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The Symbiosis Between Spherical Refractive Error Cylindrical Refractive Error

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Abstract

This study aimed to acknowledge the link between spherical refractive error and cylindrical refractive error, which is crucial for diagnosing and managing visual abnormalities productively. This research employed a multi-center, cross-sectional, analytical, and retrospective approach to investigate refractive errors. The objective results were refined subjectively to the best visual acuity with conventional clinical representations of refraction using the sphere, cylinder, and axis. The gathered data underwent analysis utilizing statistical software packages such as SPSS and Minitab. The data were abridged as mean, standard error, and 95% CI of the population mean. The link was determined with the box-plot function of the graph, Pairwise Pearson Correlations, and a comparison of the 95% CI of the population mean for the Spherical Refractive Error and Cylindrical Refractive Error. Line plot graphs were utilized to quantify the ratios of With-the-rule (WTR) astigmatism, Against-the-rule (ATR) astigmatism, and Oblique astigmatism (OA). The degree of astigmatism was highest in individuals with spherical refractive error between -0.12 D to -2.87 D (Low Myopia) and between +3.12 D to +5.00 D (Moderate Hyperopia). Mean cylindrical valuation was -0.69±0.05 in Low Myopia and -1.86±0.41 D in Moderate Hyperopia. The proportion of WTR astigmatism decreased in (47–54) year age group, whereas the distributions of ATR astigmatism increased in the (39–46) year of age groups. Correlation between Spherical Refractive Error & Cylindrical Refractive Error was r=0.018, p=0.613. Except for low myopia and moderate hyperopia, the spherical refractive component appears to be autonomous of the cylindrical refractive integrant. Refractive spherical and cylindrical correlations are not as brawny as those between the other eyes.

Keywords: Spherical refractive error, Cylindrical refractive error, Astigmatism, With-the-rule astigmatism, Against-the-rule astigmatism, Oblique Astigmatism.

INTRODUCTION

The human eye is a astonishing visual network that authorizes us to appraise and interpret the world around us. But visual oddity can take place due to various considerations and influence, including refractive errors. As light is transmitted through the refractive elements of the eye, refractive errors arise when the light rays are not focuses onto the retina. Spherical and astigmatic are two definite types of visual impairment that can arise in individuals and affect a significant portion of the population (43% of global vision loss), while the later one is the most common pattern, affecting 40.4% and 14.9% in adults and children respectively [1]. While they are incompatible in nature, there can be an alliance between them in some cases. Let's delve into the interrelation between astigmatism and spherical refractive error.

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Spherical refractive error, having a uniform focusing power in all meridians of visual system, primarily influenced by myopia (causing light focuses in front of the retina) and hyperopia (causing light focusing behind the retina).

On the contrary, astigmatism, also known as cylindrical refractive power, is another type of refractive error that affects the eye's potential to focus light properly on the retina. Contrasting spherical refractive error, which causes unfocused rays at all meridians, cylindrical refractive power specifically strikes the clarity of vision in certain orientations or axis.

Astigmatism occurs when the refractive elements (cornea and/or the lens) have an irregular shape instead of being perfectly spherical. This asymmetric shape results in light to be focused at several points on the retina, resulting in distorted visual perception.

While astigmatism and spherical refractive error can materialize independently, the coexistence of these two refractive elements can have various influences and impressions [2]. An astigmatic eye along with myopia or hyperopia may have complex visual muddle where both the shape and the overall refractive power of the eye are involved. Acknowledging the link between spherical refractive error and astigmatism is crucial for diagnosing and managing visual abnormalities productively.

Research advocates that the correlation between these two conditions is frequent. Assorted studies have prospected the association between spherical refractive error and astigmatism, seeking to throw light on the fundamental mechanisms and clinical implications [2–4].

MATERIALS AND METHODS

Study Design

This study was a multi centered, cross-sectional, analytical and retrospective, where we studied the refractive errors of 400 patients at three Optometry clinics in Kolkata, West Bengal. The study population was individuals from variant places of Kolkata, West Bengal [5, 6].

