ANDES PEDIATRICA
REVISTA CHILENA DE PEDIATRÍA

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Andes pediatr. 2021;92(6):896-903
DOI: 10.32641/andespediatr.v92i6.3527

ORIGINAL ARTICLE

Myopia and Myopic Astigmatism in school-children

Miopía y Astigmatismo miópico en escolares

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Received: November 25, 2020; Approved: Jun 15, 2021

What do we know about the subject matter of this study?

There is an epidemic increase in myopia worldwide. In children, the evidence points to the lack of exposure to natural light. In Chile, the situation of myopia in the pediatric population is unknown.

What does this study contribute to what is already known?

Myopia trend in Chilean schoolchildren is on the rise. This evidence adds to the recommendations of nutritional and psychomotor health that children increase time spent outdoors in order to enhance their growth and development.

Abstract

Worldwide, there is an epidemic increase in myopia. In children, the evidence points to a lack of exposure to natural light. In Chile, the population situation of myopia in children is unknown. **Objective:** To estimate the tendency of myopia and myopic astigmatism in 1st- and 6th-grade students from the public education system in Chile. **Subjects and Method**: Ecological study based on diagnostic confirmations of the JUNAEB Medical Services Program, between 2012 and 2018. Annual country prevalence of myopia and astigmatism was estimated by region and sex. The screening evaluation included visual acuity using Snellen Eye Abbreviated chart, red reflex, Hirschberg test, Titmus test, Cover test, ocular motility, and anterior segment examination. Chi2 and logistic regression were used to assess differences and linear regression to estimate average annual change. **Results**: Between 2012 and 2018, myopia and myopic astigmatism had a heterogeneous geographical presentation. Myopia and myopic astigmatism ≥ 3 dioptres increased by an annual average of 0.11% (R2 0.67) and 1.21% (R2 0.90), respectively, in 1st-grade children and by 0.2% (R2 0.65) and 8.7% (R2 0.79), respectively, in 6th-grade children. Myopia < 3 dioptres decreased by 0.13% annual average (R2 0.45) in 1st-grade children and myopic astigmatism < 3 dioptres by 0.5% (R2 0.53) in 6th-grade children.

Keywords:
Myopia;
Astigmatism;
Refractive Errors;
Child Development

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How to cite this article: Andes pediatr. 2021;92(6):896-903. DOI: 10.32641/andespediatr.v92i6.3527

High myopic astigmatism affected men more than women and myopia < 3 dioptres affected more 6th-grade females. **Discussion**: In schoolchildren of the public education system, myopia and myopic astigmatism ≥ 3 dioptres tend to increase. The protective effect of natural light against myopia has been demonstrated in longitudinal and experimental studies. This evidence is to be considered in promoting children's time spent outdoors.

Introduction

Visual acuity is the finest measure that a visual system can give resolution to[1]. Multiple factors can reduce it, including refractive errors such as astigmatism, hyperopia, or myopia. In the case of astigmatism, an irregular curvature of the cornea causes a distorted perception of objects. Most of the time people are born with this condition and the likelihood of developing astigmatism is usually hereditary[2]. Hyperopia is an inherited defect of the eye that causes blurred near vision, whose early detection and intervention can promote its disappearance in adolescence[3]. Myopia is a refractive error due to an alteration of the cornea, the crystalline lens, or the axial length of the eyeball, which causes blurred vision at a distance. It has a hereditary factor and is also associated with individual habits and environmental factors that influence its occurrence[4].

Worldwide, myopia is increasingly prevalent[4,5], with some areas of East Asia reaching epidemic levels, with a prevalence of up to 80-90% in young people finishing their school years[5-9]. This trend has also been described in Australia, Europe, and the United States, among others, both in schoolchildren[10,11] and adults[12,13].

