SOFIA UNIVERSITY "ST. KLIMENT OHRIDSKI"

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VISION SCREENING IN SCHOOL-AGE CHILDREN

Scientific specialty: Optometry

ABSTRACT

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The Phd thesis contains 124 pages, 14 tables, 22 figures and 115 cited sources, presented in 6 Chapters corresponding to the tasks set.

PURPOSE AND OBJECTIVES OF THE PHD THESIS

The aim of the current PhD thesis is based on initiated childhood vision screenings:

• To ensure timely detection and prevention of visual disorders in children of school age in Bulgaria.

• To propose solutions to some of the problems identified.

The formulation of the PhD thesis tasks is as follows:

1. To review the specifics of the child's vision development and the needs for screenings and prevention in school-aged children.

2. To develop an adapted methodology for children's vision screening, tailored to existing and potential specific needs, as well as resource possibilities.

3. To develop a methodology for improving the practical training of specialists for conducting school vision screenings.

4. To analyze the results obtained for prevalence of myopia, risk factors for myopia and health coverage in school-age children.

5. To analyze results for the unusual prevalence of visual impairments detected in school screening.

6. To present a concept for building an info-structure for knowledge management in the children's vision health care system.

RELEVANCE OF THE DISSERTATION TOPIC

The primary goal of pediatric vision screening is to detect children with previously unidentified vision disorders so that early therapy can be administered. According to the recommendations of the World Health Organization (WHO) [1] screening programs should include effective, inexpensive and reliable tests to detect conditions that can lead to serious health problems. The problem with the increasing prevalence of myopia, found in a number of regions of the world recently, is particularly relevant. The review of the literature shows that for Bulgaria there is not enough data on the prevalence of visual disorders in school-age children [2-6]. Also, no publications were found with proposed methods for children's vision screening in Bulgaria. There is a shortage of specialists in primary health care for children's vision, as well as problems in sharing and using data and knowledge in the field.

Chapter 1: Children's Visual System: Development, Disorders, Screenings

The literature review made in Chapter 1 of the dissertation shows that in the process of development of the visual system in children, it is essential to detect visual disorders in time. In this Chapter, the historical development of vision screening in children is traced and it is noted that despite the optimizations offered over time, it is still difficult to specify generally accepted methods and there is a need for additional research.

Also, it can be concluded that there are no regular large-scale epidemiological studies on visual disorders in children in Bulgaria. The analysis of literature sources shows that a very large percentage of children have not had an eye examination, there are no accepted, validated methods for vision screening of school-age children, there is a need for more specialists prepared to perform vision screening. Also, the literature review found no attempts to identify available knowledge resources in the community to be classified and integrated into an organized knowledge base. The conclusions of the literature review substantiate the goals set in the dissertation.

Chapter 2: Screening methodology developed and used in the dissertation

The screening methodology developed and used in the dissertation includes a series of tests, as well as a protocol for recording their results. The set of tests includes objective (without requiring a response from the patient (retinoscopy, autorefractometry)) and subjective (assuming responses from the patient during the examination (with a trial frame and set of glasses, or with a phoropter and optotype table)) assessment of the clinical refraction. A circular arrangement of screening workstations has also been proposed and tested. Attention is paid to preliminary preparation and communication, which prove to be essential in optimizing the process and minimizing screening time.

The tests included in the screening protocol are selected so that:

• To be relatively easy and convenient to perform in conditions outside the clinic;

• To be non-invasive, to minimally disturb the learning process in the school;

• To be used accessible (for most ophthalmological and optometric practices) devices and equipment;

• To have good sensitivity and specificity;

• To cover the maximum number of visual disorders - those typically appearing at school age, or missed and not diagnosed at an earlier stage of children's development.

When developing the screening methodology, the following requirements and circumstances were taken into account:

• To test the maximum number of children in the minimum possible time;

• To be consistent with available resources (devices and specialists);

• To be part of the practical training of Optometry students.

In order to meet the above requirements, the so-called "round screening methodology" has been developed, used and validated. With it, the children visit all the test bases located in an appropriately sized school room. An essential detail in the planning for directing children is to consider the duration of each test, so that there is no crowding in front of some bases. For each child, a protocol is completed with test results, as well as a questionnaire to identify risk factors and cover health needs for children's visual disorders.

Figure 2.1 presents a vision screening protocol form where the selected tests can be trace out .

VISION SCREENING PROTOCOL

Date: …………………………………….

Location:………………………………………………………………..

Name:.. Age:................ gender:…..

Subjective complaints: does not see clearly far and/or near; eye strain and fatigue; double vision; something else..

RESULTS

1. Hirschberg test: (+) / (-)
2. Bruckner test: (+) / (-)
3. Lang test: (+) / (-)
4. Motility test: (+) / (-)
5. Cover Test: 5m: (+) / (-) ; 33cm: (+) / (-)
6. Alternating Cover Test: 5m: (+) / (-) ; 33cm: (+) / (-)
7. Autorefractometry:

	Sph	Cyl	Ax
OD			
OS			

8. Visual acuity, for distance, without correction: VOD=…… VOS=……..

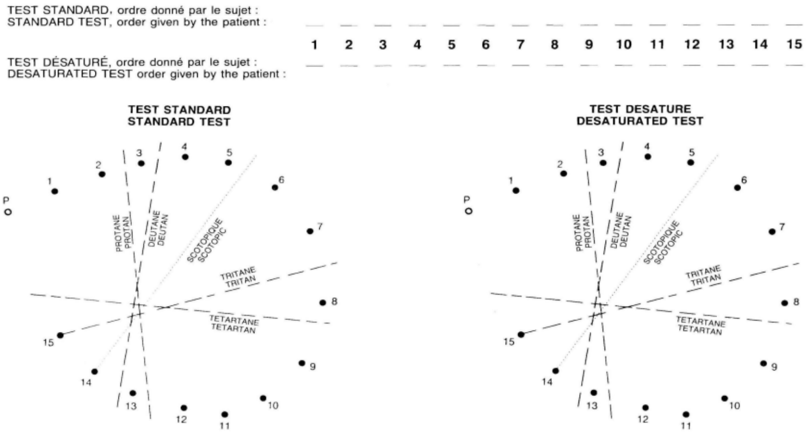
9. Visual acuity, for distance with +1,5: VOD=…… VOS=…….

