ABSTRACT

Dissertation submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D110200 – Public Health

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"Prevention and Early Detection of Refractive Errors in School-Aged Children"

Relevance of the Research Topic

Refractive errors remain the leading cause of visual impairment in children and adolescents worldwide (Fricke et al., 2018). Among them, myopia is the most prevalent type and, in its severe form, is the primary cause of visual blindness in children. High myopia is significantly more likely (by 10 to 40 times) to lead to sight-threatening complications such as early cataract, glaucoma, retinal detachment, and myopic macular degeneration, among others, which in turn may result in irreversible vision loss (Flitcroft D.I., 2012). According to Rudnicka et al. (2016), as of 2015, the global prevalence of myopia in individuals under the age of 19 was estimated at 12.5%, which corresponds to approximately 312 million children. However, in recent years, the prevalence has increased dramatically. In some highly developed urban areas of East and Southeast Asia, including South Korea and China, the prevalence of myopia among school-aged children has already reached 80%, with high myopia occurring in 10–20% of cases (Ohno-Matsui et al., 2016).

In Kazakhstan, the rate of vision impairment among schoolchildren was 7.4% according to preventive medical examinations conducted in 2002. In a 2006 study of schoolchildren in the Almaty region, decreased visual acuity was detected in 13.9% of cases, and in 39% of these, the cause was identified as myopia (Aubakirova, 2006). According to official statistics, the share of myopia in the overall structure of ocular diseases in the Republic in 2012 was reported to be 20–25%. However, data from active medical screenings indicate that the actual prevalence of myopia is approximately 3.5 times higher than official figures (Botabekova, 2013).

The critical period for the onset and progression of myopia in children is recognized as the school years, with the most rapid development occurring between the ages of 8 and 15 (Low, 2010). Early detection and regular ophthalmological monitoring play a decisive role in preventing and controlling the progression of myopia in childhood and adolescence. A promising approach in this context is the implementation of remote computer-based screening programs within schools.

Research aim: To develop a comprehensive program for the prevention and early detection of refractive errors in school-aged children.

Research objectives:

1. To assess the prevalence and structure of refractive errors among students of gymnasium and general education schools in Almaty.

2. To identify the risk factors contributing to the development of myopia in school-aged children in Almaty.

3. To evaluate the effectiveness of remote computer-based screening in detecting refractive errors among schoolchildren in Almaty.

4. To develop and pilot a phased intervention program for the early detection, prevention, and control of refractive error progression in school-aged children..

Research methods

A combination of various methods and research designs was used to address the specific objectives of the dissertation. At the first stage, a theoretical analysis of both domestic and international scientific literature on refractive errors was conducted. The second stage was implemented as an observational cross-sectional study, which enabled the assessment of the prevalence and structure of refractive errors among schoolchildren and the identification of key risk factors for the development of myopia. At the stage of evaluating the effectiveness of remote computer-based screening and the implementation of a Program for the Prevention and Early Detection of Refractive Errors in School-Aged Children, the research employed elements of an experimental (crossover) design, without randomization or blinding. The following methods were used throughout the study:

- Bibliographic and theoretical analysis of relevant literature;
- Clinical methods (ophthalmologic examination, visual acuity testing, refractometry);
- Sociological methods (questionnaire development and surveys);
- Statistical data analysis, including regression models.

Statistical processing of the data was conducted using MS Excel and NCSS software (NCSS, Utah, USA). The study was approved by the Local Ethics Committee of Kazakh National University (IRB-A064).

Object of the study: School-aged children — students of grades 1, 5, and 9 of secondary schools in Almaty.

Subject of the study: Epidemiological indicators and risk factors for the development of refractive errors, as well as measures for early detection and prevention of progression.

Main Provisions Submitted for Defense:

The prevalence of refractive errors among schoolchildren in Almaty is relatively high, reaching 31.6%. Myopia is the most prevalent type of refractive error among school-aged children. Its prevalence varies with age and educational level (grade).

Behavioral factors, such as outdoor activity and regular sports, are associated with a reduced risk of developing myopia in children.

Remote computer-based screening demonstrated high effectiveness, comparable to standard ophthalmologic examinations.

A comprehensive program has been developed to prevent the onset and progression of refractive errors in schoolchildren.

Research results

1. The overall prevalence of refractive errors in the school sample from Almaty was 31.6%. Among refractive errors, myopia accounted for 89.4%, hyperopia 10.6%, and astigmatism 8.8%. The general prevalence of myopia in the

studied population was 28.3%, which is comparable to prevalence rates reported in several other countries.

2. A statistically significant correlation was found between the prevalence of myopia and both student age and education level (ranging from 17.6% in lower grades to 40.5% in higher grades). The only reliable predictor of myopia development was the grade level: compared to first-grade students, the risk of developing myopia increased 1.78 times in fifth-grade students and 3.34 times in ninth-grade students.