Eye Examination

Eye examination is a crucial diagnostic procedure and was conducted based on standardized clinic protocol in optometric practice. Pre-examination formalities were processed including the registration and consent taking, followed by gathering patient’s present complaints and history (both general and ocular). Refractive errors were assessed objectively using Retinoscope (HEINE BETA 200) and/or with AR Auto-refractometer which is calibrated every 6 months. The objective results were refined subjectively to the best visual acuity with conventional clinical representations of refraction using sphere, cylinder, and axis.

Near and distance visual acuity were evaluated in each eye separately using the illuminated Snellen’s optotypes, wearing full refractive correction in the trial frame/habitual spectacle correction. The Snellen’s value converted to LogMAR equivalent, and Visual Acuity recorded in LogMAR value. Visual Acuity Conversion Chart to be followed regarding this and mentioned in Table 1 [7].

To ensure standardized measurements across sites, ophthalmic examinations were carried out in the respective clinics by Clinical Optometrists including the investigator, who obtained minimum degree of Bachelor of Optometry from UGC recognized university; evaluated objective and subjective refraction, anterior and posterior segment using slit lamp biomicroscopy.

Inclusion and Exclusion criteria

The Investigator conducted a detailed review regarding all the relevant literature independently and based on the abstract included criteria accordingly. All the inclusion and exclusion criteria are listed in Table 2.

Table 1. Visual acuity conversion chart.

Snellen's Fraction	**Acuity Value**
Meters	***LogMAR***
6/6	0.00
6/7.5	0.10
6/9	0.18
6/12	0.30
6/15	0.40
6/18	0.48
6/24	0.60
6/30	0.70
6/36	0.80
6/45	0.88
6/60	1.00

Table 2. Inclusion and exclusion criteria

Inclusion criteria	**Exclusion criteria**
Age limit: 7 years to 50 years [8–10]	History of Ocular Comorbidities (Active Systemic diseases with eye involvement) affecting refractive status and/or development [11].
Discontinuation or no history of wearing Contact Lens for 2 months.	Current use of systemic medications, which may affect/alter refractive state [12, 13]. e.g. Analgesics, Anti-hyperglycemic, Bronchodilators, Corticosteroid, Chloroquine and Hydroxychloroquine, Pentosan Polysulfide Sodium, Topiramate, Niacin, Fingolimod [14].
Anterior Segment and Posterior Segment within normal limits.	Presence of ocular pathology such as cataract, corneal opacity, ptosis, glaucoma, retinal disorders, and any other ocular anomalies like amblyopia, strabismus which interrupt visual stimulus [15].
Individual with good general health.	Premature infants (gestational period less than 37 weeks) [16].
	LBW (less than 2500 g).
	Family history of Consanguineous marriages [17].
	Participant involved in another clinical study.
	Participant is a close relative or in a blood relation of a member of the study, including the investigator.

Definitions and calculation of Refractive Error

In this study, the outcomes of subjective refraction derived by refractive acceptance were used for investigation. A refractive error ≥ + 0.125 diopter (D) and ≤ - 0.125 D was defined as hyperopia and as myopia, respectively. Refractive value recorded in steps of 0.125 D.

Myopia was classified as mild, moderate, and high at scales of:

- Low Myopia: - 0.125 D to - 02.875 D
- Moderate Myopia: -03.00 to - 05.875 D
- High Myopia: ≥ - 06.00 D.

On the other hand, classification by the degree of Hyperopia are as follows:

- Low Hyperopia: +0.125 D to +03.00 D,
- Moderate Hyperopia: +3.125 D to +5.00 D
- High Hyperopia: >+05.00 D

Subjective cylindrical value for all participants designated with a negative notation and value ≥ ± 0.125 D considered as Astigmatism. Spherical equivalent (SE) has been calculated adding half of the cylindrical value to the spherical one.