10. Color vision tests (+) / (-)

10.1 Ishihara.:

10.2. D-15:

10.3. LD-15



Conclusion:...

Newfound condition:...

Figure 2.1. Vision Screening Protocol Form.

In figure 2.2. the vision screening questionnaire form is presented.

A typical distribution of test bases, in an ordinary classroom, is shown in Figure 2.3. The numbers from 1 to 9 indicate the different bases:

1. Admission base, the children present the informed consent forms filled in and signed by a guardian, as well as the questionnaire. They receive their report of test results and are asked if they have any vision complaints. They receive instructions and guidance to the next base.

2. An objective refraction measurement is performed with an autorefractometer, without using cycloplegic drugs.

3. Stereopsis tests.

4. Cover test, alternating Cover test, motility.

5. Visual acuity, monocular without correction and with optical lens +1.5 D.

6. Duplicate 5 as this test takes longer.

7. Hirschberg's test, Bruckner test.

8. Color vision tests.

9. The children leave the completed protocol, a check is made to see if they have not missed any examination and they are sent outside. The report is given to the team leader for conclusion and completion of the parent/guardian information form.

VISION SCREENING QUESTIONNAIRE

Date: …………………………………….

Location:…………………………………………………………………..

Name:.. Age:................ gender:…..

Subjective complaints: does not see clearly far and/or near; eye strain and fatigue; double vision; something else...

QUESTIONS:

1. Has the child had an eye examination so far?

A) Yes B) No

2. How often does the child visit an ophthalmologist?

A) More often than once a year B) Once a year

C) Once in two years D) Less than once in two years

E) So far, he/she has not been examined

3. Does the child have prescription glasses?

A) Yes B) No

3. 1 If the answer is "yes" does the child wear them?

A) Yes B) No C) Sometimes

4. Do the parents wear glasses or contact lenses?

A) Yes (please underline the correct one: mom, dad, both) B) No

5. Does the child wear sunglasses?

A) Yes B) No

6. How much time a day does the child look at the screen of electronic devices (computer, phone, tablet)?

Figure 2.2. Vision Screening Questionnaire Form.

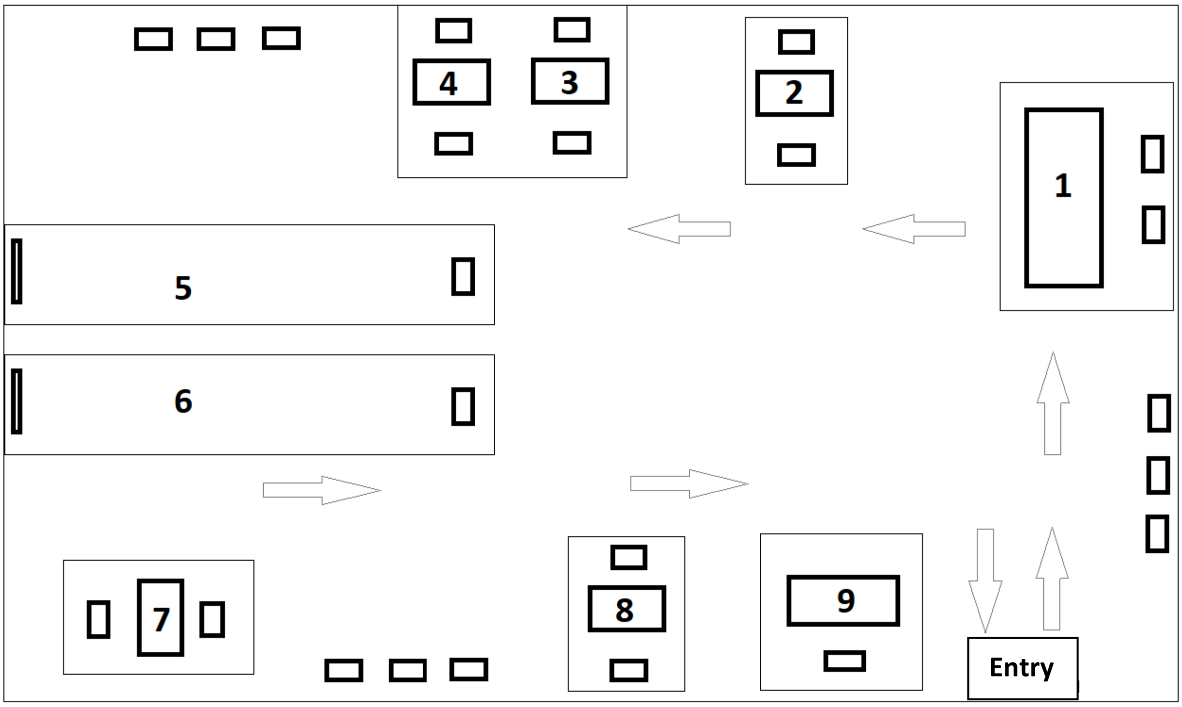


Figure 2.3. A typical distribution of test bases in a screening room.

In order to be successfully implemented the school vision screening, a significant and including a wide variety of tasks, preliminary preparation is required. After preparing the methodology of working and assuring appropriate devices and equipment, the team of eye specialists should be trained and instructed. At the same time, communication with the school administration should be carried out, an appropriate period of time should be agreed upon, necessary declarations for each child, a room in the school (with appropriate dimensions and lighting). Engaged in the preparation and conducting of the screenings presented in the dissertation are: teachers, optometrists, ophthalmologists and students from the specialty "Optometry" at SU "St. Kliment Ohridski"; teachers and representatives of the administration from the respective schools. Practical experience shows that good communication and collaboration between all involved in the organization are extremely important for the effective practical implementation of the screening.

The screening methodology, developed and presented in the dissertation, has been validated with practical implementation in 5 schools located in different types of settlements and regions of Bulgaria:

● Devnya, in November 2016, in "Vasil Levski" secondary school, 335 children aged 6-15 were examined;

● Sapareva Banya, January 2018, 203 children participated, from 7 to 18 years old ;

● Veliko Tarnovo, Secondary School "Bacho Kiro", within two visits of the team (in March and April 2019), due to the large number of children in the school. Here, the total number of children who passed the tests is 748, aged 6 to 16;

● Sofia (two schools) – the sports school "Gen. Vladimir Stoychev" in October 2017. There are 181 participants in total, aged 10 to 17;

And, in January 2020, at Vasil Aprilov Secondary School, with the participation of 137 children, aged 6 to 14 years.