The high rate of increase in the prevalence of myopia cannot be explained by genetic factors alone, so the focus has shifted to the potential role of environmental factors involved in this change[6,14], such as those associated with indoor activities, including homework, study hours, and exposure to device screens such as cell phones, tablets, or computers[11,15,16]. Outdoor activities, which may or may not imply physical activity, provide the eye with natural light, acting as a protective factor against the onset of myopia[11,15,17,18].

Exposure to natural light, such as two to three hours outdoors per day in addition to school time, would have protective effect against myopia[6,18-21], including children with both myopic biological parents[22]. The physiological mechanism behind the benefit of natural light on the eye is still unknown, although it has been postulated that ultraviolet (UV) light exposure may play a role in myopia, as it may enhance the positive regulation of the myopia suppressive gene EGR1[23,24].

In Chile, there is little evidence on the type of anomalies that cause visual impairment[25,26]. A study on the prevalence of visual limitation in schoolchildren from two municipalities of the country (FONIS 2012 SA 12/2223) concluded that, despite an increase in refractive errors during the last 15 years, the prevalence of visual impairment in schoolchildren has not significantly increased. This could be explained by the wide coverage and continuity of the annual program of Medical Services of the National Board for Student Aid and Scholarships (JUNAEB)[25,27], which performs visual, hearing, and spinal health screening of school children attending the public education network. JUNAEB's ophthalmologic evaluation focuses on preschoolers and students in 1st and 6th grade[28]. In the last two, visual acuity can be assessed with an eye chart with letters as recommended[1].

Analyzing the trend of myopia and myopic astigmatism in schoolchildren from public schools that benefit from the state school health program serves as an initial approach to understanding the situation of myopia in Chilean children and as a guide for posing new research questions and testing hypotheses. The objective of this work was to estimate the trend of myopia and myopic astigmatism in 1st and 6th grade schoolchildren from attending the public education system in Chile between 2012 and 2018.

Subjects and Method

Ecological study based on JUNAEB Medical Services Program data of ophthalmological diagnosis confirmation of 1st and 6th grade schoolchildren attending public schools between 2012-2018. The screening evaluation included visual acuity using the Snellen E Abbreviated chart, the red reflex test, the Hirschberg test, Titmus test, Cover test, ocular motility, and anterior segment eye examination[28]. The ophthalmologic diagnosis confirmation data were obtained by transparency law (AJ009T0001329) and consolidated in a single file, in which the nomination of variables and their categories were standardized.

The diagnosis confirmation variable was defined as free text, with more than one diagnosis per subject. Text analysis was performed using Python programming language. Diagnosis confirmations were read and analyzed using the NLTK libraries for text preprocessing, and RE to implement regular expressions. Text preprocessing consisted of removing capitalization and accents. Each type of diagnosis was identified using a function designed by the researchers that provided variability in the way the diagnosis was written. In total, 15 functions were created to extract JUNAEB's preset diagnoses, that is to say: healthy, mixed astigmatism less than 3 diopters (dp), mixed astigmatism greater than 3 dp, myopic astigmatism less than 3 dp, myopic astigmatism greater than 3 dp, hyperopic astigmatism less than 5 dp, hyperopic astigmatism greater than 5 dp, myopia less than 3 dp, myopia greater than 3 dp, hyperopia less than 5 dp, hyperopia greater than 5 dp, strabismus, amblyopia, convergence insufficiency, and anisometropia. Due to blank rows, 0.6% of the data was removed in the text analysis process.

The diopter is the unit of lens refraction whose focal length is one meter. This measurement indicates the power required by a lens to adjust an out-of-focus image in the correct area of the eye (refraction). Diopters are measured on a scale of 0.25 in 0.25 and the graduation can be positive, as in the case of hyperopia which requires converging lenses, or negative, as in the case of myopia which requires diverging lenses. The cut-off points for the different diagnoses are based on the probability of causing amblyopia: 3 diopters for the diagnoses of mixed astigmatism, myopic astigmatism, and myopia; and 5 diopters for the diagnoses of hyperopic astigmatism and hyperopia[29].

