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THE PREVALENCE OF ACCOMMODATIVE AND VERGENCE DYSFUNCTIONS IN AZERBAIJAN

MASTER THESIS

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RIGA 2020

ANOTĀCIJA

Maģistra darb ir uzrakstīts angļu valodā uz 35 lpp. Tas satur 19 tabulas, 2 pielikumus un 16 atsauces uz literatūras avotiem.

Maģistra darba mērķis ir izvērtēt akomodācijas un verģences traucējumu izplatību un veidus Azerbaidžānas galvaspilsētas baku studentu vidū. Pētījumā piedalījās 192 dalībnieki (15-36 g.v.). Visiem tika veikta bezmaksas redzes pārbaude, kur detalizēti tika izvērtēta refrakcija, akomodācija un verģence. Rezultāti parāda, ka 51 ± 4 % dalībniekiem novēro dažāda veida akomodācijas un verģences darbības traucējumus vai to kombinācijas. Visbiežāk novērotās problēmas ir akomodācijas ekscess un konverģences nepietiekamība. Netiek novērota dzimuma un vecuma ietekme uz akomodācijas un verģences darbības traucējumu izplatību.

Atslēgas vārdi: izplatība, akomodācijas darbības traucējumi, verģence darbības traucējumi, okulārā refrakcija.

ABSTRACT

The Master thesis is written in English on 35 pages. It contains 19 tables, 2 appendixes, and 16 references.

The aim of the thesis is to investigate the prevalence and types of accommodative and vergence dysfunctions among students in Baku city capital of Azerbaijan. 192 participants (15-36 years old) had participated in free eye examinations where detailed refractive, accommodative and vergence examination was performed. The results demonstrate that 51 ± 4% of participants have accommodative or vergence dysfunctions or their combinations. The most dominant dysfunctions are accommodative excess and convergence insufficiency. There are no effect of gender or age of the participant on the prevalence of the accommodative and vergence dysfunction.

Keywords: prevalence, accommodative dysfunctions, vergence dysfunctions, ocular refraction.

TABLE OF CONTENT

ABBREVIATIONS

AE – accommodative excess

PRA – positive relative accommodation

NRA – negative relative accommodation

AF – accommodative facility

AIF – accommodation insufficiency

CI – convergence insufficiency

CE – excess of convergence

DI – divergence insufficiency

DE – divergence excess

PFV – positive fusion vergence

NFV – negative fusion vergence

NPC – near point of convergence

FVD – fusional vergence dysfunction

VH – vertical heterophoria

BE – basic esophoria

BX – basic exophoria

AC/A – accommodative convergence/accommodation ratio

AD – accommodative dysfunction

BD – binocular dysfunction

ISA – ill sustained accommodation

UA – unequal accommodation

PA – paralysis of accommodation

INTRODACTION

If we look back to our previous generations, when survival depended on hunting, fishing, and farming, we can see that the most important visual functions were good distance visual acuity and stereoscopic vision. The visual system had to respond to changing distance stimuli. Today the emphasis has shifted from distance to two-dimensional near vision tasks such as reading, desk work, and computer work. Most people who lack appropriate accommodative and vergence abilities try to accomplish near vision tasks and start to have developing ocular discomfort or become fatigued and observe reduction of visual performance. Symptoms often associated with accommodative and vergence dysfunctions include blurred vision, headache, ocular discomfort, ocular or systemic fatigue, diplopia, motion sickness, and loss of concentration during work (Cooper et al., 2011). The accommodative and vergence dysfunctions combined with their impact on everyday activities, make this significant area of concern.

An optometrist is the first health care practitioner who diagnoses patients with accommodative or vergence dysfunctions. Examination, diagnostic, treatment, and management options are described to reduce the risk of visual disability from these binocular vision anomalies.