The testing of the methodology proposed in the dissertation for school vision screening shows high efficiency in terms of the number of children tested in a certain time. Despite the possible variations in each individual case, it can be summarized that, according to practical experience, about 150 children can be examined in 8 hours of team work. It is recommended that the minimum number of team members include two supervisors (ophthalmologists, optometrists, teachers) and 6–7 Optometry students. The feedback from the screenings in all schools is very positive and the satisfaction of parents, children and teachers is high, which is shown in the letters of appreciation received. The students participating in the teams also express themselves very positively about their professional experience.

An additional conclusion from the practical experience is that it would be useful in the future to work on better awareness of children, teachers and parents about vision and eye health care. Plans for future screenings include preparing short educational presentations on the topic for children and another for parents.

Chapter 3: Methodology for the preparation and practice of Optometry students, developed and introduced in the process of working on the dissertation

Chapter 3 of the dissertation presents the developed methodology for improving the practical training of Optometry students for conducting school vision screenings. Work with students is divided into three stages:

● Preliminary stage – familiarization with the screening methodology that is used and additional practice with some of the tests;

● Practical work during a real screening in the presence of teacher;

● Final stage – discussion of practical cases experienced by students during school screening.

Since the screenings involved students from the last courses of study, they were already familiar with all the tests included in the protocol (Chapter 2). In the process of work, it is found that it is necessary to provide additional practice with binocular vision tests. Binocular vision disorders are less common than ametropia and often go undiagnosed. It sometimes takes years of practice to see a large number and variety of such cases. Within the framework of training, it is very difficult to provide a number of patients who also have a variety of binocular disorders. A different approach was used to solve this task: simulation of binocular disorders using optical lenses. Prisms from a trial set or prism bars were used to simulate deviations of the optical axes of both eyes of a patient. To simulate ametropia and anisometropia (difference in the amount of ametropia in the right and left eye), optical lenses from the trial set, placed in a trial frame, were used. Protocols were developed for students' practical exercises with binocular tests. The protocols have been validated by being used in practical exercises. Protocols are found to perform the task they were designed to solve. As an example, below is the protocol for the Hirschberg test and the Krimsky test developed and used during practical exercises with the students:

PROTOCOL FOR STUDENTS PRACTICAL EXERCISE

TOPIC: Hirschberg test, Krimsky test

Student:………………………………………………………… fac. number:……………

Summary for theoretical preparation: The Hirschberg test is a screening test for the presence of strabismus (misalignment of the eyes) in which the position of the corneal reflex of both eyes is assessed. It is quick to perform and requires little cooperation from the patient. Useful for testing for strabismus in newborns, young children, patients with poor vision, patients who cannot fixate or track well - or in any situation where a full assessment of eye alignment is not possible.

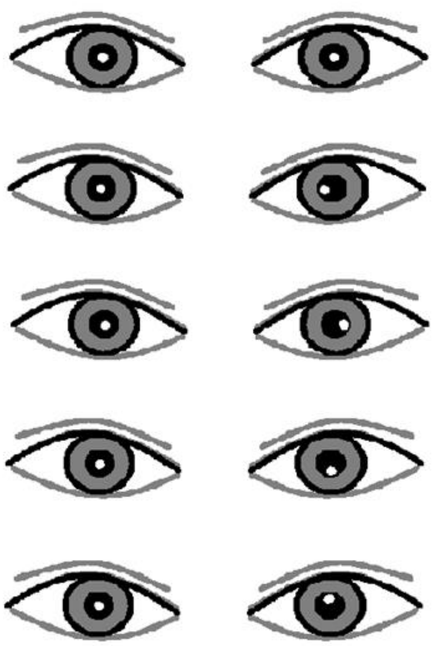
Required equipment: ophthalmoscope, medical flashlight, or flashlight from a mobile device.

Procedure:

1. It is performed in a well-lit room. Additional use of localized lighting is also recommended so that the patient's eyes can be easily seen without shadows.
2. The patient should be without correction, in the general case. If it is assumed that refractive correction will change the result (for example, with significant hyperopia), the test should be performed with the necessary optical correction.

3. The light source used is positioned horizontally 40 to 50 cm from the patient, with the light directed towards the patient's nose. The back of the flashlight should be very close to the tip of the eye specialist performing the test.
4. The patient is instructed to look at the light with both eyes open.
5. The location of the corneal reflex was observed in each eye separately. For this purpose, briefly cover each eye in turn. It is necessary to consider that the reflex is often decentered about 0.5 mm nasally with respect to the center of the pupil, since the kappa angle is usually positive.
6. The location of the corneal reflexes is then compared with the patient looking with both eyes open (i.e., without any occlusion). The eye that has the same kappa angle as in the monocular test is the fixating eye. The location of this reflex should be considered a reference position.
7. If heterotropia is present, the corneal reflex of the other eye will shift in the direction opposite to that of the ocular deviation. For example, in the case of esotrpoia, the corneal reflex will be displaced temporally on the patient's cornea relative to the position of the reflex in the other eye.
8. The magnitude of the deviation from the reflex shift in millimeters (mm) relative to the reference position is estimated, using the approximation of 1 mm = ~22Δ (according to other sources 1 mm = ~15Δ).

Table: Hirschberg test results.



Hirschberg test

1. Normal position of corneal reflexes

2. Exotropia (the eye is deviated outwards)

3. Esotropia (the eye is deviated inwards)

4. Hypertropia (the eye is deviated upwards)

5. Hypotropia (the eye is deviated downwards)

Krimsky test: The procedure is the same, only the scoring is different – a prism bar is used in front of the fixating eye to center the corneal reflex in the deviated eye.

Hirschberg's test is mainly indicative, it is difficult to obtain a more precise diagnosis based only on this test. According to some authors, even experienced practitioners can obtain results that differ by up to 10 Δ. In practice, with small children, a variant with photo or video recording is often used. Krimsky's test allows a more precise determination of the magnitude of the eye deviation.