To ensure a greater number of observations in the study period, we estimated the prevalence of myopia and myopic astigmatism among schoolchildren referred for diagnosis confirmation in 1st and 6th grade separately, since children who attended first grade in 2012 attended 6th grade in 2017. Annual differences in the prevalence of myopia and myopic astigmatism were assessed at the country level using the Chi-square test; regional level and sex stratification estimations were made with use of logistic regression; average annual change was estimated using linear regression. Analyses were performed with STATA IC v14.0.

Results

Between 2012 and 2018, 168,290 ophthalmological evaluations were recorded from 5,377 schools. Of these, 58,046 corresponded to 1st grade and 57,552 to 6th grade schoolchildren respectively.

1. First grade

a. Myopia: affected 5.6% of schoolchildren, distributed equally between males and females (p 0.741), with heterogeneous presentation throughout the country. In the case of myopia < 3 dp, it affected 4.3% of schoolchildren, with heterogeneous geographic distribution by regions of the country, with a minimum of 1.2% in Aysén and a maximum of 9.7% in Antofagasta, with no differences by sex (OR 0.98; p 0.798), and with an annual trend decreasing by 0.13% on average (R^2 0.45 and R^2-adjusted 0.34) (figure 1). On the other hand, myopia ≥ 3 dp affected 1.4% of schoolchildren, with heterogeneous regional distribution, with a minimum of 0.3% in Atacama and a maximum of 4.1% in Antofagasta, with no differences by sex (OR 0.99; p 0.849), and with an annual trend increasing by 0.11% on average (R^2 0.67) (Figure 1).

b. Myopic astigmatism: affected 33% of schoolchildren, equally distributed between males and females (chi^2 p 0.578), with heterogeneous presentation throughout the country. Myopic astigmatism < 3 dp affected 20.1% of schoolchildren. At regional level, its presentation was heterogeneous, with a minimum of 7.9% in Atacama and a maximum of 26% in El Maule, without differences by sex (OR 0.97; p 0.173), and with an annual trend decreasing by 0.23% on average (R^2 0.29) (Figure 1). Myopic astigmatism ≥ 3 dp affected 13.3% of schoolchildren, its regional presentation was heterogeneous, with a minimum of 3.5% in Atacama and a maximum of 34.8% in Antofagasta, and with an annual trend increasing by 1.21% on average (R^2 0.90) (Figure 1) and with 0.6% greater chance of occurrence in males (OR 1.06; p 0.015).

2. Sixth grade

a. Myopia: affected 18.1% of schoolchildren, 17.1% males and 18.9% females (chi^2 p <0.0001), with heterogeneous presentation throughout the country. In the case of myopia < 3 dp, it affected 15.2% of schoolchildren. At regional level, its distribution was heterogeneous, with a minimum of 6.2% in Atacama and a maximum of 30.2% in Antofagasta, and with an annual trend decreasing by 0.5% on average (R^2 0.53) (Figure 2), and with 19.6% greater chance of occurrence in females (OR 0.86; p <0.0001). Myopia ≥ 3 dp affected 3% of schoolchildren. At regional level, its presentation was heterogeneous, with a minimum of 1.8% in Atacama and a maximum of 8.4% in Antofagasta, without differences by sex (OR 0.99; p 0.868), and with an annual trend increasing by 0.2% on average (R^2 0.65) (Figure 2).

b. Myopic astigmatism: it affected 38.1% of schoolchildren, 38.8% males and 37.6% females (chi^2 p 0.005), with heterogeneous presentation throughout the country. Myopic astigmatism < 3 dp affected 26.6% of schoolchildren. At regional level, its presentation was heterogeneous with a minimum of 13.1% in Antofagasta and a maximum of 36.5% in Coquimbo, followed by Maule with 36.4%, without differences by sex (OR 0.97; p 0.173), and with an oscillating annual behavior (R^2 0.03) (figure 2). Myopic astigmatism ≥ 3 dp affected 11.7% of schoolchildren. At regional level, its presentation was heterogeneous, with a minimum of 7.7% in Coquimbo and a maximum of 28.6% in Antofagasta, with an annual trend increasing by 8.7% on average (R^2 0.79) (Figure 2), and with 33% greater chance of occurrence in males (OR 1.33; p< 0.0001).

