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Iris Color Distribution and Its Relation with Refractive Errors, Amblyopia, and Strabismus in Children

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Abstract

Background: Despite the presence of various reports regarding the association between iris color and some ocular diseases in adults, there is little evidence of such relation in children.
Objectives: Determine the distribution of iris color in seven-year-old children in Iran and its relation with refractive errors, amblyopia, and strabismus.
Methods: In this cross-sectional study, 3414 seven-year-old school children were selected from six cities through multistage random sampling. The iris color in this study was classified into dark brown, medium brown, light brown, yellow, green, gray, and blue. All subjects were examined for visual acuity, refraction, and binocular vision assessment.
Results: Of the 3414 selected samples, 3030 children participated in the study (89% response rate). The prevalence and 95% confidence intervals (CI) of myopia, hyperopia, and astigmatism was 3.03% (2.30 - 3.99), 6.20% (4.40 - 8.65), and 17.42% (13.30 - 22.48), respectively. Amblyopia was detected in 1.85% (1.10 - 3.12) and the prevalence of strabismus was 2.50% (1.86 - 3.35). Dark brown was the most common iris color at 52.50% (50.06 - 54.93) in boys, 46.07% (43.49 - 48.68) in girls, and 49.50% (47.72 - 51.28) in the total sample population. According to logistic regression results, the odds ratio (95% CI) of hyperopia was 0.3 (0.15 - 0.6) in those with medium brown iris color and 0.23 (0.1 - 0.47) in those with dark brown eyes compared to the group with yellow or green iris colors.
Conclusions: Approximately 90% of the studied subjects had dark or medium brown eyes. Given that people with yellow or green eyes are at a higher risk of hyperopia, it is recommended that these individuals be given attention in this regard during screening, and the presence of hyperopia be taken into consideration during refraction examinations for these children.

Keywords: Iris Color, Refractive Errors, Amblyopia, Strabismus, Iran

1. Background

Iris color is a polygenic trait affected by racial and genetic factors and has received attention in light of its protective role for the ocular tissue (1-3). Eye color is mainly determined by melanocytes and their melanin content (3). The highest amount of melanin is found in iris epithelial pigments, which are on the posterior iris. Melanin is also present in the stroma and the anterior part of the iris (4-7). While iris color ranges from lightest (blue) to darkest (brown or black), only three categories are used to classify the iris color: blue, green-hazel, and brown (5).

Iris pigments have specific physiological properties that protect the underlying tissues against ultraviolet rays (8). On the other hand, studies have shown that there is a relationship between iris color and certain eye diseases, such that eyes with dark irises are at a higher risk of developing cataracts (9). This is while individuals with light iris colors have an increased risk of developing age-related macular degeneration (10-12) and ocular uveal melanoma (13).

The importance of the relationship between iris color and eye diseases lies in their relationship with eye diseases, most of which impose heavy burdens that can be avoidable. Refractive errors are one of the important diseases

which have a significant relationship with iris color. Although various studies have shown that there is a relationship between eye color and myopia (14), our extensive search showed that there was no study on the relationship between iris color and amblyopia, hyperopia, and strabismus. Since iris color is a known risk factor for certain eye-related diseases, examining the relationship of iris color with unstudied eye diseases may yield valuable results. Given the high prevalence of refractive errors, amblyopia, and strabismus in Iranian children (15-17), as well as the lack of study on the relationship of iris color with amblyopia and strabismus, a study in this regard seemed necessary.

2. Objectives

Determine the distribution of iris color and its relation with refractive errors, strabismus, and amblyopia among children in Iran.

3. Methods

The present study was conducted cross-sectionally in 2017. The target population of the study were seven-year-old children in urban areas of Iran, and thus, children enrolled in first grade were considered.

3.1. Sampling Method

To perform multistage cluster sampling, the country was divided geographically based on the population density, and one city was randomly selected from each of the six sections (Figure 1). These included Sari, Birjand, Ardabil, Bandar Abbas, Dezful, and Arak. Information regarding the number of first graders in these cities was obtained from the Ministry of Education. Then, to have a sample of 500 school children from each city, 250 female and 250 male children were selected.

3.2. Examinations

At every school site, the study optometrists selected a space that offered proper lighting and dimensions where they could conduct the examinations. On the exam day, first participants' demographics were recorded, and then, they proceeded for the examinations.