There are no studies demonstrating the prevalence of accommodative and vergence dysfunctions in some countries such as Azerbaijan. Therefore, the aim of the thesis is to investigate the prevalence and types of accommodative and vergence dysfunctions among students in Baku city capital of Azerbaijan. 192 students (15-36 years old) from universities had participated in free eye examinations. During the eye exam, the special designed protocol (see Appendix 1) were used that contained the information about subjective and objective refraction, anamnesis, dominant eye, binocular balance, accommodative amplitude, positive (PA) and negative (NA) accommodation, accommodative facility (AF), accommodative convergence and accommodation (AC/A) ratio, sensory state and stereopsis, phoria or tropia, and fusional vergence.

The objectives of the thesis are:

1. to evaluate the prevalence of accommodative and vergence dysfunctions;
2. to specify the main types of accommodative and vergence dysfunctions;
3. to specify the prevalence of accommodative and vergence dysfunctions according to age.

The hypothesis of the study is that prevalence of accommodation and vergence dysfunction in Azerbaijan will be similar to the results in other studies at the same geographic region. According to the results, we can evaluate if these problems are more/less in our country and discuss the reason of it.

1. LITERATURE REVIEW

1.1. Types of accommodative dysfunctions

Six types of accommodative dysfunctions can be classified: accommodative excess (AE), accommodative insufficiency (AI), accommodative infacility (AIF), ill-sustained accommodation (ISA), unequal accommodation (UA) and paresis (paralyses) of accommodation (PA). Patients can have any of these dysfunctions. Some of these dysfunctions are not functional. For example, etiology of paresis and unequal accommodation is neurological or traumatic, but other types have functional causes. Crystalline lens or third cranial nerve pathologic condition (such as a result of trauma, toxify, cycloplegic agents, or neuropathy) can be the reason of paresis or paralyzes of accommodation (Griffin & Grisham, 2002).

There are variety of symptoms that are observed in patients with accommodative dysfunction (see Table 1.1). Most of them are nonspecific and cannot be treated as a diagnostic tool.

Table 1.1

Symptoms in accommodative anomalies (Wajuihian & Hansraj, 2015).

Number	Symptoms
1	Blurred vision for near tasks
2	Headaches/eyestrain/dull orbital pain/pulling sensation around the eyes
3	Loss of comprehension/avoidance of near work
4	Watering or conjunctival or eyelids irritation, sensitivity to light
5	Eye fatigue/dizziness/sleepiness
6	Blurred vision worse after reading/near work
7	Difficulty focusing from far to near, or near to far
8	Holds reading material close or farther way
9	Difficulty sustaining attention on near point tasks; distance blur after performing near work

AI is defined as “insufficient amplitude of accommodation to afford clear imagery of a stimulus object at a specified distance, usually the normal or desired reading distance” (Griffin & Grisham, 2002). Usually this type of disorder can be found in presbyopic patients. In such case, it is considered as physiological disorder. However, it can be also pathological if it is observed in a young or pre-presbyopic persons. Thus, all age groups can suffer from this condition. The indicator of AI is abnormal accommodation amplitude, positive relative accommodation (PRA) and negative relative accommodation (NRA), fail of accommodation facility test.

The most common complaint in the case of ISA is blurred vision after prolonged near work. This problem is very similar to AI. One of the symptoms is reduced positive relative accommodation rate (Wajuihian & Hansraj, 2015). To mesure the degree of ISA, vision specialists have to use accomodative facility test. This test should be carried out for at least 1 min because ISA depend on an accommodative stamina. Thus, at the begining of test, patient can demonstrate normal speed of accommodation but efforts can decrease after a few cycles (Griffin & Grisham, 2002).

Another diagnosis of accommodative dysfunction is AIF. These patients have trouble in changing accommodative response when switching focus between far and near and back. They have asthenopia, difficulty with concentration, intermittent blur during near work (Cacho-Martinez et al., 2010).

