

The visual status of adolescents in Riyadh, Saudi Arabia: a population study

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Purpose: The visual status of adolescents in Saudi Arabia (SA) has not been well reported. To date, the prevalence and types of refractive errors (REs), amblyopia, strabismus, and correctable visual impairments have not been quantified. The aim of the study was to investigate the visual status in adolescents in Riyadh, SA.

Methods: This study was based on a population cross-sectional and random cluster design. After design and the sample calculations, 1,007 participants, 12–20 years of age, were screened during the study. Nine participants were excluded due to ocular disorders. The participants were assessed for REs, distance visual acuity logarithm of the minimum angle of resolution, contrast sensitivity, stereoacuity, pinhole test findings, and cover–uncover test findings.

Results: The results showed that 55.5% of the participants had some form of REs, while correctable visual impairment was found in one-fifth of the screened participants. Myopia was the dominant type (53.3%, ranged from -0.50 DS to -14.00 DS), whereas hyperopia was found in 2.2% ($+2.00$ DS to $+5.50$ DS) and astigmatism was present in 15% (-0.75 DC to -5.25 DC). Only 43% of the participants had corrected REs; however, the noncompliance for spectacle use was 20.25%.

Conclusion: This study was the first attempt to investigate the visual status in adolescents in SA. It provided estimations of the REs, amblyopia, and strabismus. The high prevalence of REs emphasizes the need to identify the best proactive strategies to detect and manage REs to reduce the incidence of visual impairment in SA. Increasing awareness about eye health and employing efficient screening programs could help to address the need for REs corrections.

Keywords: amblyopia, myopia, refractive errors, Riyadh, Saudi, strabismus, visual impairment

Introduction

Approximately 2.3 billion people globally have impaired vision due to refractive error (RE).¹ The number of people with visual impairments due to uncorrected RE (URE) was predicted to be 101.2 million in 2010, which was a 15% increase since 1990.² This number is suggested to double by 2020 as a result of avoidable causes, such as URE, cataracts, and vitamin A deficiency, suggesting the urgent need for more efforts to avoid this crisis.³ URE has economic and social implications on the quality of life, with global economic damages estimated at ~\$269 billion per annum because of lost productivity.^{4,5}

The RE has been linked to physiological and environmental factors, such as near work distances and time spent performing outdoor activities.^{6–8} The prevalence of myopia has increased worldwide, reaching levels as high as 80% of the population in some Asian countries.^{9–12} In 2010, a global myopia prevalence of 2 billion people was reported. If these trends continue, 50% of the world population in 2050 will be myopic.¹³

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The worldwide RE prevalence has marked differences across geographical locations, due to racial, age, gender, and ethnic factors. These differences have an influence on the strategies used to manage URE.⁵ Furthermore, RE treatment is a priority in the global initiative for the elimination of avoidable blindness (VISION 2020: The Right to Sight). However, no effective strategy can be implemented without knowing the exact extent of the disorder. Only a few studies have assessed the visual status in Saudi children in the past decades.^{14–17} Moreover, they have included participants only from preschools and primary schools.^{14–17} Population-based studies in adolescents, 12–20 years of age, are important for proactive planning, implementation of suggestions, and monitoring protocols and/or interventions to eliminate avoidable visual impairment in this very productive age group. To the best of our knowledge, this is the first study that aims to investigate the visual status of adolescents in Riyadh, Saudi Arabia (SA).

Methods

Compliance with ethical standards

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Institutional ethical approval was obtained from the Ethics for Scientific Research Committee, King Saud University. Approval was also obtained from the Ministry of Education and the school headmasters. A written informed consent was obtained from all individual participants' parents included in the study, as well as verbal consent from the participants.

Study design and participants

The present study followed a cross-sectional population design. The sample population consisted of students attending elementary and high schools, who were 12–20 years of age.

A structured survey concerning the general and ophthalmic history of the participants and their families was collected. The survey included information about the family's general and ocular history as well as their social characteristics, which included whether the parents are relatives or not, the parents' education, the participant's order in the family, and does any of their sibling have ocular abnormality. Moreover, structured detailed information was collected about the participants' general and ocular history, their lifestyle habits (environmental factors), and the date of the last visit to an eye specialist. However, the environmental factors collected and their impact on the visual status is not presented in this

manuscript; however, it is intended to be reported in the future. Most of these questions were in dichotomous format, where more information is required if the answer was yes.