First, uncorrected visual acuity was measured using the Snellen E chart at six meters. Then, non-cycloplegic autorefraction was done with the TOPCON RM8800 autorefractometer (Topcon Corp., Tokyo, Japan), and results were refined with retinoscopy (HEINE BETA 200, HEINE Optotechnik, Germany) and a lens box (MSD Meniscus Trial Lenses, Italy). For those with an uncorrected visual acuity worse than 20/20, subjective refraction was tested, and best corrected visual acuity was recorded.

Figure 1. The geographical location of the studied cities. Among all the cities across the country, six cities of Sari, Birjand, Ardabil, Bandar Abbas, Dezful and Arak were randomly selected.

The cover test was performed by an experienced ophthalmologist at near and far using a Snellen chart and a near E chart. The central letter on the line one row above the best visual acuity of the examinee was selected as the fixation point. To examine the iris color, the participant's iris with the pupil undilated was illuminated with a penlight, and the color was determined by comparing it to standard photos. Finally, all schoolchildren underwent cycloplegic refraction after instilling cyclopentolate 1% drops.

3.3. Definitions

In accordance with a previous study (15), the definition of refractive errors was based on the cycloplegic spherical equivalent (SE) refraction. Myopia was defined as an SE equal to or worse than -0.5D. Hyperopia was defined as an SE of +2.0D or worse. The diagnosis of amblyopia was based on a best corrected visual acuity equal to or worse than 20/30 or an inter-ocular difference of two or more lines of acuity in the absence of any pathology (18).

For the iris color, the definitions of "yellow or green", "gray or blue", and "light brown" colors were based on that used in the Beaver Dam Eye Study. When an iris had more than one color, the dominant color (more than 50%) was

recorded. Overall, the amount of pigment in the iris was taken into account rather than the actual color.

3.4. Data Analysis

Data analysis was performed using the Stata 12 software. We used percentages and 95% confidence intervals (CI) to describe the prevalence of different types of refractive error and iris color. Simple logistic regression was used to investigate the relationship between iris color and refractive errors. Cluster effect was applied to account for the sampling method. A significance level of 0.05 was considered.

3.5. Ethical Issues

The Ethics Committee of Arak University of Medical Sciences approved the study protocol. Every stage of the study was conducted in accordance with the Tenets of the Helsinki Declaration. All parents signed a written informed consent.

4. Results

Using a multistage cluster sampling approach, 49 schools were selected from six cities in Iran. Of the 3414 selected students, 3030 participated in the study (89% response rate), and 53.3% (n = 1615) were boys. In the present study, the prevalence (95% CI) of myopia, hyperopia, astigmatism, amblyopia, and strabismus was 3.03% (2.30 - 3.99), 6.20% (4.40 - 8.65), 17.42% (13.30 - 22.48), 1.85% (1.10 - 3.12), and 2.50% (1.86 - 3.35), respectively.

Table 1 shows the prevalence (95% CI) of iris color by gender, city of residence, and refractive error. Overall, the most and least common iris colors were dark brown 49.50% (47.72 - 51.28) and gray or blue 0.39% (0.22 - 0.69), respectively. Dark brown was the most common color in boys and girls, with a prevalence of 52.50% (50.06 - 54.93) and 46.07% (43.49 - 48.68), respectively. In addition, iris color prevalence differed by city, such that the most common color was medium brown in the cities of Dezful and Sari with prevalence rates of 45.78% (41.44 - 50.18) and 50.59% (45.80 - 55.38), respectively, while the most common color in the cities of Bandar Abbas, Ardabil, Birjand, and Arak was dark brown. There was no gray or blue iris color in Birjand or Bandar-Abbas. Dark brown was the most common iris color in myopic 48.86% (38.55 - 59.26) and astigmatic 47.47% (43.41 - 51.57) children, while medium brown was the most common color in cases with strabismus, amblyopia, and hyperopia.

Logistic regression results showed no relationship between iris color and amblyopia, strabismus, or myopia, while there was a statistically significant relationship between iris color and hyperopia, such that, compared to those with yellow or green iris color, the prevalence of hyperopia was 0.30 (0.15 - 0.60) in medium brown eyes and 0.23 (0.10 - 0.47) in dark brown eyes (Table 2).

5. Discussion

The present study is the first to examine iris color distribution in seven-year-old children. Given that iris color changes up to about the age of six years (1) and is almost constant afterwards, determining the most common eye color at this age and its relation to different types of refractive errors and amblyopia can be useful for identifying high-risk groups.