The main symptom of AE is blurred vision at distance and near after prolonged work at near. İn case of AE, patient has difficulty in relaxing accommodation, and showing greater accommodative response on stimulus. During the eye examination, patient fails accommodative facility test, especially showing difficulty with +2.00 D during monocualr accommodative facility testing. In addition, there are abnormal result of PRA and NRA. Another symptom of AE is that a patient tries to bring stimulus closer to the eye while doing near work. To be accurate with diagnos of AE, using of dynamic retinoscopy is very important. If patient's accommodative responce during the Nott or MEM tests leads the accommodative stimuli by 0.25 D, we can be sure that AE is presented. AE diagnosis can be used in case of accommodative spasm and pseudo-myopia (AE can induce pseudo myopia) (Griffin & Grisham, 2002; Wajuihian & Hansraj, 2015). Thus, accommodative spasm appears as a spasm of cyliary muscle that do not allow normal functions of accommodation and creates extreamly blured and hurdly correctable vision at distanec and near (Griffin & Grisham, 2002). Another form of AE is sustained accommodation or so called "night myopia" which is not abnormal if in the range of 1.00 D without dioptric stimulus (Griffin & Grisham, 2002). AE can occur also as a secondary problem like in a patients with insufficient positive fusional convergence. They try to over-accommodate to maintain fusion and thus create AE (Griffin & Grisham, 2002).

The main diagnostic tools for accommodative dysfunctions are visual function examination results. Most analyzed accommodative disorders are AI, AE, and AIF, but their diagnosis criteria vary in different studies. Thus, Table 1.2 presents diagnostic criteria for accommodative dysfunctions used by Hosseini-Yazdi et al. (2015). Not all signs should be presented to make appropriate diagnoses, however, there are mandatory and optional signs (see Table 1.2).

Table 1.2

Diagnosis criteria for accommodative disorders (Hosseini-Yazdi et al., 2015).

Accommodative excess

Signs: Need to be present signs 1-3, and two of 4-6.

1) Variable visual acuity findings.
2) Variable static retinoscopy and subjective refraction.
3) Difficulty clearing +2.00 D with monocular accommodative facility, ≤6 cpm.
4) Difficulty clearing +2.00 D with binocular accommodative facility, ≤3 cpm.
5) Low MEM finding, <+0.25 D.
6) Reduced negative relative accommodation (NRA), ≤1.50 D.

Accommodative infacility

Signs: Need to be present signs 1 and 2.

1) Fails binocular and monocular accommodative facility assessment using ±2.00 D lenses, monocular ≤6 cpm, and binocular ≤3 cpm.
2) Low positive and negative relative accommodation, PRA ≤1.25 D, NRA ≤1.50 D.

Accommodative insufficiency

Signs: Need to be present signs 1 and 2, and two of 3-5.

1) Reduced amplitude of accommodation. Push-up accommodative amplitude at least 2.00 D below Hofstetter's calculation for minimum age-appropriate amplitude: 15 - 0.25 * age.
2) Fails monocular accommodative facility with -2.00 D, ≤6 cpm.
3) Fails binocular accommodative facility with -2.00 D, ≤3 cpm.
4) High MEM finding, >+0.75 D.
5) Low PRA, ≤ 1.25 D.

Table 1.3

Diagnosis criteria for accommodative disorders (Garcia-Munoz et al., 2016).

Dysfunction	Fundamental signs	Complementary signs
Accommodative excess	MAF <6 cpm with +2.00 D lenses	PRA ≥3.50 D BAF <6 cpm (difficulty with +2.00 D lenses) MEM <0.25 D NRA <1.50 D
Accommodative infacility	MAF <6 cpm with ±2.00 D lenses	BAF <3 cpm (difficulty with ±2.00 D lenses) PRA <1.25 D NRA <1.50 D
Accommodative insufficiency	Reduced AA: 2.00 D < Minimum AA (15-0.25 x age)	MAF <6 cpm (difficulty with -2.00 D lenses) BAF <3 cpm (difficulty with -2.00 D lenses) MEM >0.75 D PRA <1.25 D

Similar system was used by Garcia-Munoz et al. (2016) to diagnose accommodative dysfunctions. They divided them in fundamental and complementary signs (see Table 1.3). To make any diagnoses of accommodative disorder, they had to present fundamental signs and at least two or more complementary signs. Most of them were based on the criteria previously described by Scheiman & Wick in their book (2002) (Cacho-Martinez et al., 2010) (see Table 1.4).