Sample calculation and identification

The sample size was calculated using the Epi-Info, version 7 (Centers for Disease Control and Prevention, Atlanta, GA, USA; <http://www.cdc.gov/epiinfo/7/>). A multistage cluster sampling method was used, where 20 highly populated schools from different parts of Al-Riyadh city were randomly selected and the classes included were also randomly selected. In details, these criteria were the inputs in the Epi-Info program. The number of students in both intermediate and high schools was ~470,000 (obtained from the Riyadh General Directorate of Education, March 2016). The prevalence of RE was estimated at 10%–25% based on previous studies in this geographical region.¹⁸ The margin of error was set at 5% (95% confidence), the design effect was set at 2, and the clusters equal to 20. The overall minimal sample required was 644 participants. In each school, a designated area was provided by the school where all the tests for all the students were conducted; the team visiting the school made sure that the venue was safe and suitable for the students and that it was a well-lit room.

The assessed measures were as follows: visual acuity (VA), RE, ocular deviation, stereoacuity, contrast sensitivity (CS), strabismus, amblyopia, and correctable visual impairment.

VA measurement

The VA measurements were recorded monocularly at a distance of 4 m using the logarithm of the minimum angle of resolution (logMAR) VA chart (the non-illuminated Early Treatment Diabetic Retinopathy Study chart with Sloan letters [Precision Vision, La Salle, IL, USA]). First, the VA was measured without correction, then with the participants' habitual corrections, if applicable. VA of the right eye was always measured first, followed by VA of the left eye. Testing began with the smallest line that could be seen, and the participant was instructed to read as many letters as possible in the next row. The VA was recorded in terms of the smallest line identified, the scores excluded the letters not identified in the line, or included the number of letters identified in addition to the line.

RE measurement

The RE was measured without a cycloplegic agent using a handheld autorefractor (ARK-30; Nidek, Gamagori, Japan). The ARK-30 automatically started measuring the RE when it

was in the right position according to centering and focusing indicators. The same autorefractor was used for all participants throughout the study. As a proactive measure, if the autorefractor did not provide reliable readings for any reason, a distance retinoscopy was conducted. In addition, retinoscopy was performed in a dark room with the participant sitting comfortably at a convenient working distance for both the participants and the examiners. The working distance power was added as a minus power in the trial frame. The participant was instructed to maintain the fixation at a non-accommodative distant target. However, the retinoscopy procedure was not needed and ARK-30 was performed to all participants.

Pinhole acuity

The pinhole acuity test was used in participants who were unable to reach the 0.00 logMAR line (6/6). We examined the pinhole acuity to indicate for any improvement in acuity and the presence of amblyopia. Once the pinhole was conducted, the outcome of the autorefractor was placed in a trial frame and the VA was monocularly measured in the same procedure stated earlier to document any improvement in VA (correctable visual impairment). For those students who had RE, a letter was sent to the parents to inform them of their child's condition and suggesting a visit to eye care professional for a comprehensive eye exam.

Stereoacuity measurement

The stereoacuity was used to determine the participant's depth perception and ability to fuse stereoscopic targets. We measured stereoacuity using the Randot stereo test, which is a subjective test designed for a quick assessment of the presence and degree of stereopsis. The test consisted of contoured circles at 10 levels of disparity (ranging from 20 to 400 seconds of arc at 40 cm) and provided a finely graded sequence. Within each of the 10 targets were 3 circles. Only one of the circles had crosses disparity and would stand out. The examiner held the test perpendicular to the line of sight at 40 cm in a well-illuminated room with the patient wearing crossed polarized glasses over the correction if habitually used. The participants were asked not to tilt their head. They were then asked which one seemed to float forward or appeared different from the other 2 circles. If one is missed, the examiner tested the preceding line to determine whether the participant could see it or was guessing. The level of stereopsis of the last one accurately identified was noted. The main aim of using the Randot test was to help in indicating the presence of amblyopia. Impaired stereopsis under binocular conditions has been reported to be the most common deficit associated with amblyopia.¹⁹

CS measurement

The monocular CS was measured using the MARS CS test (numerical version; Mars Perceptrix Corporation, Chappaqua, NY, USA). The chart was held at 50 cm and the illumination was set at ~ 85 cd/m². The participants were instructed to read from top to bottom, scoring 0.04 logCS units for each correct letter. The test was stopped if the participant made 2 errors in a row.