Table 3 shows the most common iris color in different studies (5, 9, 12, 19-23). It should be noted that comparison of the results of studies in this field should be done with caution because studies have used different categorizations in reporting their results. Therefore, these differences should be taken in consideration before making any comparisons. According to our findings, nearly half of the seven-year-old children had dark brown eyes. More than 90% had dark brown and medium brown eyes, and nearly one-tenth of the subjects had light eyes (light brown, yellow or green, and gray or blue). Our study findings were quite consistent with the findings of other studies in Iran such as that by Hashemi et al. (23), who reported medium brown as the most common eye color in their study in Tehran in 2010 (in Hashemi et al. study: 54.09% and in our study: 49.50%) However, our results are significantly different from studies in other countries. Studies on European subjects (5, 19). Americans (20) and Europeans living in Australia (9, 12) showed that the most common color was blue/gray.

Based on the results of this study and other studies conducted around the world, it may be argued that the difference in iris color is due to two reasons: first, the method used in our study and Hashemi's study (23), is different from the method used in studies in some other countries (5, 9, 11, 12, 19, 20), which can justify part of the difference. The second reason, which is the more important reason, is genetic factors. As such, different studies on iris color in different parts of the world suggest factors such as race, genetics and factors such as consanguineous marriages and socioeconomic status (5, 24). Differences in the distribution of eye colors in the studied cities also validate this finding.

The results of our study showed similar distributions of different iris colors in two genders, such that dark brown was the most common color in both genders. Hashemi et al. (23), also showed that the distribution of

Table 1. Distribution of Iris Color by Gender, City of Residence, and Refractive Error in Seven-Year-Old Children

Variables	Prevalence of Iris Color % (95% Confidence Interval)				
	Grey or Blue	Yellow or Green	Light Brown	Medium Brown	Dark Brown
Total	0.39 (0.22 - 0.69)	2.17 (1.71 - 2.76)	7.65 (6.76 - 8.65)	40.26 (38.52 - 42.02)	49.50 (47.72 - 51.28)
Sex					
Boy	0.30 (0.12 - 0.74)	2.10 (1.50 - 2.93)	7.80 (6.58 - 9.21)	37.27 (34.94 - 39.66)	52.50 (50.06 - 54.93)
Girl	0.49 (0.23 - 1.03)	2.26 (1.60 - 3.18)	7.49 (6.22 - 8.98)	43.67 (41.10 - 46.27)	46.07 (43.49 - 48.68)
City					
Dezful	0.20 (0.02 - 1.41)	2.20 (1.22 - 3.94)	8.63 (6.46 - 11.44)	45.78 (41.44 - 50.18)	43.17 (38.87 - 47.57)
Bandar-Abbas	0	0.40 (0.10 - 1.59)	5.01 (3.40 - 7.31)	42.48 (38.21 - 46.87)	52.10 (47.71 - 56.46)
Ardabil	0.93 (0.39 - 2.23)	4.12 (2.73 - 6.19)	8.81 (6.68 - 11.54)	25.32 (21.81 - 29.19)	60.78 (56.56 - 64.85)
Birjand	0	1.44 (0.72 - 2.86)	9.40 (7.23 - 1.21)	40.68 (36.66 - 44.84)	48.46 (44.31 - 52.63)
Sari	0.71 (0.23 - 2.21)	1.67 (0.80 - 3.48)	4.79 (3.11 - 7.32)	50.59 (45.80 - 55.38)	42.20 (37.54 - 47.01)
Arak	0.56 (0.18 - 1.74)	3.01 (1.85 - 4.87)	8.49 (6.39 - 11.18)	39.43 (35.35 - 43.66)	48.49 (44.25 - 52.75)
Refractive errors					
Myopia	0	1.13 (0.15 - 7.70)	7.95 (3.82 - 15.82)	42.04 (32.15 - 52.62)	48.86 (38.55 - 59.26)
Hyperopia	0	6.47 (3.61 - 11.32)	14.11 (9.63 - 20.22)	40.00 (32.88 - 47.56)	39.41 (32.32 - 46.69)
Astigmatism	0.52 (0.16 - 1.60)	3.82 (2.53 - 5.74)	8.86 (6.80 - 11.48)	39.30 (35.38 - 43.36)	47.47 (43.41 - 51.57)
Amblyopia	1.92 (0.26 - 12.64)	3.84 (0.95 - 14.29)	5.76 (1.85 - 16.58)	51.92 (38.40 - 65.16)	36.53 (24.55 - 50.45)
Strabismus	8.33 (1.04 - 43.92)	3.03 (0.73 - 11.58)	3.44 (1.69 - 6.89)	2.37 (15.59 - 3.60)	3.46 (2.50 - 4.77)

Table 2. Simple Logistic Regression for the Relationship of Iris Color with Amblyopia, Strabismus, and Refractive Errors in Seven-Year-Old Children