Classification by the degree of astigmatism are as mentioned:

- Low Astigmatism: < 1.00 D,
- Moderate Astigmatism: 1.00 D –1.875 D; and
- High Astigmatism: ≥ 2.00 D

We have also contemplated astigmatism with axes from 60 to 120° (90 ± 30) as Against-the-rule (ATR), from 150 to 30° (180 ± 30) as With-the-rule (WTR), and the rest as oblique astigmatism (OA).

Sample Size

The baseline sample size was determined using the Calculator by Rao soft, Inc. The recommended sample size with 53.1% response distribution, 95 CI, and 5% margin of error is 376 to assess the efficacy. As such, the final sample size of 400 eligible subjects was more than adequate to detect the effectiveness [18].

Statistical Analysis

The statistical analysis was conducted using the Minitab 19 Statistical Software, and SPSS statistics software package, version 28.0. The data were abridged as mean, standard error, and 95% CI of the population mean.

The link between Spherical Refractive Error and Astigmatism was determined with the Box-plot function of the graph, Line plot diagram, Matrix plot, Pairwise Pearson Correlations, and a comparison of the 95% CI of the population mean for the Spherical Refractive Error and Cylindrical Refractive Error. With-the-rule (WTR) astigmatism, Against-the-rule (ATR) astigmatism, and Oblique astigmatism (OA) ratios were quantified by line plot graph.

RESULTS

Upon examining the datasets, it was observed that, out of the 400 participants, 208 (52%) were males. The mean age of the experimental subjects in this study was 27.55±0.6457 (Range: 7 to 50) Years.

The investigation encompasses different types of refractive error distributions in the following Table 3, to gain a comprehensive understanding.

The dispensation of the mean and the standard error of assorted refractive error are presented in Table 4.

The spherical refractive error showed a trend towards myopia in the age group of 31–38 years. The hypermetropic inclination is shown in the age group of 47–54 years. The highest cylindrical mean value is seen in the age group of 15–22 years and 39–46 years. In case of Spherical Equivalent, the vogue towards myopia is highest in 31–38 years of age group, with the highest mean value (-1.64 D), and then proceed towards hypermetropia.

Table 3. Distribution of different types of refractive error

	Percent	**Frequency**
High hyperopia	0.37	3
Moderate hyperopia	1	8
Low Hyperopia	23.75	190
Emmetropia	4.5	36
Low myopia	51.75	414
Moderate myopia	16.5	132
High myopia	2.13	17
Total	100	800

Table 4. Distribution of the mean, standard error (SE), and 95% ci (confidence interval) of population mean of spherical refractive error, cylindrical refractive error, and spherical equivalent (SE) of the subjects in different age groups.

Age Range (in years)	Spherical Refractive Error			Cylindrical Refractive Error			Spherical Equivalent		
	Mean	*SE*	*95% CI of population mean*	*Mean*	*SE*	*95% CI of population mean*	*Mean*	*SE*	*95% CI of population mean*
7–14	-0.52	0.16	(-0.835, -0.199)	-0.76	0.06	(-0.8802, -0.6479)	0.90	0.16	(-1.220, -0.578)
15–22	-1.07	0.15	(-1.357, -0.776)	-0.89	0.07	(-1.0341, -0.7437)	-1.50	0.14	(1.789, -1.217)
23–30	-1.00	0.18	(-1.356, -0.655)	-0.71	0.07	(-0.8421, -0.5746)	-1.36	0.18	(-1.720, -0.999)
31–38	-1.33	0.25	(-1.831, -0.837)	-0.62	0.09	(-0.7949, -0.4460)	-1.64	0.26	(-2.168, -1.121)
39–46	-0.05	0.19	(-0.431, 0.319)	-0.87	0.07	(-1.0125, -0.7309)	-0.49	0.19	(-0.876, -0.108)
47–54	0.41	0.14	(0.139, 0.695)	-0.57	0.07	(-0.7077, -0.4286)	0.13	0.15	(-0.164, 0.429)

The central tendency of each distribution, indicated by mean Spherical, mean Cylindrical and mean Spherical Equivalent were -0.67± 0.08 D (95% CI: -0.8213, -0.5187), -0.77±0.03 D (95% CI: -0.8279, -0.7096), and -1.05±0.08 D (95% CI: -1.2088, -0.8999) respectively.

