Disruption of Normal Refractive Development in Individuals with Ocular and Oculocutaneous Albinism

Pavan Kumar Verkicharla (✉ pavanverkicharla@lvpei.org)

LVPEI: LV Prasad Eye Institute <https://orcid.org/0000-0001-7755-2178>

Swapnil Thakur

LVPEI: LV Prasad Eye Institute

Priyanka Kammari

LVPEI: LV Prasad Eye Institute

Rohit Dhakal

LVPEI: LV Prasad Eye Institute

Anthony Vipin Das

LVPEI: LV Prasad Eye Institute

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Abstract

Purpose

Albinism is known to disrupt emmetropisation in animal models. However, it is not clear if the same effect is seen in humans. This study aimed to investigate the refractive profile in individual diagnosed with ocular albinism (OA) and oculocutaneous albinism (OCA) based on a large dataset.

Methods

Required data from 618 individuals (61% males and 39% females) diagnosed with albinism were exported from the eyeSmart electronic medical records of L V Prasad Eye Institute. Overall, there were 112 (18%) individuals diagnosed with OA and 506 (82%) with OCA. Based on the spherical equivalent refraction (SER), individuals were classified as emmetropes, myopes, and hyperopes.

Results

The overall spherical equivalent refraction of the individuals ranged from -25.00D to +12.00D with median 0.25 (-2.00 to 2.25). The proportion of individuals with albinism (combined OA, OCA) having hyperopia and myopia (overall: N=282;46% vs. N=245;40%) were similar ($p = 0.18$), and the least were with emmetropia (overall: N=91;14%). Across all the age groups (0-10, 11-20, 21-30, > 30 years) the frequency of hyperopes and myopes were significantly higher ($p < 0.05$) compared to emmetropes. Both high degrees of hyperopia and myopia were found in individual diagnosed with OA and OCA. Irrespective of the albinism type, with-the-rule (70%) astigmatism was the most prevalent compared to other types of astigmatism. The frequency of with-the-rule astigmatism was significantly high in the presence of nystagmus compared to individuals with no nystagmus in both OA (75 % vs 25%, $p = 0.01$) and OCA (77% vs 23 %, $p = 0.014$) group.

Conclusion

The presence of both high hyperopia and high myopia and very less numbers with emmetropia across all age groups indicates disrupted normal refractive development in individuals with albinism. With-the-rule astigmatism and nystagmus may result in meridional degradation of retinal image leading to impairment of normal emmetropisation process in individuals with albinism.

Introduction

Albinism is a group of inherited disorder characterized by either reduced or complete absence of melanin pigment due to mutation of Tyrosinase (TYR) gene that codes for TYR enzyme. Reduction in melanin biosynthesis results in hypopigmentation of structures such as skin, hair, iris, ciliary body, choroid, retinal pigment epithelium, and decrease in grey matter volume.[1–3] Broadly, albinism is classified into two types, ocular albinism (OA) which affects only pigmented part of the eye with no cutaneous involvement, and oculocutaneous albinism (OCA) which affects both eye and other parts of the body such as skin and hair.[1] Poor development of fovea and neurological deficit (abnormal decussation of nerve fiber) in albinos accounts for reduced visual acuity,[4] stereoacuity,[5] nystagmus,[6, 7] and strabismus.[8]

Myopia was reported as the common refractive error type in animals with albinism.[9–11] However, studies which have investigated refractive error profile in humans with albinism reported a skewed distribution of refractive error towards hyperopia, with a mean spherical equivalent refractive error (SER) ranging from 0.46 D[12] to 2.81 D[13] and with-the-rule astigmatism (WTR) being more prevalent among all types of refractive errors.[14, 15][13, 16]^{20,21} The only exception to this were the reports by Edmunds et al.[12] (N = 16) and Perez–Carpinell et al.[17] (N = 7) which have indicated equal distribution of refractive error type and a skewed distribution of myopia (mean: -3.50 ± 6.16 D), respectively. Schweigert et al.[18] analyzed longitudinal change in refractive error for 10 years in 75 children with albinism and found no significant change in the mean refractive error in three visits spread across a decade (2.81 ± 2.40 D vs. 2.53 ± 3.40 D vs. 2.15 ± 4.00 D).