Table 1.4

Diagnosis criteria for accommodative disorders (given by Scheiman & Wick, 2002 and summarized in Cacho-Martinez et al., 2010).

Disorder	Definition	Characteristics	
		Symptoms	Signs
Accommodative excess	Condition in which the patient has difficulty with relaxation of accommodation.	Asthenopia and headaches associated with near tasks and intermittent blurred distance vision.	• Variable visual acuity findings. • Variable static and subjective. • Low degree of against-the rule-cylinder • Low MEM or FCC findings. • Low negative relative accommodative (NRA). • Fails MAF and BAF facility with +2.00 D.
Accommodative infacility	Condition in which the patient has difficulty in changing the accommodative response level.	Difficulty focusing from distance to near and near to distance, asthenopia associated with near tasks, difficulty with attention and concentration when reading, intermittent blur associated with near tasks.	• Fails MAF and BAF with ±2.00 D. • Low PRA and NRA.
Accommodative insufficiency	Condition in which the patient has difficulty stimulating accommodation.	Very similar to those associated with presbyopia. Are associated with near tasks, may include: blurred near vision, discomfort and strain, fatigue and difficulty with attention and concentration when reading.	• Low accommodative amplitude (AA). • Low positive relative accommodation (PRA). • Fails monocular and binocular accommodative facility (MAF, BAF) with -2.00 D. • High MEM or fused cross-cylinder (FCC) findings.

1.2 Types of vergence dysfunctions

A lot of people suffer also from vergence dysfunction but do not know about it. There are many types of vergence dysfunctions or also called binocular dysfunctions (also non-strabismic binocular anomalies) (Cacho-Martinez et al., 2010): convergence insufficiency (CI), convergence excess (CE), divergence insufficiency (DI), divergence excess (DE), basic exophoria (BX), basic esophoria (BE), fusional vergence dysfunction (FVD), and vertical heterophoria (VH).

The most common and better studied vergence dysfunction is CI. However, the etiology of this problem is not well known yet and there are a lot of hypotheses. Most of the time symptoms occur when a person starts to work on computers or other devices, or during visually demanding work. CI symptoms are associated with headaches, asthenopia, blurred vision

during reading, low rate of NPC (near point of convergence), exophoria at near, reduced positive fusional convergence (PFV), and a low result of NRA (Cooper et al., 2011). In some of the cases, CI is classified as a supranuclear disorder of ocular motility. Coordination of convergence eye movements are regulated in our midbrain and pons. Some part of our cerebellum receive signal about near response and initiate vergence tracking. If there is any imbalance, the process of convergence can be very poor, and it is also reducing our accommodation abilities (Brune & Eggenberger, 2018).

The etiology of CE is hyperkinetic convergence to near stimuli. CE is rarer dysfunction with a high degree of AC/A ratio (gradient method), a higher degree of esophoria at near than at distance (the difference is at least 3 pd), low negative fusional reserves, and low degree of PRA (Salmanova, 2016).

Patients with DI usually have esophoria, that is higher at distance than at near, and low AC/A ratio. They can experience symptoms including intermittent blur and intermittent diplopia that tend not to change within time (Cacho-Martinez et al., 2010). Usually patients with primary DI have horizontal double vision at distance (intermittent or constant), normal fusion at near, and reduced divergence amplitude. The secondary DI have neurologic reason and start with distance esotropia (Kirkeby, 2014).