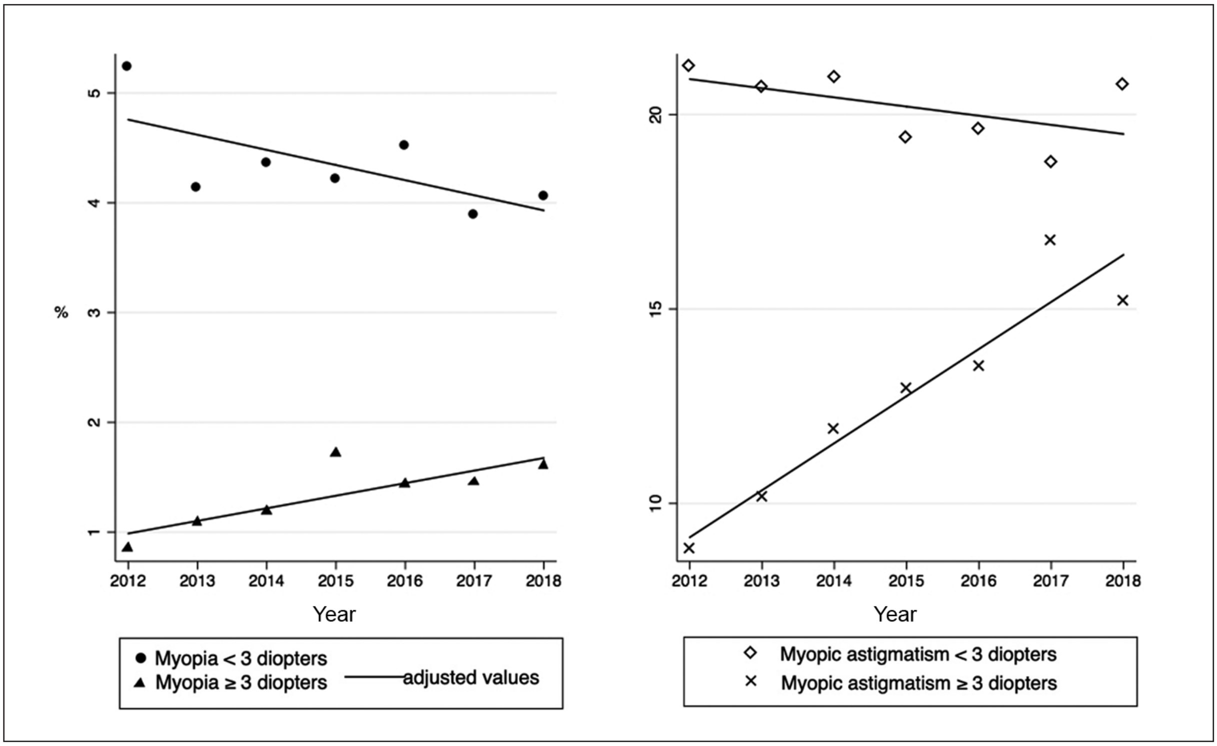

Figure 1. Annual prevalence of myopia and myopic astigmatism less and more than three diopters in 1st grade schoolchildren referred for diagnosis confirmation within JUANEB Medical Services Program 2012-2018.