Earlier studies that investigated refractive profile in individuals with albinism had a limitation of smaller sample size (N = 7 to 75 overall, and < 10 with high degree of refractive error). Therefore, the presence of small difference in distribution between emmetropic, myopia or hyperopic cohort, could skew the result towards one side thereby falsely increasing the prevalence of particular refractive error. Considering the possible hypothesis of the influence of albinism on disturbing the emmetropisation,[16] it is important to establish the association between refractive error and albinism based on large sample distributed across different age groups and albinism type. This study aimed to investigate the refractive error profile in individuals with ocular albinism and oculocutaneous albinism across different age groups based on a sample of 618 individuals with albinism.

Methods

This is a retrospective study, conducted at the LV Prasad Eye Institute (LVPEI), Hyderabad, India. The individuals who presented to any of the centers of LVPEI for the first-time during August 2010 to August 2018 for a comprehensive ocular examination and diagnosed with the condition of “albinism” were included in the study. A standard informed general consent was obtained from every individual or the parent/guardian of the minors, prior to their clinical examination permitting the use of their electronic medical records information for research purposes. This study was approved by the ethical institutional review board of LVPEI, Hyderabad and adhered to the tenets of the declaration of Helsinki.

Overall, there were 618 individuals who met the inclusion criteria, of which 18% (N = 112) were diagnosed with OA, and 82% (N = 506) with OCA. Additionally, congenital nystagmus was noticed in 73% (N = 451) of all the individuals with albinism. The diagnosis of OCA was made when the individuals had both ocular and cutaneous findings (decreased melanin synthesis in skin, hair follicle, and eye), and as OA when the findings confined only to the eye and no cutaneous findings.[19][20]

The required variables such as demographic-details, uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA), spherical, cylindrical, axis values of objective refraction, retinal findings and the diagnosis of each eye was extracted from the eyeSmart electronic medical records (EMR) of LVPEI.[21] Further analysis was performed only on right eyes data as the spherical equivalent refraction was not significantly different between right and left eyes ($p = 0.74$). The individuals with missing data or with any of the other ocular

conditions that could influence the refractive error were not included in the study (for example: cataract, aphakic, psuedophakic, post refractive surgeries, keratoconus, silicone oil insertions, and pterygium).

Based on age at the baseline visit, all individuals were categorized into 4 groups in 10-year intervals i.e. 0–10, 11–20, 21–30, > 30 years. The UCVA and BCVA were estimated under normal room illumination with high contrast Snellen visual acuity chart at 20 feet, and conversion to logMAR notation was done for data analyses. Vision was assessed qualitatively based fixing and following (FFL) techniques in 29 preverbal children (< 3years), and in two children (> 3 years) who were non-cooperative for either logMAR visual acuity and Lea symbols. Out of 618 individuals with albinism, recording BCVA in both eyes was possible in 458 (74.1%) individuals. The objective refraction using retinoscope and subjective refractions were performed by trained optometrists. Cycloplegic refraction was performed 30 minutes after the instillation of 1% cyclopentolate eye drops in 50% (N = 312) of the individuals per age (< 16 years) and clinical requirements.

The SER was defined as the sum of the spherical and half of the cylindrical power. Myopia was defined as SER less than – 0.50 diopters (D). Based on degree of myopia, individuals were categorized into mild (< -0.50D to -3.00D), moderate (<-3.00D to -6.00D), high myopia (<-6.00D). Hyperopia was defined as spherical equivalent refraction more than + 0.50 D. Based on degree of hyperopia, individuals were categorized into mild (> + 0.50D to + 3.00D), moderate (> + 3.00D to + 6.00D) and high hyperopia (> + 6.00D). Emmetropia was defined as spherical equivalent between – 0.50 to + 0.50 D. Based on the cylindrical component of the eye, astigmatism was classified as with-the-rule (WTR) if the axis meridian was between 15 degrees on either side of the horizontal meridian (N = 412; 77%), against-the-rule (ATR) if the axis meridian was between 15 degrees on either side of the vertical meridian (N = 27; 5%) and oblique astigmatism if the axis was from 15 to 75 degrees or 105 to 165 degrees (N = 98; 18%). When the individuals were not able to read any letter at any distance, visual acuity was recorded using counting fingers (CF) technique where they were asked to count fingers at progressive shorter distances (distance was recorded when the tasks were performed reliably by the individual). If CF was not applicable, then the examiner used hand movement (HM), and positive perception and projection of torch light (PR & PL). Poor visual acuity was defined as the combination of CF, HM, and PR & PL.