The most widely accepted theory of DE etiology involves innervation and is based upon the use of the eyes. Patients with this diagnosis have exophoria at near much less than at distance (at least 10 pd difference), and AC/A ratio is high (Cacho-Martinez et al., 2010). There is a theory that DE appears at approximately 6 years old because of heavy near work condition. For this reason, some articles say that DE is closely related to an accommodative anomaly (Cooper, 1977). We can recognize two types of DE: true and simulated DE. The true is intermittent with high AC/A ratio and is not affected by occlusion. However, simulated DE is so called pseudodivergence excess which characterized with small angle of deviation at near compared to distance, but it becomes equal after occlusion. Usually DE reported with diplopia and asthenopia which is a result of intermittent divergent squint. Near point of convergence, accommodation and stereopsis is normal (Daum, 1984).

Patients with BX show nearly equal degree of exophoria at distance and near. They have nonspecific complaints like asthenopia and intermittent diplopia either at distance or at near, AC/A ratio is normal. At the end of the day these symptoms can increase (Cacho-Martinez et al., 2010).

Similarly, we can describe patients with BE. They have nearly equal degree of esophoria at distance and near and normal AC/A ratio. They also can experience asthenopia, intermittent

diplopia either at distance or at near and intermittent blur. All symptoms can get worse at the end of the day (Cacho-Martinez et al., 2010).

FVD is less known vergence disorder with uncertain etiology. It does not show any disorder until asthenopia occurs. Patients have problems with reading at near, intermittent blur, burning tearing, sleepiness when reading. At the same time, the only finding is reduced fusional ability at distance and near (Cacho-Martinez et al., 2010).

VH can have neurological, cardiovascular and traumatic reasons. Symptoms are hyper or hypophoria. Usual complaints are losing place while reading, sleepiness, and inability to concentrate during visual tasks (Cacho-Martinez et al., 2010).

As can be seen, there is not a lot information about BX, BE, FVD, and VH in the literature. One reason is that these are quite rare and make a small percentage of diagnostic statistics. In Table 1.5, more detailed description of each non-strabismic binocular anomaly can be found as given by Scheiman and Wick (2002) in the work of (Cacho-Martinez et al., 2010).

Table 1.5

Classification of non-strabismic binocular anomalies (given by Scheiman & Wick, 2002 and summarized in Cacho-Martinez et al., 2010).

		Characteristic	
Disorder	**Definition**	**Symptoms**	**Signs**
Convergence insufficiency	Patient with orthophoria or exophoria at distance, low AC/A ratio and significant exophoria at near greater than the distance phoria.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, intermittent diplopia, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, words move on the page, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Greater exophoria at near than at distance • Reduced positive fusional vergence (PFV) at near • Reduced vergence facility at near with base-out prisms. • Intermittent suppression at near. • If suppression is significant, stereopsis may be reduced. • Receded near point of convergence. • Low AC/A ratio. • Fails BAF with +2.00 D. • Low MEM or FCC. • Low NRA. • Exofixation disparity.
Divergence insufficiency	Patient with esophoria at distance, low AC/A ratio and distance phoria will be significantly greater than the near phoria.	Asthenopia associated with distance tasks. May include: intermittent blur or diplopia at distance, symptoms worse at the end of day, symptoms are generally	• Esophoria greater at distance than at near. • Reduced negative fusional vergence (NFV). • Reduced vergence facility at distance with base-in prism. • Esofixation disparity at distance.