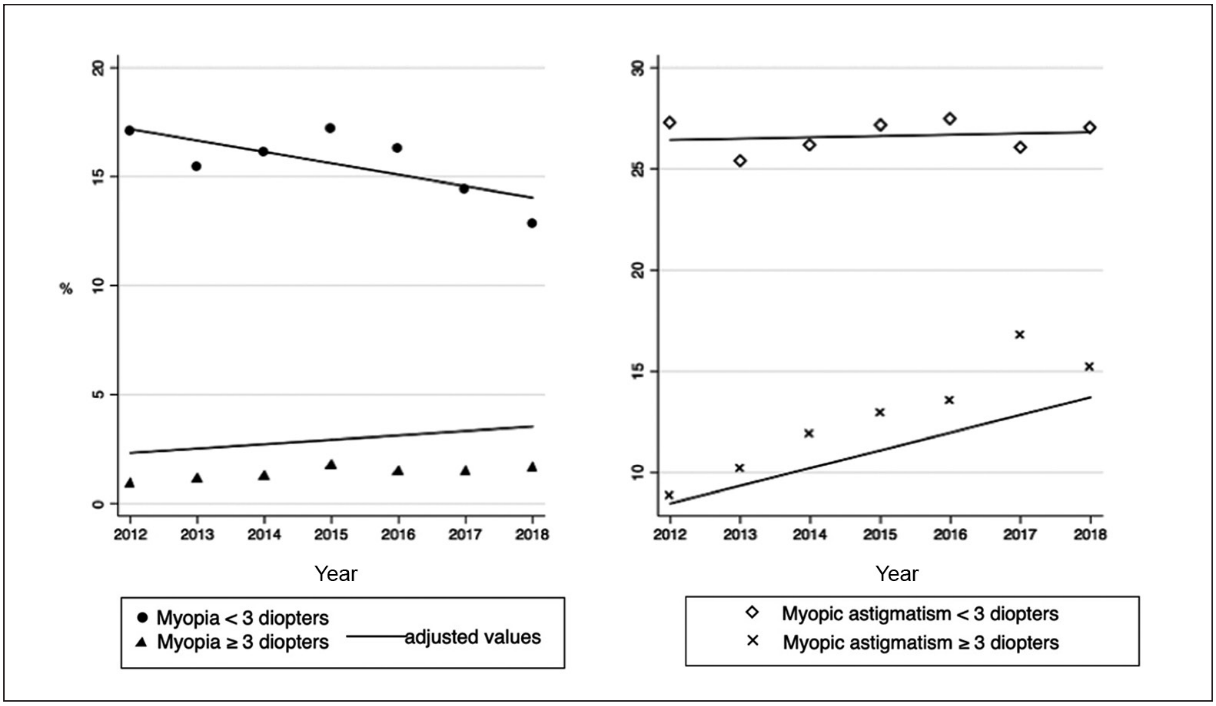

Figure 2. Annual prevalence of myopia and myopic astigmatism less and more than three diopters in 6th grade schoolchildren referred for diagnosis confirmation within JUANEB Medical Services Program 2012-2018.

Discussion

Monitoring visual health is essential for the development of public policies that seek to prevent and eliminate avoidable causes of visual impairment. Although the challenge of unraveling the mechanism by which natural light prevents the onset of myopia remains unclear, its protective effect on visual health has been demonstrated in longitudinal and experimental studies[10,17,30-34]. In 1932, Arnold Sorsby postulated that it is unlikely the problem of myopia be solved without intensive study in its breeding ground, the schools[35].

Genetic factors alone cannot explain the rapid increase of myopia prevalence, thus the focus has shifted to environmental factors involved in this change[6,11,14-16]. If intense educational systems and modern lifestyles that imply less time spent outdoors continues, by 2050 half of the world's population will suffer from myopia and 10% will have high myopia, which doubles and quintuples, respectively, what was reported in 2000[36].

In children, chances of having myopia due to living in an urban area is 2.6 times that of children from rural areas[9]. Outdoor activities –that may or may not imply physical activity– provide the eye with natural light that acts as a protective factor against the onset of myopia[11,15,17-21]. Two to three hours of daily exposure to natural light in addition to school time would have a protective effect against myopia[6], suggesting that exposure to ultraviolet light would have a role in the positive regulation of the myopia suppressive gene EGR1[23], although not yet confirmed by other studies[37,38]. On the other hand, a negative correlation has been described between the vitamin D levels and the degree of myopia, which would not be a causal relationship but the parallel effect of exposure to light that prevents the development of myopia and stimulates the production of vitamin D[39]. Although blue light from electronic devices affects visual health[40], these conditions would not be associated with increased myopia[16].