To determine the annual progression of myopia, a sub- analysis was performed on the subset (N = 67) of individuals who had come for two visits with a gap of 365–400 days after the baseline visit. The annual myopia progression was calculated as the difference between spherical equivalent refractive error at 1-year follow-up visit and at baseline.

Statistical analysis

IBM SPSS statistics 23.0.0 (SPSS, Inc, Chicago, IL) was used to perform all the statistical tests and the inbuilt features of MS-Excel 2016 (Microsoft Corporation) were used to plot the graphs. Descriptive statistics of the variables such as age, gender, nystagmus, types of refractive error, astigmatism and types of albinism, were provided in the form of frequencies. The Shappiro-Wilk test indicated that SER, age, and BCVA were not normally distributed. Median and interquartile range (IQR) were calculated for age, SER, BCVA, and astigmatism. Mean $\pm$ standard error (SE) was calculated for the spherical equivalent at baseline visit and for annual myopia progression. Chi-square test/Contingency table was used to identify the significance of the

difference in proportions of hyperopia, myopia, and emmetropia and the individuals with and without nystagmus in WTR, ATR, and oblique astigmatism in both albino groups. To assess if the median SER varied between gender. Mann-Whitney test were applied. Similarly, the same test was applied to evaluate the difference in BCVA between two albino groups. Kruskal-Wallis test was performed to test the significance level of SER in different age groups age groups. '*P*' value of < 0.05 was considered statistically significant.

Results

The distribution of individuals based on age, gender and refractive error are summarized in Table 1. Overall, the median (IQR) age of all the individuals with albinism was 10 (5-18) years. Individuals with OA were slightly older than the individuals with OCA individuals (14 (7-24) vs. 9 (5-16) years, $p = 0.001$). Overall, there were 376 (61%) males and 242(39%) females combining both the albinism groups. The median SER of males and females in both OA and OCA groups was similar ($p=0.96$ and $p=0.30$, respectively). No significant difference ($p = 0.903$) in SER was observed between different age groups (0-10, 11-20, 21-30, > 30 years) in individuals diagnosed with OA. However, there was a statistically significant difference in SER between age groups in OCA as determined by Kruskal-Wallis test ($p = 0.013$). Overall, there was a significant difference in median SER in different age group in individual with albinism ($p < 0.009$) with median SER showing overall myopic shift with increasing age.

Figure 1 shows the distribution of refractive error in individuals with ocular and oculocutaneous albinism. The overall SER of the individuals (combined OCA and OA) ranged from -25.00 D to +12.00 D indicating the presence of both high hyperopia and high myopia in individuals diagnosed with albinism.

The most prevalent refractive error type across individuals (combined OA, OCA, with or without congenital nystagmus) were hyperopia (overall: $N= 282$; 46%) and myopia (overall: $N= 245$;40%), and the least was emmetropia (overall: $N=91$; 14%). Overall, there was no significant difference in the percentage of individuals in myopic and hyperopic refractive groups ($p = 0.18$). Figure 2 shows the proportion of hyperopes and myopes were significantly higher compared to emmetropes across all age groups ($p<0.001$).

Considering both the groups i.e., OA and OCA together, the sub-group analysis of refractive error revealed that the proportion of individuals with mild hyperopia was significantly greater ($N=174$; 61%) compared to mild myopia ($N = 132$; 53.8%), $p = 0.016$; the proportion of moderate hyperopia ($N= 73$, 25.8%) was significantly higher compared to moderate myopia ($N=40$,16.3%), $p = 0.002$. However, the proportion of high myopia ($N=73$, 29.7%) was significantly high compared to hyperopia ($N= 35$, 12.4 %), $p =0.001$ when both albino group were considered together.

Astigmatism (range: -0.25 D to -6.00 D) was found in 87% ($N= 537$) of the individuals with the median of -2.50 (-3.13- to -1.38) D. Irrespective of the albinism type (OA or OCA), the most prevalent type of astigmatism noted was WTR (70%), followed by OA (20%) and the least was ATR (10%). The proportion of WTR astigmatism was significantly higher in the presence of nystagmus compared to individuals with no nystagmus in both OA (75 % vs 25%, $p = 0.01$) and OCA (77% vs 23 %, $p = 0.014$) group (Figure 3).