PRACTICUM

Hirschberg test (exercise with a patient being a group mate)

Result	Date	Signature of the teacher

Hirschberg's test of prism-simulated deviation (with a group mate as the patient):
Recommendation: use large simulating prisms to avoid compensation of induced deviation when triggering the fusion reflex.

Selected simulating prism	Result	Date	Signature of the Teacher

Hirschberg test, with masked prism-simulated deviation (with a group mate as patient):

Selected simulating prism	Result	Date	Signature of the Teacher

Krimsky test, with masked prism-simulated deviation (with a group mate as patient):

Selected simulating prism	Result	Date	Signature of the Teacher

The practice of Optometry students in the field during school vision screening includes, first, arranging the workplaces according to the individual test bases. Under the guidance of teachers, they learn to distinguish the appropriate lighting conditions in the room provided, which are different for different tests. It is also important to arrange the posts in a certain sequence and at an appropriate distance from each other. Students are instructed to contact a teacher for assistance with a result obtained, or for the manifestation of a visual impairment that they have doubts about how to report. The next practice introduced and important for training is the mandatory rotation of posts so that each student works with each of the screening tests used. In addition, a protocol was developed in which each student noted how many children he tested at each base, as well as how many positive and negative results he obtained when conducting each test.

The final stage, from the point of view of the Optometry students' training, covers the reporting of the work done in the field and discussion of practical cases that the students have seen during the screening. At this stage, the idea of setting a task for the students to describe and present a case study from the screening, explaining what they noticed, what their assumptions about the reasons were and what they discussed with the teacher, also appeared. As an additional benefit, it can be pointed out that some of the students participating in the screenings, who are interested in scientific work, are involved in the processing and analysis of the data collected in the protocols. This makes it possible to do master theses and doctoral projects.

As conclusions from Chapter 3 of the PhD thesis, it can be noted that as a result of the experience gained from the conducted school vision screenings, the benefit for the practical training of Optometry students is visible. The developed training methodology and the protocols included in it give students the opportunity to gain skills and confidence in performing tests included in vision screenings. The use during exercises of simulation with optical means of binocular disorders, allows to overcome the lack of a sufficient number and with a variety of disorders, necessary for the full training of students.

Additionally, during the screenings, future optometrists have the opportunity to gain invaluable experience and also feel the responsibilities and importance of their profession and its place in the primary health care system.

Given that, after analyzing the literature review made in Chapter 1, the need for more specialists trained in pediatric vision screening was noted, the work presented in this Chapter is a contribution to addressing the problem.

Chapter 4: Myopia in Bulgarian school children: prevalence, risk factors, and health care coverage

Myopia among children and adolescents has become an increasingly significant topic of research in recent years. Myopia is the most common cause of distance vision impairment, and its onset occurs most often in school-aged children. Uncorrected myopia in children can affect their performance in school and lead to a lower quality of life, affecting both the individual and the community [7]. High myopia significantly increases the risk of developing a number of eye diseases and complications, such as retinal detachment, glaucoma, cataracts, and degenerative changes in the macula [8]. Numerous studies have found an increased incidence of myopia in young people and children, the increase being dramatic, up to (60–80)% in East Asian countries, about (25–40)% in Western Europe. The increase in myopia in the USA has almost doubled in the last 30 years, reaching 41.6% [9]. Globally, in the year 2000, myopic people were about 1.4 billion, and the forecast is to reach 4.8 billion in 2050 [9]. The increased rate of growth in the prevalence of myopia is expected to pose significant challenges to the organization and provision of vision health care. Age of onset and duration of myopia progression are the most significant predictors of high myopia later in life [10]. At the same time, the great progress of therapies to slow the growth of myopia, also called myopia control therapies or myopia management therapies, should be considered. Over the past 10 years, a number of studies have confirmed the possibilities and the achieved results of special spectacle lenses, contact lenses and orthokeratology, developed to reduce the growth of high myopia among adolescents. All this confirms that the provision of adequate and affordable health care is essential to avoid vision impairment caused by myopia. All people with myopia should have access to adequate and timely optical vision correction [10]. Additionally, identifying and assessing risk factors for myopia can optimize prevention activities.

Chapter 4 of the PhD thesis presents the results for the prevalence of myopia among children from several schools in three cities in Bulgaria [A1]. The methods used and the results obtained are described. Data on some of the risk factors for myopia, collected through a specially prepared questionnaire, were also analyzed: age, gender, heredity, sports activities, time spent in front of screens. An analysis was also made of the data on the coverage of myopia with health care, and the following were used to define the health coverage: previous examinations of the children with myopia, presence of prescribed optical correction, regular wearing of the prescribed glasses.

The results showed that children with myopic objective refraction less than or equal to -0.75 D and decimal visual acuity less than or equal to 0.8 in at least one eye were 236 out of 1401 or 16.85%. The prevalence of myopia varies by age, geographic location, and school profile. The percentage of myopic children in the 6-10 age group was 14.2% compared to 19.9% in the 11-15 age group. The prevalence of myopia among children in the urban population was 31.4% (capital city) and 19.9% (middle city), respectively, and only 8.4% in the small town and surrounding village group. Our results show a 53% increase in the prevalence of myopia in the 11-15 age group compared to a 2009 report [6]. Analysis of data related to health coverage factors of all myopic students showed that 71.6% had a previous eye exam, 43.2% had a prescription for corrective glasses, 27.5% wore their glasses regularly. Risk factors for a higher likelihood of myopia are gender (female), age (adolescence) and visually impaired parents. Living in a small town and daily sports activities correspond to a lower probability of myopia. Screen time (hours per day, subjectively reported) was not statistically associated with an increased likelihood of myopia when other risk factors were accounted for.

Table 4.1 presents the number and percentages of children with myopia for the different grouping variables.