Figure 1 exemplifies the relationship between Spherical Refractive Error and Cylindrical Refractive Error. The degree of astigmatism was highest in individuals with spherical refractive error between -0.12 D to -2.87 D (Low Myopia) and between +3.12 D to +5.00 D (Moderate Hyperopia). Mean cylindrical valuation was -0.69±0.05 in Low Myopia and -1.86±0.41 D in Moderate Hyperopia.

Figure 2. The proportion of WTR astigmatism decreased with age from (7–14) years age group to (47–54) year age group. A diverse distribution has been noted in case of ATR astigmatism; the proportion increased in the (39–46) years of age groups but have witnessed a drastic fall in (47–54) years age group, reflecting a complexity of the apportion.

The scattering rate of WTR astigmatism increased at higher degrees of cylinder error up to 4.12 to 5 D range (Figure 3). In case of ATR astigmatism, it abolishes with higher degree of cylindrical value. Oblique astigmatism persists with the highest value in higher grade of cylinder.

Additionally, the inquiry surveyed the mean cylindrical value in With-the-rule Astigmatism, Against-the-rule Astigmatism, and Oblique Astigmatism groups, which were -1.14±0.05, -1±0.05, and -0.98±0.15 D, consequently.

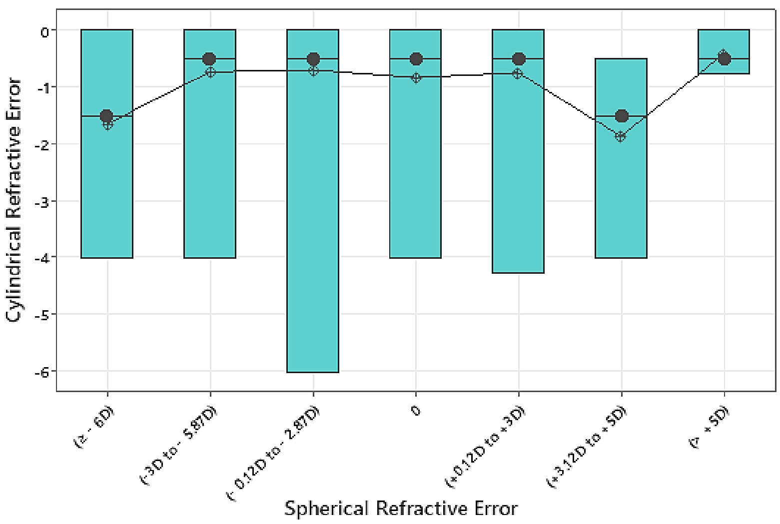

Figure 1. The link between spherical refractive error and cylindrical refractive error.