The percentage of individuals with poor visual acuity was greater in OCA group (88 %) compared to OA group (13 %), with significant difference ($p = 0.0001$) in median BCVA between individuals with OCA 0.80 (0.60 to 1.00) log MAR and OA 0.50 (0.30 to 0.80) log MAR. Individuals with congenital nystagmus 0.80 (0.60 to 1.00) log MAR showed to have significantly less ($p = 0.001$) BCVA compared to those without nystagmus 0.60 (0.30 to 0.80) log MAR. without nystagmus (0.8 ± 0.3 logMAR vs. 0.6 ± 0.4 logMAR, $p = 0.001$).

Annual follow-up evaluation was conducted in 11% (67) of the total study cohort. Out of which, 15% (N=10) of the individuals had OA and 85% (N=57) had OCA. The most prevalent type of refractive error in this cohort was hyperopia (N=30; 45%), followed by myopia (N=29; 43%) and emmetropia (N=8; 12%). The mean SER $\pm$ standard error of mean [SEM] in myopes was -4.0 ± 0.77 D and in hyperopes was 2.61 ± 0.41 D; the corresponding annual progression was -0.16 ± 0.24 D and -0.50 ± 0.25 ($p = 0.04$), respectively with an overall mean annual progression was -0.67 ± 0.56 D.

Discussion

The current study was conducted to examine the refractive profiles in a large cohort of patients diagnosed with ocular or oculocutaneous albinism. The main findings that emerge from the present retrospective analysis indicate that both hyperopia and myopia were more prevalent compared to emmetropia in individuals with albinism, which was consistent across all age groups. Furthermore, myopic shift in mean SER was observed with increase in age in individual diagnosed with albinism. High degree of refractive error showed unequal distribution with greater proportion of high myopia compared to high hyperopia.

In both the OA and OCA groups, high degree of WTR astigmatism was consistently prevalent compared to ATR astigmatism and oblique astigmatism. WTR astigmatism was more prevalent in the presence of nystagmus compared to individuals with no nystagmus. In addition, the rate of change in mean SER among subset of albino group indicated a progression of 0.67 D in a 1-year follow-up.

Previous research studies investigating refractive profile in individuals with albinism had small sample size ($N \leq 25$ in 4 studies with $N < 10$ with high refractive errors and 1 study had 75 individuals) as compared to the present study.[16, 22–24] Therefore, to our knowledge this is the first study to report refractive profile and distribution in a large cohort of patients with albinism. Based on a large data set, we report a similar proportion of mild, moderate and high hyperopic and myopic individuals with both OA and OCA groups. The distribution of SER found in this study (-25 D to $+12$ D) was evident in a related work by Perez-Carpinell et al. [17] (-3.50 ± 6.16 , $n = 7$), while the mean SER was higher compared to our findings which is likely due to smaller sample size in Perez-Carpinell et al.[17] study. On contrary, other studies have reported relatively hyperopic mean SER in a small sample of albino individuals.[12, 13, 16, 24, 25] Wildsoet et al.[16] reported mean SER $+1.07$ D (hyperopes $>$ myopes), ranging from -10.50 D to $+9.13$ D. In the current study we found similar percentage of hyperopes and myopes in both OA and OCA (45% vs. 40%, $p = 0.18$) with median SER of -0.50 D which could be attributed to large number of individuals with high myopia (> 6 D: 75 out of 246 total myopes and > 10 D: 32 of 246) compared to other studies.

In accordance to our findings of 87% individuals with albinism exhibiting astigmatism ranging from 0.25 D to 6 D, earlier studies have reported mean astigmatic refractive error ranging from 1.07 D to 2.58 D,[17, 24]