Our results show that high myopia and myopic astigmatism, equal to or greater than three diopters, have increased between 2012 and 2018 in 1st and 6th grade children who attend public schools in Chile, with heterogeneous distribution by region of the country. Increased chances of myopic astigmatism $\geq$ 3 dp occurrence was observed in males in both 1st and 6th grade, while chances of myopia $<$ 3 dp occurrence were greater 1st grade females. What is the basis for the sex differences observed in myopia when there is not physiological explanation to it? The evidence on sex differences in visual perception is heterogeneous, which suggests that there is more than one cause behind them[41]. To identify causes of sex differences in refractive errors in Chilean schoolchildren seems of great importance.

From a geographical perspective, north to south –considering the naturally available light according to latitude–, neither myopia nor myopic astigmatism show correlation or clustering by region. Antofagasta is the most affected region by myopia and myopic astigmatism while neighboring Atacama presents one of the lowest values. What makes Chile regions different from one another regarding visual acuity problems in children constitutes an evidence gap which is essential to fulfill for visual health policy decision-making.

Our study has limitations associated with the use of secondary information collected for other purposes. Although JUNAEB has been carrying out school health screening for decades, it is possible that from time to time it implements modifications in the screening routine that influence the number of observations. However, as these changes become stable with time, so do the observations. Data older than 2012 would have allowed exploring the situation of school visual health from times when technological devices either did not exist or were not massive, and from times previous to the full school day program implementation. However, and following the provisions of point No. 3 of Circular No. 28704 of August 27, 1981, of the Comptroller General of the Republic, JUNAEB does not file documentation whose date of issue is more than five years.

In the context of a myopia epidemic in countries with intensive educational systems, to prevent visual acuity decrease through exposure to natural light is essential, especially through activities that involve free play and movement that can also promote cardiovascular health, psychomotor, and social development of children. Such preventive actions require efforts from the health and education sectors, and also political will and governmental resources and funding that can guarantee healthy choices are the ones easy to make, choices such as going to the park to play or accessing an educational system that ensures the promotion of a comprehensive child development.

While in other parts of the world there is an epidemic of myopia, knowing that in Chile the trend of high myopia and high myopic astigmatism in schoolchildren is increasing, allows for new questions to rise about children visual health and the socio-environmental factors that could possibly determine this trend. While it is on every one of us to find answers to these questions, in the meantime, we do have the opportunity to act on visual acuity promotion based on the best available evidence.

Conclusions

In Chile, myopia and myopic astigmatism $\geq$ 3 diopters show an increasing trend among schoolchildren attending the public education system who are beneficiaries of JUNAEB Medical Services Program. Myopia geographical presentation is heterogeneous. Stratification by sex shows increased chances of high myopic astigmatism occurrence in males. Our results on the increase of myopia are consistent with the international myopia scenario. Along with the evidence from longitudinal and experimental studies on the protective effect of natural light, our results should add to the nutritional and psychomotor health efforts to increase outdoor activity time for children and adolescents for their better development and growth, and thus contribute in preventing cases of myopia by exposure to natural light. Our results raise new questions about visual health of Chilean children, for instance, regarding factors that could play a role in the distribution of myopia in children in Chile by socioeconomic status or physical activity.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors declare that the information was obtained from previous data on an anonymized basis. This study has been approved by the corresponding Research Ethics Committee.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

This study did not receive funding. Jocelyn Dunstan is supported by ACE210010, AFB170001, and FB21005 Basal Funds for Center of Excellence from ANID-Chile and FONDECYT 11201250.

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