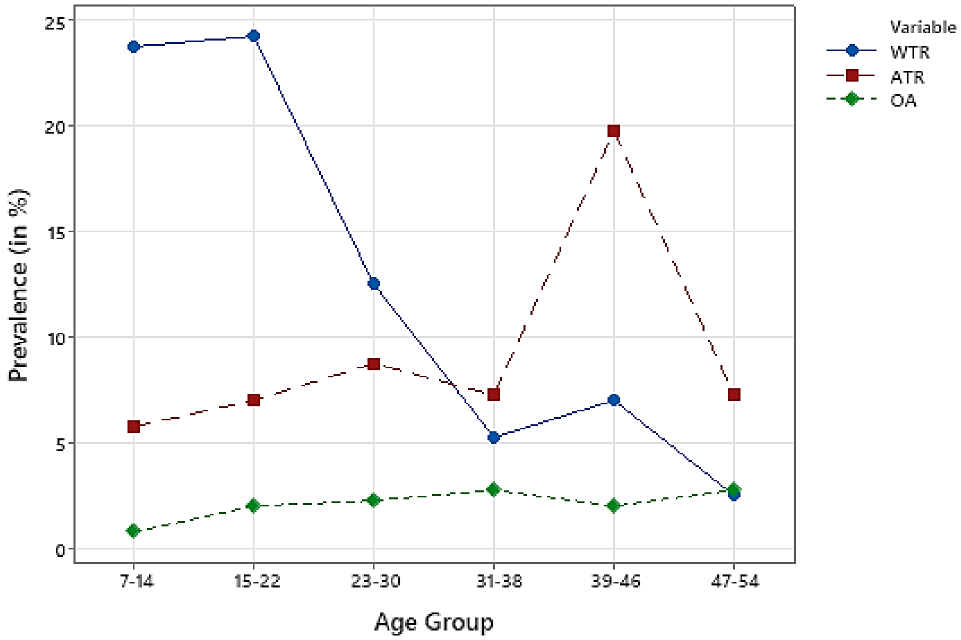

Figure 2. The apportion of different types of astigmatism in different age group.

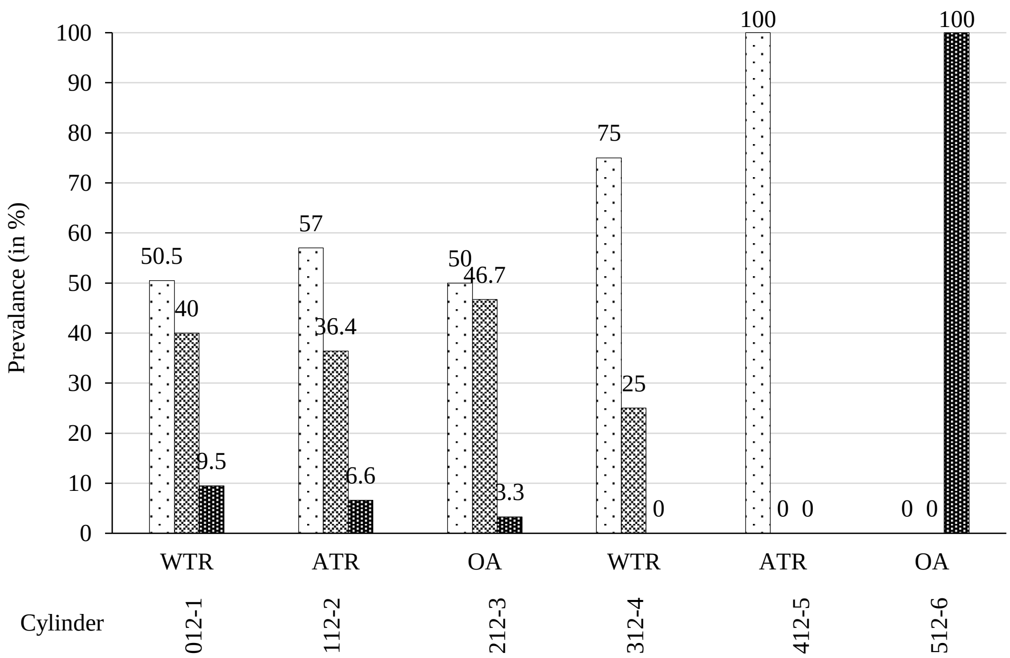

Figure 3. Distribution of different type of astigmatic orientation in different cylindrical value.

Our analysis reveals the highest prevalence of WTR Astigmatism and ATR Astigmatism in Moderate myopic and Low Hyperopic participants, respectively (Figure 4).

The investigation studied the mean spherical values for the three astigmatism classes—With-the-rule Astigmatism (WTR), Against-the-rule Astigmatism (ATR), and Oblique Astigmatism (OA) —which were -1.22±0.13, 0.18±0.14, and -0.70±0.28 D consequently.

Correlation Between Spherical Refractive Error (SPH) and Cylindrical Refractive Error (CYL)

Table 5. With a p-value of 0.613, the correlation between Spherical Refractive Error (SPH) and Cylindrical Refractive Error (CYL) isn't identified as statistically significant.