Ocular deviation assessment

Ocular deviation was assessed using the cover–uncover test, with the correction, if any, both at 3 m and at 40 cm. The participant was asked to look straight ahead at a letter at 3 m, well above their VA threshold. For near testing, the participant was asked to fixate at a pencil pen. The test started with occluding the left eye for 3 seconds. The observer looked for any correcting movement of the uncovered eye. After testing the right eye, the left eye was tested in a similar manner. If there was no manifest misalignment of either eye, the cover was moved back and forth between both eyes, with 1–2 seconds between movements.

Definitions of variables

The RE was expressed as the spherical equivalent RE (SERE). The RE cut points suggested in the RE survey in children (RESC) protocol was followed. This protocol has been widely used and was also suggested by the World Health Organization.^{20–26} The criteria for each variable are described in Table 1.

Data analysis

The data analysis included 99.1% of the collected data. The data were investigated for a normal distribution using the Kolmogorov–Smirnov test, which showed that the data were not normally distributed ($p < 0.05$). Nonparametric tests were, therefore, used where appropriate. The median and interquartile ranges (IQR) were used to report the participants' visual functions. The Spearman's rank correlation test was used to test for data similarity between right and left eye in all variables.

The SERE, unaided VA, and CS were comparable between the right and left eyes. Spearman's rank correlation coefficient revealed a strong relationship between the scores of the right and the left eye (SERE: $r = 0.80$, $p < 0.0001$; unaided VA: $r = 0.82$, $p < 0.0001$; CS: $r = 0.71$, $p < 0.0001$). The scores of the visual functions that were reported corresponded to the lowest scores of the 2 eyes.

Table 1 Definitions of the criteria used for outcomes cutoff

Variables	Definitions
Myopia	Spherical equivalent refractive error ≤ -0.50 D in one or both eyes
Hyperopia	Spherical equivalent refractive error $\geq +2.00$ D in one or both eyes
Astigmatism	Cylinder power ≥ 0.75 DC if one or both eyes were astigmatic
Emmetropia	When neither eye was myopic or hyperopic.
Unilateral amblyopia	Interocular difference in the best-corrected VA of 2 lines or more on the chart.
Bilateral amblyopia	When the best-corrected binocular VA was abnormal, even after full refractive correction.
Correctable visual impairment	Defined as a reduction of the VA of ≥ 0.30 logMAR (6/12), when VA improvement of 2 or more lines was achieved. ²⁷

Abbreviation: VA, visual acuity.

Results

Of the total 1,007 participants, 9 (0.9%) were excluded for undergoing an eye surgery or because of a previous ocular pathology. In the remaining 998 participants, the age ranged from 12–20 years (median IQR = 16 [3] years). There were 651 females and 337 male participants in the final study.

Background characteristics

In total, 525 participants passed their school exams with excellent grades (53.1%), 446 participants (45.1%) with very good or good grades, and the remaining 18 (1.8%) with passing grades. Furthermore, 17.9% were the first child, 17.9% were the second child, 18.5% were the third child, and 45.6% were greater than the third child. Moreover, 67% of the participants had RE in their family. The fathers of ~26% of the participants had RE; the mothers of 9%, and the siblings of 25% of the participants had RE. Interestingly, first-degree relatives of 42% of the participants had myopia. In terms of the parents' education, the most frequent highest degree obtained by the mothers was high school (48.5%), and that obtained by the fathers was a bachelor's degree (36.5%). However, 53 mothers (5.2%) and 20 fathers (2%) had no school certification.

Visual functions of the participants

The participants' unaided VA was a median of 0.0 and IQR of 0.20 (range, -0.01 logMAR [6/5] to 2.00 logMAR [6/120]), while the aided VA was 0.00 [-0.14] [6/6, 6/5] and ranged from 0.00 (6/6) logMAR to 1.00 logMAR (6/60). Based on the SERE, out of the 998 participants, 55.5% had RE (555 out of 998). The most frequently diagnosed RE was myopia, with 53.3% (533 participants) being myopic (ranged from -0.50 DS to -14.00 DS) and 2.2% (22 participants) being hyperopic ($+2.00$ DS to $+4.75$ DS). It has also been found that 15% (150 participants) were astigmatic (-0.75 DC to -5.25 DC) (Table 2). Of all the 555 RE cases, less than half of them (43.6%) had correcting spectacles (242 participants).

