [19].

Dastiridou, et al. investigated the relationship between AL and OR. They infused the participants' eyes with saline solution to increase the IOP from 15 mmHg to 40 mmHg. After the infusion, continuous IOP measurements were performed for 2 s. The OR measurements were recorded based on the pressure volume data. They reported a significant negative correlation between OR and AL ($p < 0.001$) [2].

To the best of our knowledge, relatively little work has been conducted to examine the influence of myopia on the optical characteristics of the eye. The aim of the present study was to determine the possible correlation between OR and other ocular parameters, including refractive error, AL, and IOP, in myopic eyes of healthy individuals.

Methods

We recruited 10 healthy adults with myopia (6 men and 4 women) from the student population at Glasgow Caledonian University. Subjects had a refractive error ranging from −2.00 D to −4.50 D. The mean spherical equivalent (MSE) calculated by adding the spherical power to half of the cylindrical power. The age of the participants ranged from 18 to 28 years. Subjects with ocular or systemic pathology, previous ocular surgery, or astigmatism greater than −1.25 D excluded. All participants enrolled in the study had a best-corrected visual acuity of 6/6 or better in both eyes.

In addition, to anesthetize the ocular surface, one drop of proxymetacaine (0.5% hydrochloride) was instilled in the right eye of each subject 2 minutes before recording the measurements. Another drop instilled if necessary. The left eye occluded at all times, and none of the participants wore any form of optical correction device during the experiment.

The study approved by the School of Health and Life Sciences Ethics Committee at Glasgow Caledonian University and was conducted in accordance with the Declaration of Helsinki for research involving human subjects. After receiving a verbal explanation of the nature of the study, all participants completed a consent form and provided information leaflets.

Instrument

AL measured using the IOL-Master ocular biometer (Carl Ziess CO, Germany). Refraction measured using the auto-refractometer ARK-900 (Nidek CO, Japan). OR and IOP were measured via Schiotz tonometry (Biro Ophthalmic Instruments, Burladingen, Germany). The averages of three readings calculated for each parameter. The OR coefficient was determined by measuring IOP with three different weights: 5.5, 7.5, and 10 g. The Schiotz tonometer was soaked in a sterilization solution for 1 h before and after applanation and was left to dry before use. After applying the Schiotz tonometer directly to the anterior surface of the eye, each subject examined using a slit lamp with a cobalt blue filter and fluorescein strips to ensure that the corneal surface was free of scratches.

Measurements Recording

Three consecutive AL measurements obtained centrally for each participant. The duration of measurement recording was <1 min. All measurements performed in the manual measurement mode. The average of the three readings was then calculated. With regard to OR, three IOP measurements performed corresponding to the following weights: 5.5, 7.5, and 10 g. Using Friedenwald's nomogram, each reading assigned a mark (three marks in total), and these marks connected with a straight line. The point at which the line cut the x-axis on the nomogram referred to the OR coefficient. While performing Schiotz tonometry, subjects instructed to lay back and look at a target on the ceiling.

Data analysis

SPSS software version 22 for Windows (IBM Corp., Armonk, NY, USA) used to perform statistical analysis of the data (*www.ibm.com/software/analytics/spss/*). The Shapiro–Wilk test performed to determine the normality of the data, which indicated that the data not normally distributed (parametric). The paired-samples t test was used to compare the means of any two variables obtained from the subjects (e.g., OR and AL). Results were considered statistically significant if the p value was <0.05.

Results

The mean (±SD) MSE of the subjects was −2.9 ± 0.75 D, and the mean (± SD) age was 21.6 ± 2.98 years. OR and MSE refractive error were significantly positively correlated (t = 12.130, df = 9, p = 0.000), wherein OR increased as the refractive error increased (Figure 1).

AL of the subjects varied from 24.1 mm to 26.2 mm (mean ± SD, 25.063 ± 0.612 mm). Furthermore, OR and AL were significantly negatively correlated (t = −106.203, df = 9, p = 0.000), wherein OR decreased as AL increased (Figure 2).