Table 4.1. Counts and sample proportions of children with myopia for the different grouping variables which we call risk factors:

Grouping characteristic	Count (Sample proportions)			
School	Rural(Small tawn) 28 (8.36%)	Urban (Capital) 43 (31.38%)	Sport(Capital) 16 (8.84%)	Urban (medium sized town) 149 (19.91%)
Age	6 - 10 128 (19.93%)	11 - 15 108 (14.22%)		
Gender	Male 103 (13.86%)	Female 133 (20.21%)		
Sport	Every day	Not every day		

	48 (11.74%) 186 (19.60%)
Screen time	Less than 4 hours More or equal to 4 hours 179 (17.92%) 51 (14.87%)
Previous examination	Yes No 67 (9.81%) 169 (23.93%)
Parents wear glasses	None of the parents At least one parent 113 (13.47%) 114 (23.46%)

The following statistical analysis was performed to determine whether the percentages of myopia were equal between the different groups according to the same grouping variables (school, age, etc.). The results are presented in Table 4.2.

Table 4.2. Chi square test for comparing equal proportions of myopia for the different risk factors

Grouping characteristic	Chi^2 test statistic	Degrees of freedom	p-value
School	51.237	3	< 0.0001
Age group (above and below 10)	7.689	1	0.0056
Gender	9.597	1	0.0019
Sport (every day versus not every day)	11.847	1	0.0006 (43 missing observations)
Time in front of the screen (less than 4 hours versus more or equal to 4 hours)	1.4638	1	0.2263 (59 missing observations)
Previous examinations	48.134	1	< 0.0001 (12 missing observations)
Parents wear glasses (at least one of the parents to wear glasses versus none of them)	20.928	1	< 0.0001 (76 missing observations)

Statistically different (at 5% significance level) are the proportions for the following risk factors: school, age, gender, sport (every day versus not every day), previous examinations, whether parents wear glasses (at least one of the parents versus none of the parents). Statistically non-significantly different are the proportions of myopic children in the two groups depending on the time spent in front of the screen (less than 4 hours versus more or equal to 4 hours per day). Figure 4.1 shows the original distribution of the variable screen time.

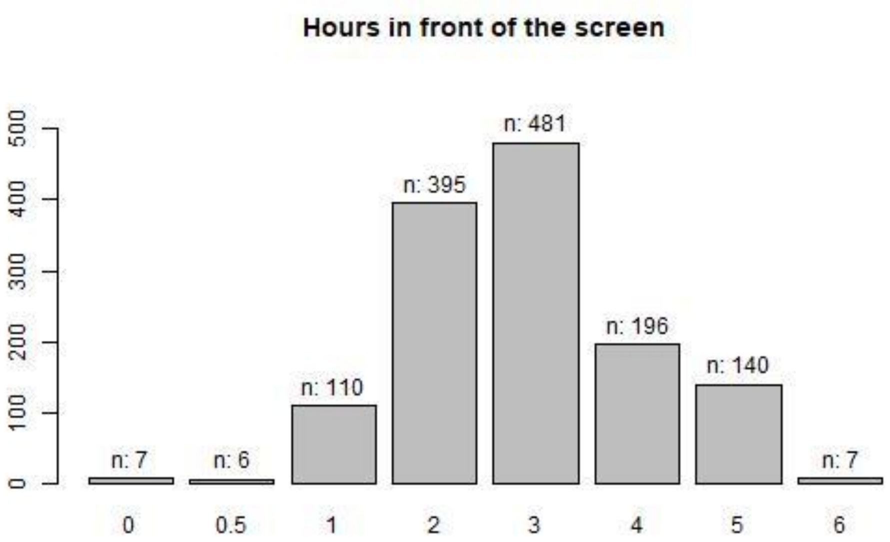


Figure 4.1. Bar plot of the variable time in front of the screen (in hours) per day

The health care coverage analysis for the children with myopia and the proportions of the levels of the different grouping variables are presented in Table 4.3. Among all myopic pupils, 169 (71.61%) have previous eye examination, 102 (43.22%) have prescribed corrective glasses.

Table 4.3. Proportions of the levels of different grouping variables among myopic children.

Grouping characteristic	Sample proportions
Examination before (yes or no)	No Yes 0.284 0.716 95% CI for No: (0.228, 0.347)
Have glasses (yes or no)	No Yes 0.568 0.432 95% CI for No: (0.502, 0.632)
Wear glasses (yes, no, sometimes)	No Sometimes Yes 0.648 0.076 0.275

A logistic regression model for having myopia or not is fitted with predictors the risk factors variables from Table 4.4 in order to identify only the significant variables. Backward elimination with 5% significance level is used to remove the insignificant variables. The estimates of the odds ratios and their 95% confidence intervals from the final model are given in Table 6.

Table 4.4. Estimates and 95% confidence intervals of the odds ratios in the logistic model with only significant risk factor variables

Variable	Estimate	Lower Bound 95% CI	Upper Bound 95% CI
Town: Sofia-Gorubliane	4.643	2.712	8.064
Town: Sofia-Sport	0.580	0.278	1.160
Town: Veliko Tarnovo	2.337	1.524	3.696
Gender (Female)	1.595	1.184	2.155
Age group: below 10	0.550	0.404	0.750
Parents wear glasses: at least one of them	1.677	1.239	2.271

The obtained results are comparable to other recently published epidemiological studies in Europe reporting the prevalence of myopia and are higher, compared to those of the small number of publications for Bulgaria. A direct comparison of the prevalence of myopia is difficult to make because of the different methods and criteria used to measure it: with or without cycloplegia, autorefractometer, retinoscopy, subjective refraction, and a cutoff value ranging from -0.25 to -1.0 D in various studies [11]. An important contribution of the work presented in this Chapter of the PhD thesis is that the results obtained for the prevalence of myopia can be used to compare with similar ones from future studies and to identify possible changes over time.

Chapter 5: An unusually high prevalence of color vision deficits in children from a small Bulgarian town

Chapter 5 of the PhD thesis presents the results of a screening conducted in a local school, in the city of Sapareva Banya, where an extremely high prevalence of hereditary color blindness among students was found [A2]. Color vision, as one of the important characteristics of visual perception, was examined during screening of 203 students aged between 6-18 years, living in the city of Sapareva Banya. The study was conducted using Ishihara pseudoisochromatic plates, Farnsworth D-15 (D-15) test and Lanthony Desaturated D-15 (LD D-15) test. The tests were performed according to their instructions. In order to save time, the tests were conducted binocularly. According to Ishihara's plates , among 87 boys and 116 girls, 9.2% and 4.31%, respectively, have hereditary color deficiency. The statistical analysis data is compared with other known ones from around the world. None of the students studied had previously been tested for color perception. Among them, students with color perception problems were found, which were not recognized by either the student, the parent, or the teacher.