and the with-the-rule astigmatism as the common findings ranging over 50–100%.[13, 17, 25] Previous reports have indicated that impaired emmetropisation in albinos was associated with increasing degree of astigmatism, with no change in spherical equivalent and refractive error.[26, 27][28] We found higher percentage of WTR astigmatism among albinos associated with nystagmus, which confirms the earlier conclusion of etiological link of with-the-rule astigmatism with nystagmus among individuals with albinism. [16] The potential explanation by Grosvenor et al.[29] indicated that the development of astigmatism in individuals with albinism are primarily corneal in origin were presence of nystagmus lowers the corneal rigidity which catalyze corneal molding under influence of eyelids. Several other factors such as genetics, extra-ocular muscle tension, eyelid pressure, visual feedback has been considered to be the possible link for the development of astigmatism.[30] Among ocular and oculocutaneous albinism, it was proposed that severe amount of glare and photosensitivity causes persistent squinting of eyes and therefore could give rise to astigmatism due to corneal molding under influence of eyelid pressure.[18] And, indeed our findings of higher percentage of with-the-rule astigmatism in oculo-cutaneous albinism could be attributed to the same. Wildsoet and colleagues[16] have speculated that emmetropisation process in albino individuals might follows different pathway through “meridional emmetropisation”, where meridional difference in image detail results in unequal emmetropisation rate in individuals with albinism. Given that emmetropisation is guided by visual feedback guided loop, it seems plausible that large meridional differences in image detail due to astigmatism with nystagmus results in abnormal visual input and thus resulting in impaired emmetropisation in albinos. The rarity of emmetropia across all the age groups provides further support of impaired emmetropisation.

We found that individuals with albinism have higher degrees of ametropia both high myopia and high hyperopia ranging from – 25 D to + 12 D. It potentially suggests that high refractive error (irrespective of the sign) might be indicative of impaired emmetropisation in individual with albinism.

In the context of percentage of type of albinism reporting to the medical service, we found that the higher percentage of albinos reporting to our eye care service were patients with oculocutaneous albinism compared to those with ocular albinism. Because, oculocutaneous cutaneous albinism affects both and eye, it is possible that the referrals from general physician to eye hospital/institutes would occur at a common rate than when an individual suffers with only ocular albinism. Given that individuals with OCA have an increased risk of skin cancer due to lack of skin pigment, and in addition glare and photosensitivity is greater in oculocutaneous group might be the reason that they usually require regular visit to eye care or skincare specialist. The low numbers of ocular albinism patients in our cohort are also explained as it constitutes only 10% of all the albinism cases.

The main strengths of the present study are the inclusion of large sample of individuals with albinism across different age and refractive error groups. In addition, we were also able follow-up large subset of albinos to determine longitudinal change in refractive error over time. There were certain limitations in the present study such as we are unable to classify oculocutaneous albinism into sub-types, and absence of biometric data (axial length, anterior chamber depth) which might have provided much detailed analysis of both refractive distribution and biometry among various sub-types of oculo-cutaneous albinism. Secondly, we cannot rule

out the presence of corneal astigmatism which could be potential reasons of higher percentage of WTR in individuals with albinism.

In conclusion, based on a large data set of individuals with albinism, a large variation in refractive error profile is noted in both ocular and oculo-cutaneous albinism, with similar distribution of both hyperopes and myopia, and with WTR meridional astigmatism being most prevalent. Similar proportion of individuals in high degrees of refractive error indicates impaired emmetropisation in individuals with albinism. Further longitudinal studies are warranted to investigate the potential role of meridional astigmatism on visual input, and especially given the nature of disease, albinism may improve understanding the association between melanin, dopamine, and refractive error.

Declarations

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Conflicts of Interest: None

References

1. Summers CG: **Albinism: classification, clinical characteristics, and recent findings.** *Optom Vis Sci* 2009, **86**(6):659-662.
2. von dem Hagen EA, Houston GC, Hoffmann MB, Jeffery G, Morland AB: **Retinal abnormalities in human albinism translate into a reduction of grey matter in the occipital cortex.** *Eur J Neurosci* 2005, **22**(10):2475-2480.
3. Karabas L, Esen F, Celiker H, Elcioglu N, Cerman E, Eraslan M, Kazokoglu H, Sahin O: **Decreased subfoveal choroidal thickness and failure of emmetropisation in patients with oculocutaneous albinism.** *Br J Ophthalmol* 2014, **98**(8):1087-1090.
4. Winsor CN, Holleschau AM, Connett JE, Summers CG: **A cross-sectional examination of visual acuity by specific type of albinism.** *J aapos* 2016, **20**(5):419-424.
5. Lee KA, King RA, Summers CG: **Stereopsis in patients with albinism: clinical correlates.** *J aapos* 2001, **5**(2):98-104.
6. Davis PL, Baker RS, Piccione RJ: **Large recession nystagmus surgery in albinos: effect on acuity.** *J Pediatr Ophthalmol Strabismus* 1997, **34**(5):279-283; discussion 283-275.
7. Guillery RW: **Why do albinos and other hypopigmented mutants lack normal binocular vision, and what else is abnormal in their central visual pathways?** *Eye (Lond)* 1996, **10** (Pt 2):217-221.