In addition, MSE and AL were significantly negatively correlated (t = −60.268, df = 9, p = 0.000), wherein AL decreased as the refractive error increased (Figure 3).

As expected, a significant positive correlation was also found between OR and IOP (t = −44.630, df = 9, p = 0.000), wherein OR increased as IOP increased (Figure 4).

On the contrary, no significant correlation found between IOP and refractive error (Figure 5).

Similarly, no significant correlation found between IOP and AL (Figure 6).

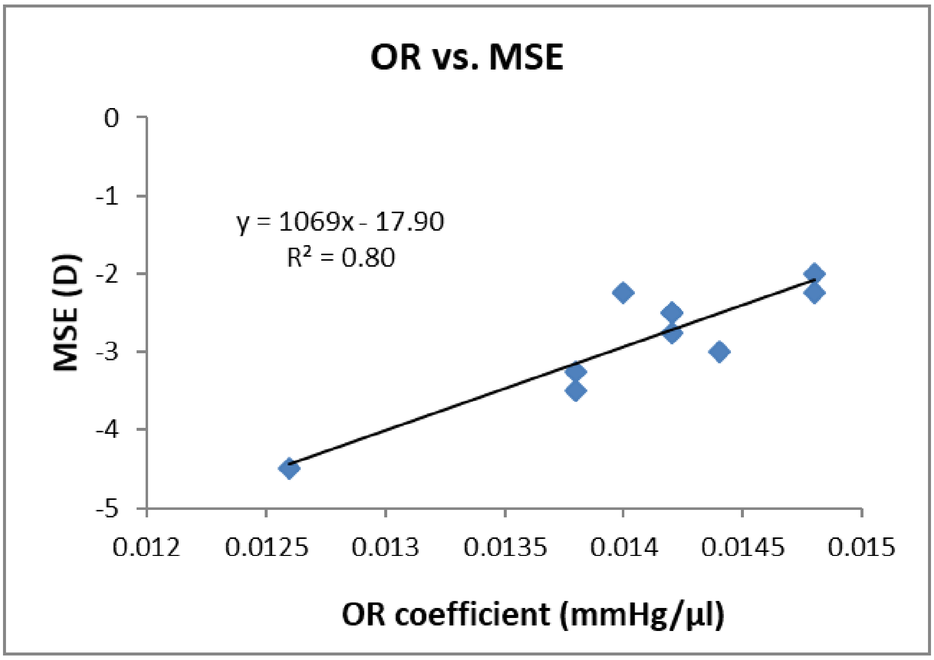

Figure 1: The significant linear relationship between OR and MSE in subjects with myopia.

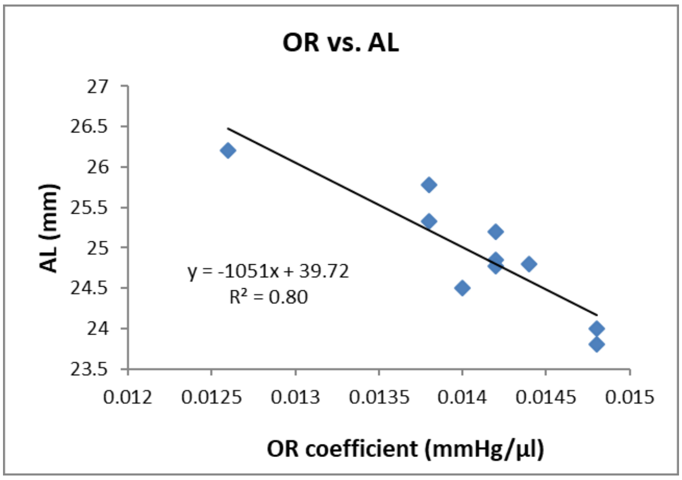

Figure 2: The significant linear relationship between OR and AL in subjects with myopia.