		longstanding, in contrast to a recent history of acute symptoms.	
Convergence excess	Patient with orthophoria or moderate degree of esophoria at distance, high AC/A ratio and esophoria at near significantly greater than that at distance.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, intermittent diplopia, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, words move on the page, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Significant esophoria at near, greater than at distance. • Reduced negative fusional vergence (NFV) at near. • Reduced vergence facility at near with base-in prisms. • Low PRA. • Fails BAF with -2.00 D. • High MEM or FCC. • Esofixation disparity.
Divergence excess	Patient with a low to moderate degree of exophoria at distance and a high AC/A ratio, with a degree of exophoria at near significantly less than that at distance.	Associated with distance tasks: complain of eye turning out, occasional near point asthenopia, patient closes one eye in bright light.	• Greater exophoria at distance than at near. • High AC/A ratio. • Suppression at far. • Limited NFV, adequate PFV. • Difficulty with first and second degree of fusion.
Fusional vergence dysfunction	Patient with orthophoria at distance and near or a low degree of phoria at far and near, with fusional vergence ranges reduced in both base-in and base-out directions.	Associated with reading and near tasks. May include: asthenopia and headaches, intermittent blur, symptoms worse at the end of day, burning, tearing, inability to sustain and concentrate at near, sleepiness when reading, decreased reading comprehension over time, slow reading.	• Ortophoria or low degree of eso- or exophoria at distance and near. • Reduced PFV and NFV at far and near. • Reduced vergence facility with both base-out and base-in prism. • Low PRA and NRA. • Fails BAF with ±2.00 D.
Basic esophoria	Patient with esophoria at distance and a normal AC/A ratio, with near phoria approximately equal to the distance phoria.	Associated with distance and near tasks. May include: asthenopia, intermittent blur, intermittent diplopia and symptoms worse at the end of day.	• Esophoria of approximately equal magnitude at near and at distance. • Reduced NFV at far and near. • Reduced vergence facility at distance and near with base-in prism. • Low PRA. • Fails BAF with -2.00 D. • High MEM or FCC findings.

			• Esofixation disparity at far and near.
Basic exophoria	Patient with exophoria at distance and a normal AC/A ratio, with near phoria approximately equal to the distance phoria.	Associated with distance and near tasks. May include: asthenopia, intermittent blur, intermittent diplopia and symptoms worse at the end of day.	• Exophoria of approximately equal magnitude at near and at distance. • Reduced PFV at far and near. • Reduced vergence facility at distance and near with base-out prism. • Low NRA. • Fails BAF with +2.00 D. • Low MEM or FCC findings. • Exofixation disparity at near and distance.
Vertical deviations	Patient with either hyper or hypophoria.	Blurred vision, headaches, asthenopia, diplopia, car and motion sickness, inability to attend and concentrate during sustained visual tasks, sleepiness, loses place when reading.	• Anomalous head position. • Hyperphoria. • Reduced PFV y NFV. • Reduced vergence facility at distance and near with base-out and base-in prism. • Vertical fusional vergence may be reduced or unusually large, depending on the duration of the vertical deviation.

Hosseini-Yazdi et al. (2015) used more specific diagnosis criteria analyzing various convergence disorders in Iran, where they added also basic exophoria (see Table 1.6). This is quite similar to one used by Garcia-Munoz et al. (2016) (see Table 1.7).

Table 1.6

Diagnosis criteria for convergence disorders (Hosseini-Yazdi et al., 2015).

Convergence insufficiency

Signs: Need to be present signs 1-3, and two of 4-7.

1) Moderate to high exophoria at near, >6 pd.
2) Reduced positive fusional vergence at near, ≤11/14/3 for blur, diplopia and recovery (at least one of three).
3) Receded near point of convergence, >10 cm for loss of fusion, >17.5 cm for recovery.
4) Low calculated AC/A ratio, <3/1.
5) Fails binocular accommodative facility testing with +2.00 D, ≤3 cpm.
6) Low MEM, <+0.25 D.
7) Low NRA, ≤1.50 D.

Convergence excess

Signs: Need to be present signs 1-2, and two of 3-6.

1) Significant esophoria at near, >2 pd.
2) Reduced negative fusional vergence at near, ≤8/16/7 for blur, diplopia and recovery (at least one of three).
3) High calculated AC/A ratio, >7/1.
4) Fails binocular accommodative facility with -2.00 D, ≤3 cpm.
5) High MEM, >+0.75 D.
6) Low PRA, ≤1.25 D.