8. Merrill KS, Lavoie JD, King RA, Summers CG: **Positive angle kappa in albinism.** *J aapos* 2004, **8**(3):237-239.
9. Jiang L, Zhang S, Chen R, Ma L, Wang X, Wen Y, Qu J, Zhou X: **Effects of the Tyrosinase-Dependent Dopaminergic System on Refractive Error Development in Guinea Pigs.** *Invest Ophthalmol Vis Sci* 2018, **59**(11):4631-4638.
10. Jiang L, Long K, Schaeffel F, Zhang S, Zhou X, Lu F, Qu J: **Disruption of emmetropization and high susceptibility to deprivation myopia in albino guinea pigs.** *Invest Ophthalmol Vis Sci* 2011, **52**(9):6124-6132.
11. Rymer J, Choh V, Bharadwaj S, Padmanabhan V, Modilevsky L, Jovanovich E, Yeh B, Zhang Z, Guan H, Payne W *et al*: **The albino chick as a model for studying ocular developmental anomalies, including refractive errors, associated with albinism.** *Exp Eye Res* 2007, **85**(4):431-442.
12. Edmunds RT: **Vision of albinos.** *Arch Ophthal* 1949, **42**(6):755-767.
13. Loshin DS, Browning RA: **Contrast sensitivity in albinotic patients.** *Am J Optom Physiol Opt* 1983, **60**(3):158-166.
14. Yahalom C, Tzur V, Blumenfeld A, Greifner G, Eli D, Rosenmann A, Glanzer S, Anteby I: **Refractive profile in oculocutaneous albinism and its correlation with final visual outcome.** *Br J Ophthalmol* 2012, **96**(4):537-539.
15. Khanal S, Pokharel A, Kandel H: **Visual deficits in Nepalese patients with oculocutaneous albinism.** *J Optom* 2016, **9**(2):102-109.
16. Wildsoet CF, Oswald PJ, Clark S: **Albinism: its implications for refractive development.** *Invest Ophthalmol Vis Sci* 2000, **41**(1):1-7.
17. Pérez-Carpinell J, Capilla P, Illueca C, Morales J: **Vision defects in albinism.** *Optom Vis Sci* 1992, **69**(8):623-628.
18. Schweigert A, Lunos S, Connett J, Summers CG: **Changes in refractive errors in albinism: a longitudinal study over the first decade of life.** *J aapos* 2018, **22**(6):462-466.
19. Rodríguez-Agramonte F, Izquierdo NJ, Cadilla C: **Ocular findings in patients with oculocutaneous albinism type ia with G47D tyrosinase gene mutation in Puerto Rico: a case report.** *Bol Asoc Med P R* 2013, **105**(2):62-64.
20. King RA, Summers CG: **Albinism.** *Dermatol Clin* 1988, **6**(2):217-228.
21. Das AV, Kammari P, Vadapalli R, Basu S: **Big data and the eyeSmart electronic medical record system - An 8-year experience from a three-tier eye care network in India.** *Indian J Ophthalmol* 2020, **68**(3):427-432.
22. Spedick MJ, Beauchamp GR: **Retinal vascular and optic nerve abnormalities in albinism.** *J Pediatr Ophthalmol Strabismus* 1986, **23**(2):58-63.
23. Stärk N: **[Refractive errors in visually handicapped children].** *Klin Monbl Augenheilkd* 1987, **191**(5):397-402.
24. Nathan J, Kiely PM, Crewther SG, Crewther DP: **Disease-associated visual image degradation and spherical refractive errors in children.** *Am J Optom Physiol Opt* 1985, **62**(10):680-688.

25. Jacobson SG, Mohindra I, Held R, Dryja TP, Albert DM: **Visual acuity development in tyrosinase negative oculocutaneous albinism.** *Doc Ophthalmol* 1984, **56**(4):337-344.

26. Wang J, Wyatt LM, Feliuss J, Stager DR, Jr., Stager DR, Sr., Birch EE, Bedell HE: **Onset and progression of with-the-rule astigmatism in children with infantile nystagmus syndrome.** *Invest Ophthalmol Vis Sci* 2010, **51**(1):594-601.