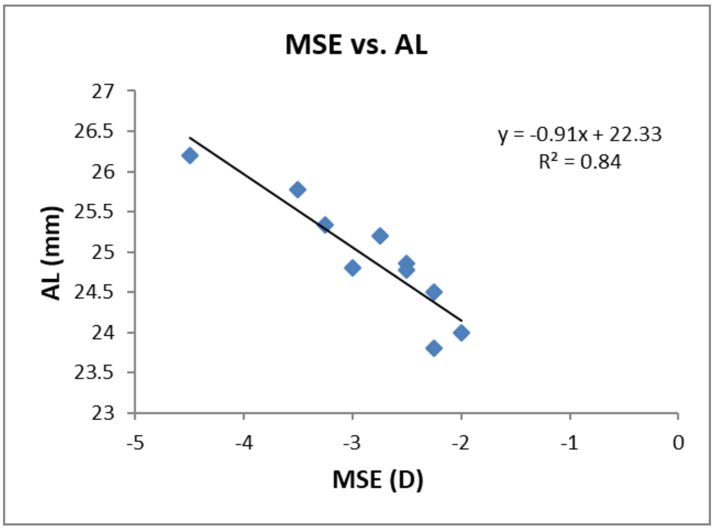

Figure 3: The significant linear relationship between MSE and AL in subjects with myopia.

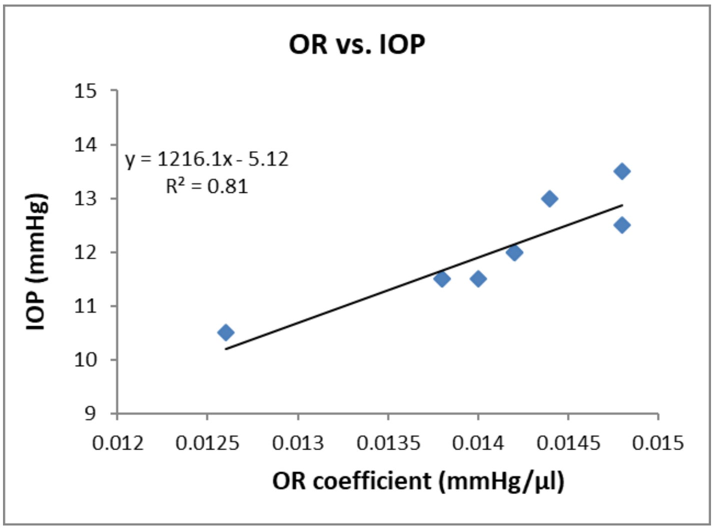

Figure 4: The significant relationship between OR and IOP in subjects with myopia.

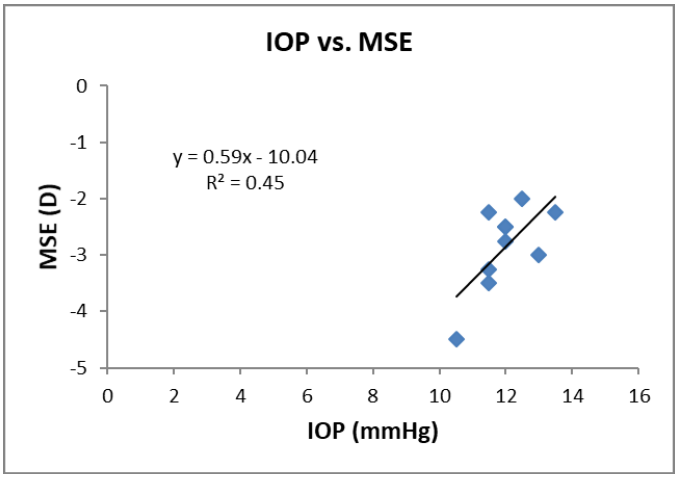

Figure 5: The relationship between IOP and MSE in subjects with myopia.