Basic Exophoria

Signs: Need to be present signs 1-2, and two of 3-6.

1) Exophoria of approximately of equal magnitude at near and distance (within 5 pd).
2) Reduced positive fusional vergence at distance and near, ≤11/14/3 and ≤4/8/5 for blur, diplopia and recovery for near and distance, respectively.
3) Normal AC/A ratio.
4) Fails binocular accommodative facility with +2.00 D, ≤3 cpm.
5) Low MEM, <+0.25 D.
6) Reduced NRA, ≤1.50 D

Table 1.7

Diagnosis criteria for binocular dysfunctions (Garcia-Munoz et al., 2016).

Dysfunction	Fundamental signs	Complementary signs
Convergence insufficiency	Significant exophoria at near (≥6 pd), greater than at far	PFV at near ≤11/14/3 pd (at least one of three) NPC ≥6 cm VF ≤13 cpm (difficulty with 12 pd base out) BAF <3 cpm (difficulty with +2.00 D) MEM <+0.25 D NRA <1.50 D
Convergence excess	Significant esophoria at near (≥1 pd), greater than at far	NFV at near ≤8/16/7 pd (at least one of three) VF ≤13 cpm (difficulty with 3 pd base in) BAF <3 cpm (difficulty with -2.00 D) MEM >+0.75 D PRA <1.25 D
Divergence excess	Significant exophoria at far (≥4 pd), greater than at near (the difference must be >5 pd)	PFV at far ≤4/10/5 pd (at least one of three) PFV at near ≤11/14/3 pd (at least one of three) NPC ≥6 cm VF ≤13 cpm (difficulty with 12 pd base out) BAF <3 cpm (difficulty with +2.00 D) MEM <+0.25 D NRA <1.50 D
Basic esophoria	Significant esophoria at far and near of equal amount (difference <5 pd is considered equal)	NFV at far ≤X/3/1 and near ≤8/16/7 pd (at least one of three) VF ≤13 cpm (difficulty with 3 pd base in) BAF <3 cpm (difficulty with -2.00 D) MEM >+0.75 D PRA <1.25 D
Basic exophoria	Significant exophoria at far and near of equal amount (difference <5 pd is considered equal)	PFV at far ≤4/10/5 pd and near ≤11/14/3 pd (at least one of three) NPC ≥6 cm VF ≤13 cpm (difficulty with 12 pd base out) BAF <3 cpm (difficulty with +2.00 D) MEM <+0.25 D NRA <1.50 D
Fusional vergence dysfunctions	PFV and NFV reduced at far and near, or VF ≤13 cpm (difficulty with 3 pd base in and 12 pd base out)	BAF <3 cpm (difficulty with ±2.00 D) PRA <1.25 D and NRA <1.50 D

1.3. Prevalence of accommodative and vergence dysfunctions

As can be seen from Tables 1.4-1.6, the criteria can vary (for example, Garcia-Munoz et al. (2016) did not consider the AC/A ratio that is considered in the study of Hosseini-Yazdi et al. (2015). These differences in the diagnoses criteria as well as the age group differences among various studies lead to wide deviation in the prevalence of accommodative and vergence dysfunctions. Hosseini-Yazdi et al. (2015) noticed that some studies (Dwyer, 1192; Pickwell & Stephens, 1975 – cited by Hosseini-Yazdi et al., 2015) applied only one sign to diagnose CI such as decreased near point of convergence or uncompensated near exophoria and reported a prevalence of anomaly 33% and 12%, respectively. Hosseini-Yazdi et al. (2015) also reported the work of Dwyer and Wick (1995) where accommodative and binocular problems were noticed in 58% of patients less than 35 years old using a maximum of 2 criteria. In comparison, Hosseini-Yazdi et al. (2015) describes also work of Porcar and Martinez-Palomera (1997) where nearly all necessary tests were used to have more accurate results. They found a prevalence of accommodative and binocular disorders to be 32,3% among 65 university students. The most common form of disorder was AE. Similar results were noticed by Lara et al. (2001) were around 22.3% of their clinic population had some form of accommodative and vergence disorder and the most popular one was AE. In contrast, other study (Montes-Mico, 2001 – cited by Hosseini-Yazdi et al., 2015) demonstrates a high prevalence of binocular dysfunctions (nearly 56%) with AI as the most dominant one.