People with hereditary color vision deficiency (CVD) are classified as anomalous trichromats, dichromats, and monochromats. Anomalous trichromatism is a relatively mild form of color deficiency. The terms protanomaly, deuteranomaly, and tritanomaly refer to defects in the red, green, and blue cones, respectively. In dichromats, color vision is formed only by the work of two types of cones. The class of dichromatism characterized by the complete absence of green cones, red cones, and blue cones is called deuteranopia, protanopia, and tritanopia, respectively. Protanomaly and protanopia refer to protane CVD, while deuteranomaly and deuteranopia refer to deutane deficiency. The CVD of protane and deutane is often described as a red-green deficiency. Tritanomaly and tritanopia are described as tritan or blue-yellow color vision deficiencies.

The lack of early childhood ophthalmological screenings for color vision in Bulgaria suggests that a large number of people affected by CVD remain undetected because they manage to adapt to the environment and their condition remains unrecognized. Because colors are widely represented in the learning process during the early school years, a student with color vision deficiency may have difficulty completing certain tasks and may develop a dislike for school and learning as a result. This, on the other hand, hinders the development of its potential. The student's color vision status is also important when choosing a future profession. There is currently no treatment for congenital CVD, but the earlier they are identified, the more timely and effective the child's adaptation can be supported. Considering these aspects, there is justifiably a growing interest worldwide in identifying the prevalence of color vision deficits in school-age children [12-14].

After conducting the Ishihara test, it was found that out of a total of 203 students, 13 (6.4%) had color vision deficiency (Figure 5.1(a)). Of them, 8 are boys (3.94%) and the remaining 5 are girls (2.46%). Statistical treatment of the sex-related results (Figure 5.1(b)) showed that among 87 boys and 116 girls, 8 (9.2%) and 5 (4.31%) were color vision deficient, respectively.

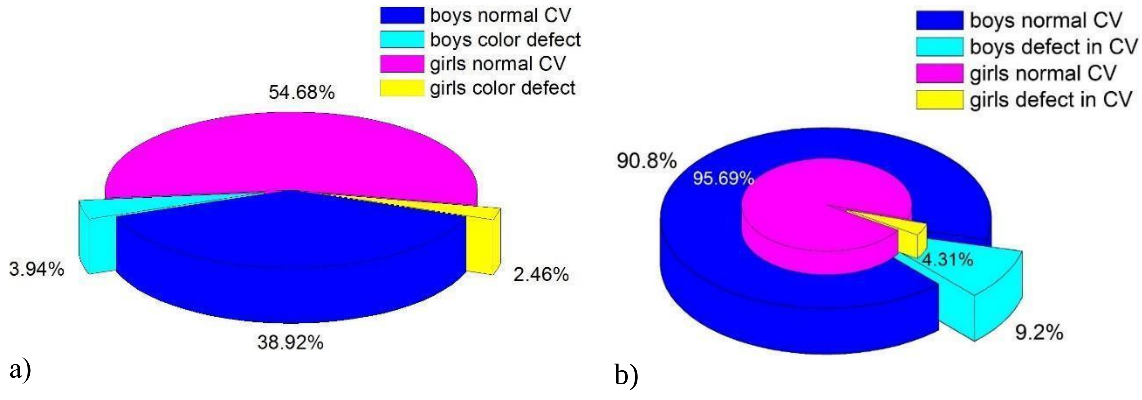


Figure 5.1. Distribution of girls and boys with normal color vision and o with CVD in a) and genger-related percentages in b).

According to epidemiological data [15], in the world about 8% of all men and about 0.5% of all women suffer from congenital CVD, and the percentage of CVD also depends on the ethnic group. A more in-depth review of the literature shows that the authors reported a higher rate with CVD among both Asian men (11.05%) [12] and women (0.83%) [16] (2.42 %) [12]. However, there is no data on such an extremely high prevalence of CVD among the female population, as found in the conducted research.

In 145 students out of a total of 203 examined with the Ishihara test, color vision was additionally examined with the Farnsworth D-15 test. Of the 13 students who failed the Ishihara test, 7 failed also on Farnsworth D-15, but 4 successfully passed the D-15, and another 2 have made mistakes which did not allow determining accurately the CVD. The results of the Ishihara and Farnsworth D-15 test are summarized in Table 5.1.

Table 5.1. Comparison between the results of the Ishihara test and the Farnsworth D-15 test.

Color Test		Pass Ishihara	Fail Ishihara	Total
Pass D15		86	4	90
Fail D15	red-green	7	7	14
	blue-yellow	23	0	41
	undefined	16	2	
Total		132	13	145

Illustrations of some of the results of students with red-green CVD according to the Farnsworth D-15 test are shown in Figure 5.2. A typical distribution of caps arrangement of deutane (Figure 5.2(a)) and protane (Figure 5.2(b)) CVD was established in two of boys examined. The result of D-15 shown in Figure 5.2(c) reveals a protanomal CVD of a girl.