27. Jethani J, Prakash K, Vijayalakshmi P, Parija S: **Changes in astigmatism in children with congenital nystagmus.** *Graefes Arch Clin Exp Ophthalmol* 2006, **244**(8):938-943.

28. Wallman J, Adams JI: **Developmental aspects of experimental myopia in chicks: susceptibility, recovery and relation to emmetropization.** *Vision Res* 1987, **27**(7):1139-1163.

29. Grosvenor T: **Etiology of astigmatism.** *Am J Optom Physiol Opt* 1978, **55**(3):214-218.

30. Read SA, Collins MJ, Carney LG: **A review of astigmatism and its possible genesis.** *Clin Exp Optom* 2007, **90**(1):5-19.

Tables

Table 1: Participant details based on age, gender, spherical equivalent, and refractive error type in individuals diagnosed with ocular and oculocutaneous albinism.

	Overall			Ocular albinism			Oculocutaneous albinism		
	N (%)			N (%)			N (%)		
		Median Age (IQR)	Median SER (IQR)		Median Age (IQR)	Median SER (IQR)		Median SER (IQR)	Median Age (IQR)
Overall	618	10 (5-18)		112	14 (7-24)		506		9 (5-16)
0-10	328 (53)	6 (3-8)	0.75 (-1.13 to 2.50)	39 (12)	6 (2-8)	0.25 (-2.00 to 1.75)	289 (88)	0.88 (-1.00 to 2.63)	6 (3-8)
11-20	177 (29)	15 (13-18)	0.00 (-3.19 to 1.94)	37 (21)	14.5 (14-17)	-0.25 (-2.63 to 2.13)	140 (79)	0.06 (-3.44 to 1.84)	15 (13-18)
21-30	69 (11)	24 (22-27)	-0.63 (-4.25 to 1.50)	17 (25)	26 (23-27)	-0.25 (-1.50 to 1.44)	52 (75)	-0.88 (-4.69 to 1.50)	24 (22-26)
> 30	44 (5)	38 (33-43)	-1.19 (-6.44 to 0.75)	19 (38)	40 (34-44)	0.50 (-5.50 to 0.75)	25 (62)	-2.00 (-7.63 to 1.00)	35 (33-42)
Gender	N (%)			N (%)			N (%)		
Males		376 (61)	0.50 (-2.00 to 2.38)		65(58)	-0.25 (-2.50 to 2.00)		0.50 (-2.00 to 2.50)	311(61)
Females		242 (39)	0.25 (-2.06 to 1.75)		47(42)	0.25 (-2.00 to 1.38)		0.00 (-2.25 to 2.00)	195(39)
Overall SER (D)									
Median (IQR)		0.25			0.13				0.50

	(-2.00 to 2.25)	(-2.22 to 1.75)	(-2.00 to 2.38)
Mean + SD	-0.55 ± 5.11	-1.02 ± 5.28	-0.44 ± 5.07
Emmetropia (D)			
N (%)	91(15)	21(19)	70 (14)
Median (IQR)	0.00 (-0.25 to 0.38)	0.25 (-0.25 to 0.50)	0.00 (-0.25 to 0.25)
Myopia (D)			
N (%)	245(40)	48 (43)	197 (39)
Median (IQR)	-2.75 (-7.25 to -1.50)	-2.75 (-6.16 to 1.50)	-3.00 (-7.50 to -1.50)
Hyperopia (D)			
N (%)	282(45)	43 (38)	239 (47)
Median (IQR)	2.44 (1.50- 4.25)	2.00 (1.25- 4.00)	2.50 (1.50- 4.38)
Astigmatism(D)			
N (%)	535 (87)	86 (15.0)	449 (72)
Median (IQR)	-2.50 (-3.13 to -1.38)	-1.50 (-2.25 to -1.00)	-2.50 (-3.44 to -1.56)

Figures

Figure 1

Distribution of individuals based on spherical equivalent refractive error in (A) ocular albinism, (B) ocular cutaneous albinism group. 'Emm' indicates emmetropia and "Mod" indicates moderate.

Figure 2

Distribution of individuals based on refractive errors in (A) ocular albinism (B) ocular cutaneous albinism group

Figure 3

Distribution of with-the-rule astigmatism (WTR), against-the rule astigmatism (ATR), and oblique astigmatism (OA) based on the presence of nystagmus in individual diagnosed with ocular and oculocutaneous albinism.