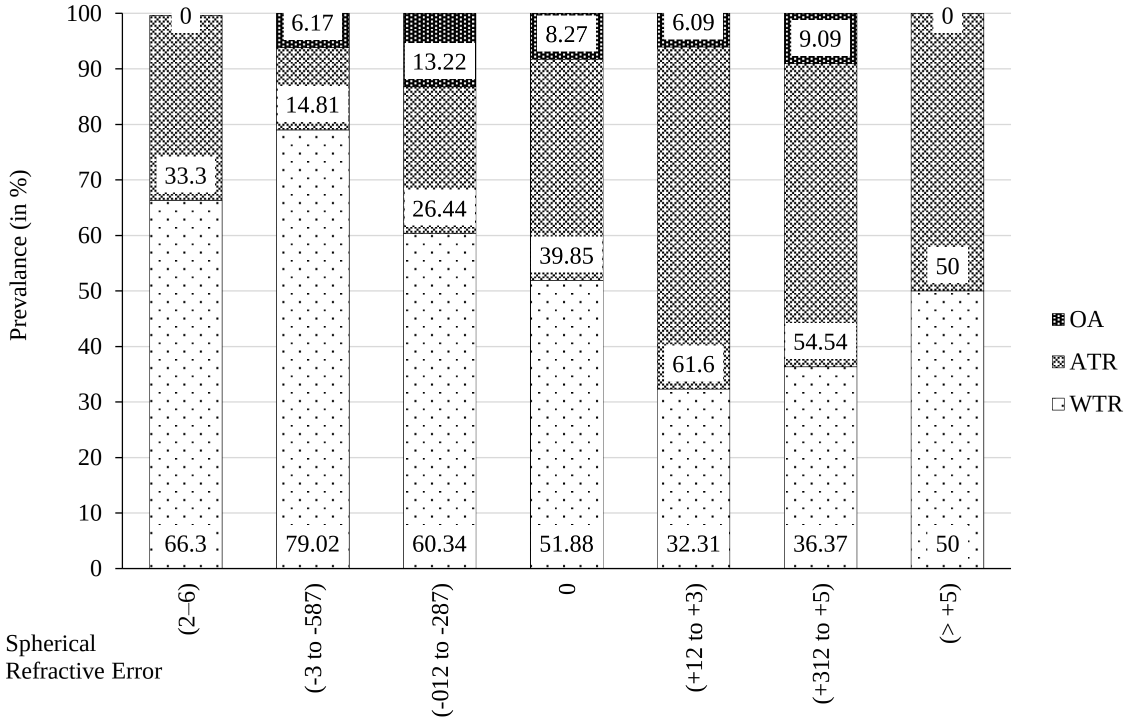

Figure 4. Distribution of different type of astigmatic orientation in different spherical value.

Table 5. Pairwise pearson correlations between SPH and CYL.

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
CYL	SPH	800	0.018	(-0.051, 0.087)	0.613