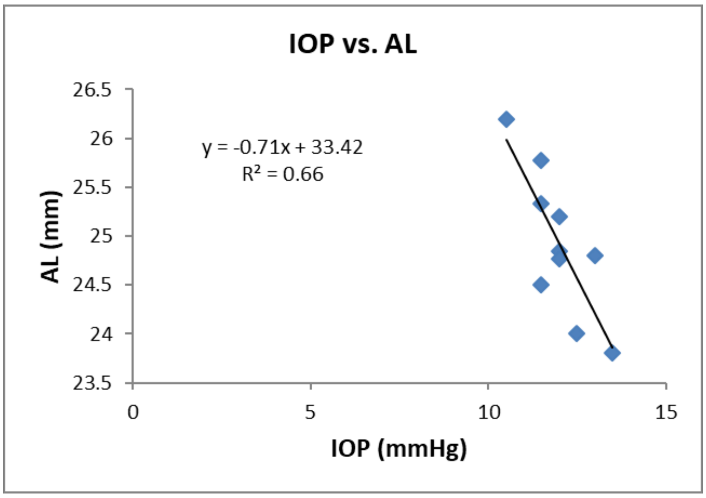

Figure 6: The relationship between IOP and AL in subjects with myopia.

Discussion

Prior studies reported that lower OR is usually associated with high myopia and high AL. In addition, high myopia is typically associated with high AL [2,9,18]. Consistent with previous work, the results of the present study demonstrated a significant linear relationship among OR, MSE, and AL. Moreover, our findings confirmed the significant association between high myopia and high AL. To the best of our knowledge, till date, no studies have investigated the relationship between OR and IOP in myopic eyes.

An increase in AL is likely to cause scleral thinning, thereby leading to a significant reduction in the OR of myopic eyes. Previous research demonstrated an association between decreased scleral thickness and increased AL [1,13,14]. The thinning of scleral collagen bundles as well as the reduced size of collagen fibrils may significantly decrease the content of scleral collagen [1,2,13,14].

In contrast, two previous publications did not report any substantial relationship between OR and myopia as no differences were found between children with and without myopia in terms of scleral stiffness and thickness [20-22]. In addition, two recent studies found no effect of sustained eye rotation on peripheral refraction or peripheral eye length [23].

Earlier investigations have examined the potential role of IOP in myopia development. One study addressed the possibility of an association between elevated IOP and myopia and reported that IOP tended to be higher in children with myopia than in children without myopia. The results of that study indicated that the probability of having high IOP is greater in subjects with myopia than in subjects without myopia. Hence, high IOP might contribute to abnormal eye growth during childhood [24].

On the other hand, another study assessed whether refractive error or AL affected by IOP. The findings of this study revealed that neither refractive error nor AL significantly correlated with IOP, which corroborates our findings [25].

It previously reported that scleral thinning likely plays a role in the axial extension of myopic eyes. In animals, monocular deprivation of form vision caused myopia in tree shrew monkeys, which was also associated with increased anterior chamber depth, increased AL, and reduced posterior scleral thickness. In contrast, the control eyes in tree shrew monkeys had shorter anterior depth, shorter AL, and greater posterior scleral thickness [13]. In humans, increased OR was associated with short AL, wherein myopic eyes were less rigid than hyperopic eyes. However, this relationship was not statistically significant [1].

Hyperopic and emmetropic eyes seem to have a rigid scleral shell and can successfully resist IOP elevation. Conversely, changes in the biomechanical characteristics of the sclera accompanied by steep AL elongation noted in myopic eyes. The sclera suggested to weaker in myopic eyes than in hyperopic or emmetropic eyes [19].

The collagen fiber bundles forming the scleral structure become thinner in the advanced stages of myopia progression. The fibers become narrower and consequently separate from each other. As a result, the posterior segment of the eyeball develops a pathological condition called posterior staphyloma. In some cases, the scleral thickness can be <100 μm. Weakening of the scleral shell is typically associated with excessive stretching and elongation of the eyeball [19].

Conclusion

The present study demonstrated that MSE, AL, and IOP are determinates of scleral elasticity, and our results revealed a significant relationship between these ocular parameters and OR. Our results corroborate previously reported findings describing that decreased MSE and increased AL are associated with decreased OR. Moreover, elevated IOP was associated with high OR. Finally, decreased MSE accompanied by increased AL. These findings suggest that the structural characteristics of the scleral shell are important in determining these ocular parameters. To confirm our findings, a future study with a larger sample size recommended. Inclusion of other parameters, such as corneal thickness, might also be useful.

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Conflict of Interest

The author have declared no conflict of interest.

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