Refractive Error	Odds Ratio (95% Confidence Interval)				
	Yellow or Green	Grey or Blue	Light Brown	Medium Brown	Dark Brown
Amblyopia	1	2.9 (0.24 - 35.01)	0.42 (0.07 - 2.60)	0.72 (0.17 - 3.10)	0.41 (0.09 - 1.80)
Myopia	1	Empty	2.03 (0.2 - 16.80)	2.05 (0.30 - 15.20)	1.93 (0.26 - 14.20)
Hyperopia	1	Empty	0.58 (0.27 - 1.25)	0.30 (0.15 - 0.60)[a]	0.23 (0.10 - 0.47)[a]
Strabismus	1	2.54 (0.24 - 26.92)	0.87 (0.18 - 4.04)	0.68 (29.41 - 1.58)	1.01 (0.47 - 2.14)

[a] Statistically significant.

Table 3. Most Common Iris Color in Different Populations Throughout the World

Study	Year	Sample Size	Age	Place	Most Prevalent Iris Color
Sturm et al. (5)	2008	3011	12 years old	Northern European	Blue/gray
Tomany et al. (19)	1990	4926	43 - 86 years old	America	Blue/gray
Regan et al. (20)	1999	1162	59 - 60 years old	America	Blue/gray
Younan et al. (9)	1994	3654	Upper than 49 years old	Australia	Blue
Nicolas et al. (12)	1995	171	52 - 93 years old	European people in Australia	Blue
Iida et al. (21)	2009	523	-	Japanese people	Brown
Chang et al. (22)	2007	401	13 - 80 years old	Seoul (Korea)	Brown
			Iran		
Hashemi et al. (23)	2010	4200	Upper than 7 years old	Tehran	Medium brown
Current study	2015	3030	7 years old	Different parts of Iran	Dark brown

iris color was not different between the two genders, which is in line with our findings; however, Martinez-Cadenas et al. (4), showed that the distribution of iris color varies between two genders and attributed this fact to the expression of certain genes, which causes women to have darker irises than men. The difference in the findings of our study with the mentioned study (4) may be due to genetic differences in different populations.

According to our findings, there was no relationship between iris color and amblyopia, strabismus, or myopia. Our extensive search in the literature found no study on the relationship between iris color and amblyopia or strabismus. The results of studies on the relationship between iris color and refractive errors are contradictory. In our study, we observed no relationship between iris color and myopia. However, Meng et al. (14), showed a correla-

tion between iris color and myopia, such that people with darker irises had a higher probability of having myopia. Although several factors were mentioned for this association, it seems that certain genes, as well as polymorphisms, are the reason for the relationship between iris color and myopia. Sun et al. (6), stated that myopic people are less likely to use sunglasses, which increases the entry of light to the eye and to control light entry, the eye increases the pigmentation in the iris that makes the iris darker to prevent excess light from entering the eye. However, further studies are needed in this regard.

Our study showed that people with medium brown and dark brown eyes, in contrast to those with yellow or green iris color, had a lower chance of developing hyperopia. Although the results of the study by Cosar and Sener (25) contradict our findings, they showed that individuals with dark eyes had a more negative SE and therefore, a higher chance of myopia and not hyperopia. Studies in animal models have also shown that animals with dark or gray eyes have a higher risk of myopia (14) and eye color has no relationship with hyperopia. On the other hand, Winn et al. (26), found no relation between eye color and refractive errors. Unfortunately, there is too much controversy in this area, and more powerful studies such as meta-analyses are recommended to find the relationship between eye color and refractive errors.

Careful examinations by the trained personnel, high participation rate, and large sample size are some of the strengths of this study. Given that random sample selection was done from different regions in Iran, the results of this study can be generalized to all Iranian seven-year-old children. Nevertheless, since our study was a cross-sectional, the observed relationships cannot be interpreted as causal.

5.1. Conclusions

What can be deduced from this study is that approximately 90% of the studied subjects had dark brown and medium brown eyes. Knowledge of iris color distribution at a younger age can help with the early diagnosis and treatment of ocular disorders, and based on the results of this study, people with yellow or green eye color have a higher risk of hyperopia than those with dark brown or medium brown eyes. Therefore, individuals with green or yellow eyes should be examined more carefully during screening for this eye disorder.

Footnotes

Conflict of Interests: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

Ethical Approval: The Ethics Committee of Arak University of Medical Sciences approved the study protocol. Every stage of the study was conducted in accordance with the Tenets of the Helsinki Declaration.

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