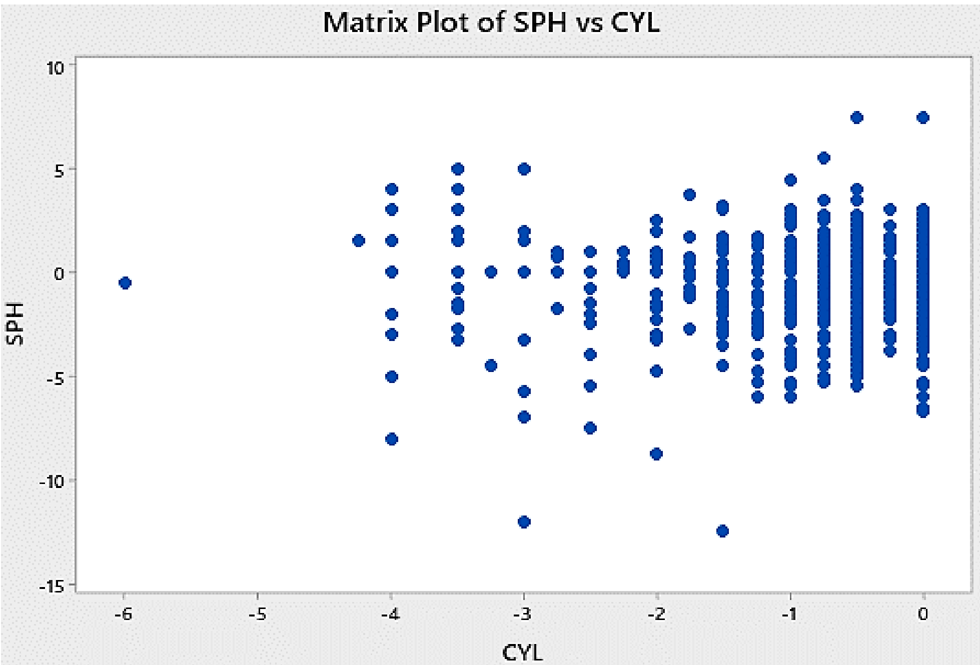

Figure 5. Matrix plot between Spherical refractive error (SPH) and Cylindrical refractive error (CYL).

Matrix plot envisioned the bi-variate relationship between Spherical refractive error and Cylindrical refractive error. In Figure-5 a non-linear pattern has been identified, which directly forbidding correlations. Hence, no significant linear correlation has been established.

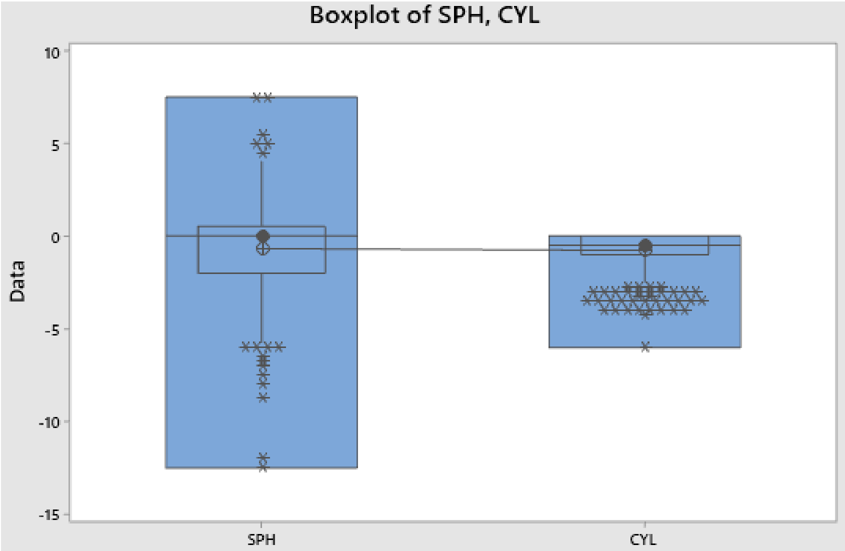

Figure 6. Box plot between spherical refractive error (SPH) and cylindrical refractive error (CYL).