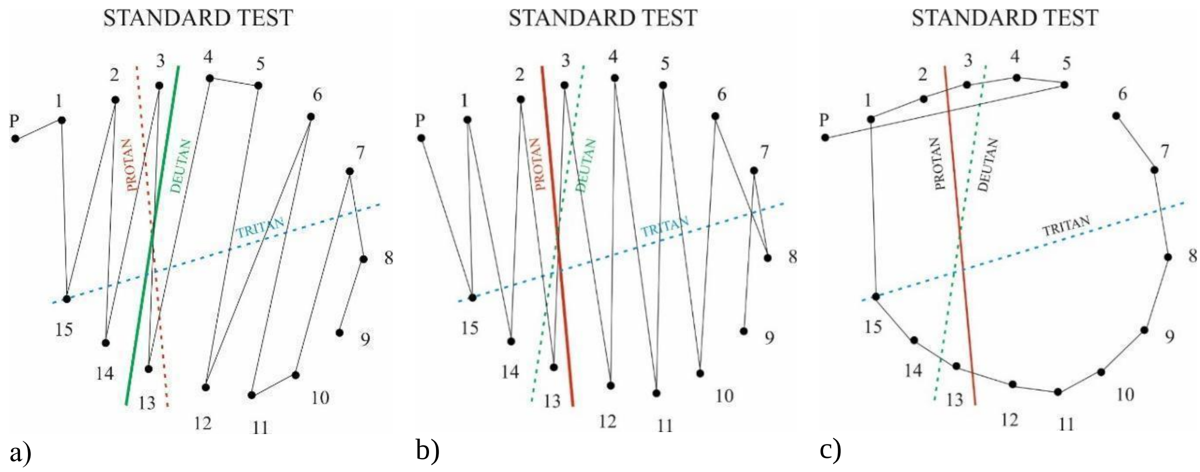


Figure 5.2. Examples of Farnsworth D-15 test arrangementsin the case of deutane (a), protane (b) and protanomalous (c) CVD.

The color vision of 91 students out of 203, surveyed with the Ishihara test, was also investigated with the Lanthony Desaturated D-15 test. The results of the two color vision tests are summarized in Table 5.4. Out of 5 students, who failed the Ishihara test, 2 also failed the Lanthony Desaturated D-15, 2 succesfully passed the LD D-15 and another 1 made blue-yellow mistakes on the LD D-15.

Table 5.2. Comparison of Ishihara and LD D-15 test results.

Color Test		Pass Ishihara	Fail Ishihara	Total
Pass LD D-15		42	2	44
Fail LD D-15	red-green	4	2	47
	blue-yellow	32	1	
	undefined	8	0	
Total		86	5	91

The rate found in the conducted study among the male population correlates with well-known data, but the extremely high rate among the female population exceeds even the highest found (2.42%) in the literature [16]. According to Farnsworth D-15 test among 62 boys and 83 girls, 4 (6.45%) and 10 (12.05%) had red-green color vision disorder, respectively. The results of D-15 for CVD in girls even exceed the global male trend. Some of the girls diagnosed with D-15 were additionally tested with the Lanthony Desaturated D-15 test, which confirmed the D-15 result. The conducted studies show that the prevalence of red-green CVD in the female population in Sapareva Banya is not lower than that determined by the Ishihara test. It should also be noted that the methodology used to study CVD is the same during all the screenings described in the dissertation, as they are supervised by the same professor. But only during the screening in Sapareva Banya was observed this unusually high prevalence of CVD.

The changes in blue-yellow perception found in a proportion of students are expected due to the continued development of both their cognitive abilities and their visual system.

A significant finding is also that during school vision screenings, unexpected anomalies in the prevalence of visual impairments may be detected, as shown by the results presented in this Chapter of the dissertation. The discovered surprisingly many children with color vision disorders, in the specific case, are not subject to therapy, but for their future development and realization in life, it is useful for them and their families to be informed about the presence of the relevant vision disorder.

On the other hand, from the point of view of scientists working in the field of vision sciences, it would be useful to do further studies in the population and in other age groups, as well as in the surrounding settlements, to clarify whether the anomaly affects a larger region and generations. It would also be interesting to look for the reasons for the unusually high prevalence of color vision defects, whether it is only a matter of a random genetic combination or there is an influence of some long-term acting chemical agents (e.g. the specific composition of the mineral water, characteristic and used in the region is one of the possible hypotheses).

Chapter 6: Knowledge Management in the Children's Vision Health Care System

Knowledge management (KM) is a major challenge for modern organizations, because knowledge currently has a key role and is becoming an important resource and source of top quality and competitive advantages. According to the knowledge-based understanding [17], the organization is seen as a social community with the primary task of integrating the specialized knowledge of individuals with its goals and services, so that organizational capabilities are developed. Knowledge forms its core competencies and is the basis of value creation. Given that tacit knowledge, as well as organizational knowledge, is difficult to imitate, competitors would hardly be able to duplicate the organization's relevant capabilities, and a strategy based on them can lead to sustainable competitive advantages [18]. Figure. 6.1 presents the main factors for the design of a Knowledge Management System (KMS) and their main characteristics.