The noncompliance for spectacle use was 20.25% (49 out of the 242 participants). Moreover, the correctable visual impairment (VA ≥ 0.30 logMAR 6/12) was present in 17.8% of the participants.

Strabismus was found in 19 (1.9%) of the participants, and the estimated amblyopia was found in 59 (5.8%) of the participants. Unilateral amblyopia was estimated at 3.9% and was more frequent than the estimated bilateral amblyopia (1.9%). Stereopsis was also tested and the depths perceived ranged from 0 to 200 seconds of arc (median: 32; IQR: 30). The CS of each eye was also among the tests that were performed with a median of 1.6 log; IQR: 0.04 (range, 0.12–1.84 log).

Finally, out of the 998 participants, 450 (45.1%) had never visited an optometrist; 295 (29.56%) had not tested their vision for >1 year before the study. The parents of the majority of the participants who had never undergone a visual examination either had no formal education or had high school certificates (63.55%).

Discussion

The prevalence of RE in school-age children was investigated in several parts of the world.^{9,11,18,28–33} The majority of these studies have used the RESC protocol, which involved cycloplegia. It has been suggested previously that auto-refractors without cycloplegia have at least 0.50 D myopic shift. Not using cycloplegia could be a limitation of the current study. However, we were not able to incorporate the cycloplegia in our protocol due to the limited resources available and due to

Table 2 Types, frequencies, and severities of the RE of the participants

RE	Mild (RE ≤ 3 D)	Moderate (3 D < RE ≤ 6 D)	High (RE > 6 D)
Myopia	422 (47.90%)	98 (9.8%)	13 (1.3%)
Hyperopia	14 (1.40%)	7 (0.7%)	0
Astigmatism	143 (14.3%)	7 (0.70%)	0

Abbreviations: D, diopters; RE, refractive error.

our expectation that our request would be faced with consent refusal from the vast majority of the parents. This might be because the parents believe that such a procedure would harm their child's eyes. Attempts have been made previously to conduct a cycloplegic RE screening; however, the vast majority of the parents did not approve such a procedure (personal communication). However, the parents might consent for the use of cycloplegia on their children but under the condition of conducting the screening in a hospital which they think is more of a controlled environment. We did not have transportation facility to take the students to a hospital and did not have access to a hospital facility. In this study, we have tried to extend the examination of visual status in residents of SA to cover a wide range of school students; therefore, we needed to conduct this study to provide estimations of the RE prevalence as its magnitude was not previously known. Moreover, although this study did not typically conform with the RESC protocol (specifically, cycloplegia and comprehensive eye exam), it followed their classification of the RE to facilitate comparison with previous and future studies.

URE is the leading cause of visual impairment and the second leading cause of blindness worldwide is associated with unemployment and decreased quality of life.^{2,34} In SA, RE is the leading cause of visual impairment (36%),³⁵ a condition that can be easily treated and managed. In this study, correctable visual impairment was highly prevalent, and was observed in 17.8% of the participants.

About half of the participants had RE, with most of these participants having myopia. About two-thirds of the participants' relatives had RE, 42% were myopic, which may have accounted for the high prevalence of RE and myopia. Moreover, half of the participants with RE were corrected with spectacles, almost 20% of them did not wear their spectacles.