3. Two behavioral factors were identified as statistically significant protective factors against myopia development in schoolchildren: time spent outdoors (OR 0.61; 95% CI: 0.43–0.86) and physical activity (OR 0.71; 95% CI: 0.54–0.94).

4. The study confirmed the effectiveness of a remote computer-based vision screening program as an alternative method for assessing refractive errors in schoolchildren. The method demonstrated a sensitivity of 96.9% and a specificity of 96.1%, while the average time per child was reduced by almost fivefold compared to routine ophthalmologic examinations.

5. The effectiveness of the developed prevention program aimed at early detection and control of the development and progression of refractive errors in school-aged children was demonstrated.

The scientific novelty

For the first time, the prevalence and pattern of refractive errors among schoolchildren in Almaty have been studied. A comparative analysis was carried out across three age groups and schools with varying levels of academic load.

A comprehensive analysis of behavioral and social risk factors for the development of myopia among schoolchildren in Almaty was also conducted for the first time, using specially designed questionnaires for parents.

The effectiveness of school-based remote computer screening for the early detection of refractive disorders was assessed.

A preventive program aimed at reducing the development and progression of refractive disorders among middle school students in Almaty was developed and piloted.

Theoretical Significance

The results of the study expand the existing body of scientific knowledge on the prevalence of refractive errors, particularly myopia, among schoolchildren in Almaty. The findings provide a baseline for future comparative studies on the dynamics of childhood and adolescent myopia. The study clarifies the role of specific behavioral and social factors in the development of myopia among schoolchildren and contributes to a deeper understanding of the mechanisms underlying refractive errors in this age group. The outcomes of the research can be applied in the development of regional programs for the prevention of visual impairment in children, the organization of educational campaigns for schoolchildren, parents, and teachers, and the planning of medical monitoring systems in educational institutions.

Practical Significance

The practical significance of the study lies in the potential for widespread implementation of remote computer-based vision screening in secondary schools as an alternative to traditional ophthalmological examinations. The further introduction of school-based computer screening programs, particularly in remote and rural areas, could address the shortage of ophthalmological personnel and help reduce the burden on the healthcare system. The developed step-by-step program for the prevention and early detection of refractive errors in school-aged children offers a more effective approach to identifying students with reduced visual acuity at an early stage, recommending timely interventions to prevent progression, and monitoring the dynamics of visual health over time. The program can also serve as a basis for the development of methodological guidelines for healthcare practitioners, the creation of mandatory and elective courses for students of higher medical and pedagogical educational institutions, and the development of clinical protocols for the diagnosis and management of refractive errors in children.

Implementation of Research Results into Practice

The remote computer-based screening program was implemented in schools No. 95, No. 8, No. 25, No. 36, No. 46, No. 120, No. 136, and the Specialized School for Children with Disabilities in Almaty.

A certificate of entry into the State Register of Rights to Objects Protected by Copyright (No. 414, dated November 5, 2018) was obtained for the "Program for the Prevention of the Development and Progression of Refractive Anomalies in Schoolchildren (Stage-by-Stage)".

The developed student vision screening card was introduced into practice at the Vision Protection Office based in Polyclinic No. 31 in Almaty.

The personal contribution of the doctoral candidate

The dissertation candidate personally participated in all stages of the research process, including the planning of the study, preparation of regulatory documentation, development of statistical accounting forms, and the collection and processing of data. In collaboration with scientific advisors, the candidate helped define the research goals and objectives, conducted statistical analysis of the obtained data, and developed practical recommendations based on the study findings. The candidate independently reviewed and analyzed over 240 domestic and international scientific sources on the research topic, interpreted the collected data, prepared reports, published results in national and international scientific journals, and wrote all sections of the dissertation.

Approbation of the dissertation results

The main findings and results of the study were presented through oral and poster presentations, as well as published works, at the following international conferences:

1. X International Conference of Ophthalmologists "East–West – 2019" (Ufa, Russia, 2019);

2. International Scientific and Practical Conference: "The Internationalization of Continuing Medical Education. Prospection" (Aktobe, Kazakhstan, May 25, 2019);

3. Scientific and Practical Conference with International Participation "Modern Ophthalmology: Integration of Science and Practice" (Almaty, Kazakhstan, October 12–13, 2018).

Published works based on the dissertation research

A total of 10 publications related to the dissertation topic have been produced, including: 1 article published in a peer-reviewed journal indexed in the international Scopus database; 3 articles published in journals recommended by the Committee for Control in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

The structure and volume of the dissertation

The dissertation comprises 114 pages of computer-typed text prepared in Microsoft Word, using font size 14. It consists of: an introduction, a review of the literature, the main part (materials and methods, results of the author's own research), a conclusion, findings, practical recommendations, 30 tables and 14 figures, a list of references including 245 sources, and 6 appendices.