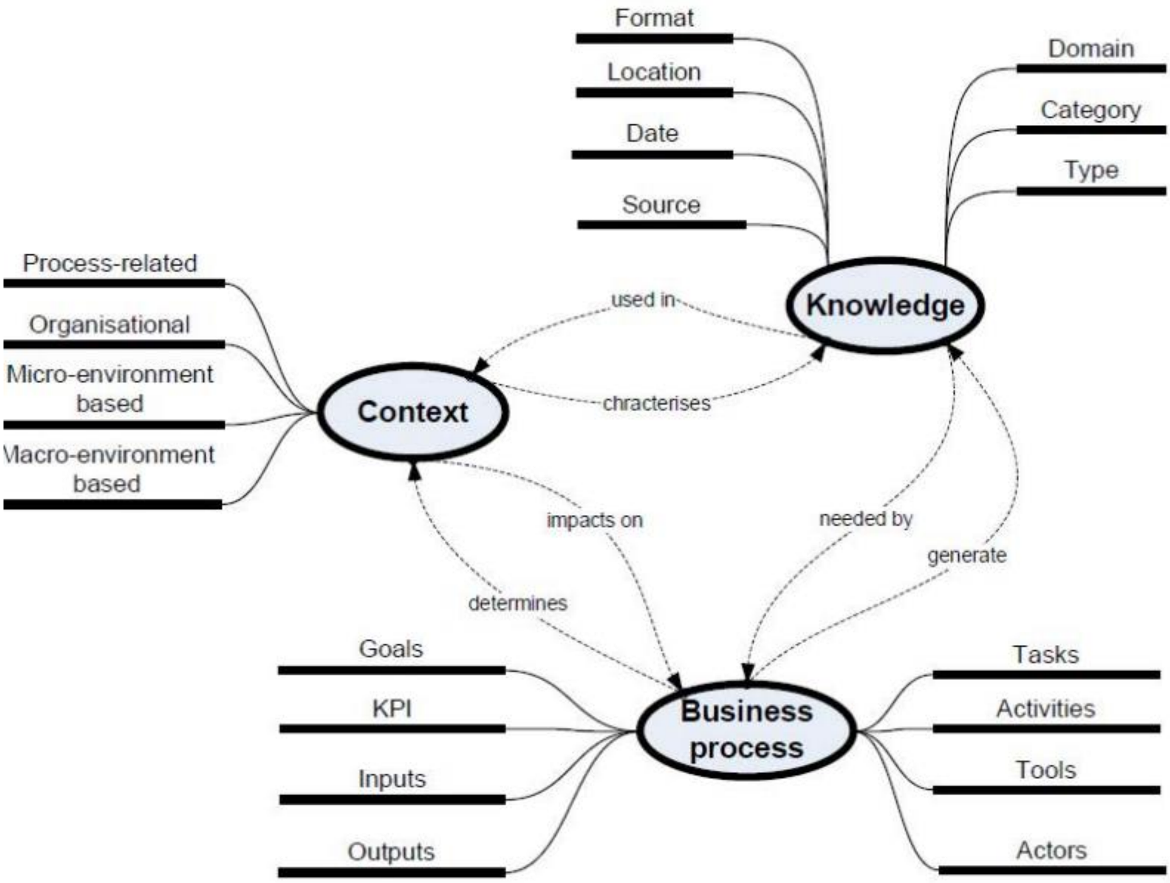


Figure. 6.1. Major factors by info-structure design and their main characteristics [19].

Chapter 6 of the dissertation presents a concept for building a knowledge management structure [A3, A4] in the pediatric vision health care system to support and connect all stakeholders in the field:

- Parents and families of children;
- Health and medical specialists - ophthalmologists, optometrists, opticians, personal physicians, etc.;
- Teachers and school administration;
- Universities and educational institutions preparing health and medical specialists in the field;
- Non-governmental organizations and patient organizations in the area;
- Representatives of the industry providing means for children's vision correction and therapy;

- Scientists and researchers;
- Health authorities and institutions administering eye health care.

The task set in this Chapter of the PhD thesis is in response to the following problems identified during the preparation, the organization of the screenings and the overview of the state of the field:

- Extremely small number of scientific publications on the frequency of various visual; disorders in children of school age in Bulgaria;
- Lack of access to information on methods and results of individual screenings conducted within the framework of different campaigns;
- Insufficient communication between individual stakeholders in the field;
- Need to collect, store data, information and knowledge in the field, as well as provide an opportunity to reuse and learn from previous experience.

In view of the literature review, in the implementation of KMS, it is important as a first step to identify the available resources - knowledge in the community, to be classified, organized and integrated into a distributed knowledge base. As a next step, the need to provide appropriate access to these resources, as well as the active involvement of all participants in the updating and maintenance of the knowledge base, is considered.

The concept of building an info-structure for knowledge management in the pediatric vision health care system could be applied in building a collaborative platform to support and connect all stakeholders in the field.

MAIN RESULTS AND CONTRIBUTIONS IN THE PhD THESIS

The results of the overview of the child's vision development and the screening needs of school-age children were analyzed. Problems have been identified in the timely detection and prevention of visual disorders in school-age children in Bulgaria. The main contributions of the PhD student are in the field of proposing and implementing solutions to some of these problems:

1. An adapted methodology for children's vision screening has been developed, tailored to the existing and potential specific needs and resource possibilities. Forms have been developed for reporting results and collecting data to improve children's vision health care. A questionnaire was developed to identify risk factors for impaired vision in school-aged children, as well as the extent of vision health care coverage. School vision screenings were initiated during which the developed methodologies and protocols were tested in practice and validated.
2. A methodology has been developed to complement the practical training of students in Optometry, for conducting school vision screenings, with the aim of overcoming the lack of staff in this specific area of primary health care. Practical tests using optical simulation of binocular vision defects have been prepared and introduced into the students' training. Real field practice in school vision screenings for Optometry students was introduced. Protocols have been developed reporting the students' performance during screening.
3. Results on prevalence of myopia, risk factors for myopia and health coverage among school-aged children in Bulgaria are presented and analyzed.
4. Results of an unusual prevalence of color vision deficiencies in children from a small Bulgarian town, detected during school screening, are presented and analyzed.
5. A concept for building an info-structure for knowledge management in the pediatric vision health care system is proposed.

LIST OF PUBLICATIONS INCLUDED IN THE DISSERTATION

A. Publications in scientific journals

1. Mila Dragomirova, Albena Antonova, Slavena Stoykova, Gergana Mihova, Denitsa Grigorova
„Myopia in Bulgarian school children: prevalence, risk factors, and health care coverage“
BMC Ophthalmology **vol 22,** 248 (2022)
https://doi.org/10.1186/s12886-022-02471-2
2. Mila Dragomirova, Snejana Iordanova
“Unusual prevalence of congenital color vision defects in children from a small bulgarian town”
Annual of the Sofia University St. Kliment Ohridski **111** (2018) 169-180.
3. Elissaveta Gourova, Mila Dragomirova
“Design of Knowledge Management Info-Structures”
EuroPLop’15: Proceedings of the 20th European Conference in Pattern Languages of programs (2015) Art. N15, 1-9.
doi:10.1145/2855321.2855337, Ref, 2015
4. Елисавета Гурова, Мила Драгомирова
„Изграждане на инфо-структура за управление на знания в организацията“
Е-списание „Педагогически форум“ брой 2, година 2016
ISSN: 1314-7986, doi: 10.15547/PF.2015.046

B. Scientific conference reports

1. Mila Dragomirova
“A Bulgarian-Irish optometry collaboration to screen school children’s vision”
EAOO 2017, Испания/Барселона.
2. Mila Dragomirova
“Children’s vision screening in a Bulgarian school”
EAOO 2016, Германия/Берлин.
3. Mila Dragomirova
„A massive children's vision screening as social entrepreneurship“
3rd Optometry Conference of Central and South-eastern Europe OCCSEE 2016, Хърватия/Сплит.

C. Conference reports presented as posters

1. Mila Dragomirova, Snejana Iordanova
“Unusual frequency of congenital color vision defects in children from a small bulgarian town”
EAOO 2018, Хърватия/Пула.

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