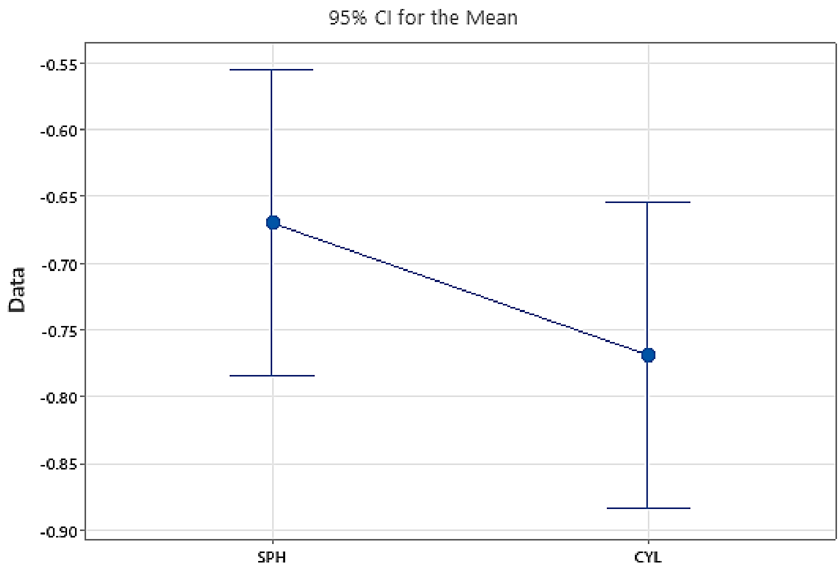

Figure 7. Comparison of 95% CI of the population means spherical refractive error & cylindrical refractive error.

Table 6. Mean for the spherical refractive error & cylindrical refractive error.

Factor	N	Mean	St Dev	95% CI
SPH	800	-0.6700	2.1804	(-0.7848, -0.5552)
CYL	800	-0.7688	0.8523	(-0.8835, -0.6540)

Figures 6. & 7 Overall pattern response for Spherical refractive error (SPH) and Cylindrical refractive error (CYL) has been manifested, which intimating overall patterns of response for SPH & CYL group.

Means

Pooled St Dev = 1.65538

Table 6. With a mean value of -0.67 (in Spherical factor) & -0.7688 (in cylindrical factor), 95% CI of the population mean of spherical factor falls between -0.7848 & -0.5552, whereas cylindrical factor of 95% CI of the population mean falls between -0.8835 & -0.6540.

DISCUSSION

Refractive data were obtained using an Auto-refractometer, and Heine Retinoscope. Measurements obtained from these instruments were a combination of spherical, cylindrical, and axis notation. Apprehending if the level of spherical refractive error influences the occurrence and extremity of astigmatism was one of the study's key goals, along with to evaluate the astigmatism risk factors in people with severe spherical refractive error.

A myopic spherical refractive trend has been exhibited in the 31 to 38 years of age group. In terms of spherical equivalent, a hyperopic leap has been identified, after showing the highest myopic peak in the 31 to 38 years of age span. Contrary to past literatures[3,4], higher cylindrical value is linked to low myopia and moderate hyperopia. With the advancement of age, the proportion of WTR astigmatism decreases, whereas the distribution of ATR astigmatism reflects a complex proportion. Up to -5.00 D of cylindrical value WTR scatters with a dominance nature, whereas ATR decreases with higher value. Spherical Refractive Error (SPH) and Cylindrical Refractive Error (CYL) doesn't justify any statistical significance ($p>0.05$). The bi-variate relationship between Spherical refractive error and Cylindrical refractive error denying correlations as no significant linear correlation has been found.

The standard error clearly provides a lucid outlook about how much a sample statistic can vary. Hence, the standard error has been taken for consideration in this study as it is most obliging for calculating a confidence interval as well. The dioptric analyzing result, apart from confidential interval, impel additional scrutiny of box/cox transformation with keratometric data, for the ample consideration of the multivariate character of residual refractive state, its alteration, or etiquette to lessen the digression from normality [19]. From a thorough evaluation of refractive elements, it's not uncustomary for the spherical refractive error and cylindrical refractive error to be separated. These observations may inform strategy verdicts related to optometry clinical management involving meridional magnification, spatial distortion, and spatial perception.

CONCLUSION

The age group of 31–38 years displayed a proclivity towards myopia as shown by the spherical refractive error. The age range of 47–54 years old evinces a hypermetropic tendency. The age groups of 15–22 and 39–46 have the highest cylindrical mean values. Those with spherical refractive errors between -0.12 D and -2.87 D (Low Myopia) and between +3.12 D and +5.00 D (Moderate Hyperopia) had the highest degree of astigmatism indicating a bi-variate relationship between Spherical refractive error and Cylindrical refractive error. The highest proportion of WTR and ATR Astigmatism has been observed in (47–54) years and (39–46) years of age group respectively.

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