The prevalence of myopia increases with age,^{10,11,36,37} which also was found in SA where preschool myopia was found in only 2.5% of the participants.¹⁷ Our current study revealed a myopia prevalence of 53.3% in adolescents. This suggests that myopia increased from preschool to adolescence, which was consistent with the findings of previous reports.^{10,11,36,37}

In this study, the myopia was the leading type of RE (53.3%), and exceeded the prevalence reported in the Caucasian population in the USA (33%–40%), Australia (17.7%), Norway (30%), and Swedish schoolchildren (49.5%).^{9,28–31} Furthermore, our results were lower than those observed in Chinese adolescents (54%), Taiwanese schoolchildren (87%), and Australians of East Asian ethnicity (59%).^{11,29,32} Our results were also similar to those found in Sudan, but higher than those reported in Jordan (17%), Turkey (3.2%),

Ethiopia (7.7%–10.2%), Iran (14.90%–29.3%), Tunisia (9.1%), Morocco (6.1%), and Egypt (12%).^{18,33,38–45} The variations in myopia prevalence between the current study and previous reports could be the result of several factors, such as genetics, lifestyle (indoor and outdoor activities), and environmental factors.^{46–50}

In the present study, the percentage of parents who had RE was high (40%). It has been reported that genetic and other environmental factors were associated with the myopia development and progression.^{50–53} Moreover, genetic factors combined with specific environmental factors influenced school myopia.^{8,54} A 24-year longitudinal study was conducted on juvenile-onset myopia of 43 pedigrees to assess the relationship of infantile RE and parental history with juvenile-onset myopia.⁴⁸ They reported that children with 2 myopic parents had a very high risk of myopia (6.42 times) compared with the children with 1 or no myopic parents.⁴⁸

The noncompliance that has been found in this study (20%) was also similar to those found in previous reports from different parts of the world, including SA.^{32,55,56} These studies showed that 20%–40% of the participants often did not wear spectacles or were not wearing spectacles with the optimum RE correction. Furthermore, it has been suggested that the constant use of spectacles could improve educational outcomes,⁵⁷ which leads to a significant increase in vision-related quality of life.⁵⁸ Not using corrective spectacles may result from cultural disincentives and esthetic concerns.^{59,60} Therefore, exploring different approaches to increase spectacle use, such as providing free spectacles, educating students/parents about the importance of wearing spectacles, and prescribing contact lenses, after assessing the participants' ocular health and hygiene, is strongly suggested.

In this study, the estimated prevalence of amblyopia was 5.8%, which is consistent with the findings of some previous studies conducted in Saudi and other parts of the world^{15,61} but higher than other studies at both the Middle East and the world.^{14,17,39,42,62–64} These discrepant results may have resulted from differences in the study population (age group) and the definition used for amblyopia. Furthermore, the targeted age group in the previous studies from SA varied significantly, and none of these studies specifically addressed adolescents. In addition, it has been suggested that prevalence of amblyopia is significantly higher in older age groups.^{62,65} Finally, it should be acknowledged that the comprehensive eye exam was not performed in this study, and therefore, may have overestimated the prevalence of amblyopia. On the other hand, we obtained an estimated baseline for the adolescent group in SA that was not available previously. The prevalence of strabismus (1.9%) was

similar to a previous report at the local level (although in different age ranges)¹⁵ but was also higher^{14,17,39,42} and lower^{18,38,62–64} than other studies at both local and international levels. Approximately one-fifth of our participants had correctable visual impairment (due to URE), which was consistent with previous findings.^{16,27,66,67} However, our findings were higher than those reported in European Caucasian children in Australia.⁶⁸ This discrepancy may be due to the wider age groups of children in the higher prevalence studies, in addition to differing prevalences of myopia and astigmatism with differences in ethnicities and the efficiencies of different health programs.

Approximately 45% of the participants in the present study never had an optometric evaluation, while the majority of their parents had a high school certificate or were uneducated, raising concerns about their visual health, and suggesting that school vision programs should be established to support healthy children.

Conclusion

This study showed a high RE prevalence as well as high URE. Prevalence estimate of the different types of RE has provided for the first time in Riyadh, SA. This showed that myopia was the most prevalent REs in adolescents. It showed a reasonably high prevalence of the correctable visual impairment. These findings could raise concerns about the health service coverage, the participants' education performance, and quality of life. Moreover, future studies are required to assess the effect of outdoor/sports activities in SA, because the climate is very dry and harsh. In addition, it will be of interest to know the effects of high-intensity sunlight and a lack of humidity on RE and myopia, especially for people living in a desert environment.

Acknowledgments

The authors extend their appreciation to the College of Applied Medical Sciences Research Centre and the Deanship of Scientific Research at King Saud University for funding this research.

Disclosure

The authors report no conflicts of interest in this work.

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