In their own study in the Mashhad University of Medical Sciences in Iran, Hosseini-Yazdi et al. (2015) tried to use maximum number of diagnostic criteria and had wide range of examinations: eye examination including visual acuity measurement, slit-lamp examination, objective and subjective refraction, evaluation of accommodation and convergence functions – near point of convergence (push up technic with accommodative target), distance and near heterophoria (alternate prism and cover test), MAF and BAF (±2.00 D flipper), accommodative amplitude (push up method), PRA and NRA, lag of accommodation (retinoscopy, MEM), calculated AC/A ratio, PFV and NFV at distance and near (prism bar). To diagnose accommodative and non-strabismic binocular disorders, they use certain criteria's (see Table 1.2 and Table 1.6). In addition, they classified patients in symptomatic and asymptomatic groups for each disorder. They had 83 patients (21.3±3.5 year) and only 16 of them (19.3%) had some accommodative and non-strabismic binocular disorders (see Table 1.8). 4 patients had a combination of accommodative and binocular disorder. Thus, they demonstrated that some patients had both, accommodative and vergence disorders.

Table 1.8

Frequency of convergence and accommodative disorders in study of Hosseini-Yazdi et al. (2015).

	Frequency	**Percent**
Normal	67	80.7
Accommodative Disorders	**6**	**7.2**
Accommodative excess	3	3.6
Accommodative excess and accommodative infacility	1	1.2
Accommodative insufficiency	2	2.4
Binocular Disorders	**10**	**12.1**
Convergence insufficiency	3	3.6
Convergence insufficiency and accommodative excess	1	1.2
Convergence excess	2	2.4
Convergence excess and accommodative insufficiency	1	1.2
Convergence excess and accommodative excess	1	1.2
Basic exophoria	1	1.2
Basic exophoria and accommodative excess	1	1.2

Not all patients with accommodative or vergence dysfunction will be symptomatic. Hosseini-Yazdi et al. (2015) tried to explain it based on the fact, that persons with dysfunctions will avoid near work and visual demanding tasks and thus will report no symptoms. As can be seen in Table 1.9, seven patients with some disorder did not experience any symptoms. All patients with accommodative excess (either as an isolated dysfunction or as a result of a binocular anomaly) presented with symptoms, but all patients with binocular anomaly but without additional accommodative disorder were asymptomatic.

Table 1.9

Comparative of asymptomatic and symptomatic patients in each diagnostic category in study of Hosseini-Yazdi et al. (2015).

	Asymptomatic	Symptomatic
Accommodative excess	0	3 (100%)
Accommodative excess and accommodative infacility	0	1 (100%)
Convergence excess and accommodative excess	0	1 (100%)
Convergence insufficiency and accommodative excess	0	1 (100%)
Basic exophoria and accommodative excess	0	1 (100%)
Convergence excess and accommodative insufficiency	0	1 (100%)
Accommodative insufficiency	1 (50%)	1 (50%)
Convergence excess	2 (100%)	0
Convergence insufficiency	3 (100%)	0
Basic exophoria	1 (100%)	0
Normal (Refractive error)	64 (95.5%)	3 (4.5%)
Total	71 (85.5%)	12 (14.5%)

Similar study was performed by the group of researchers from the University of Alicante (Universidad de Alicante) in Spain (Garcia-Munoz et al., 2016). They studied the prevalence of accommodative and binocular dysfunctions in 175 students (18-35 years). All participants had a visual health examination and a refractive examination, as well as a full set of binocular and accommodation function assessment. The diagnoses of accommodative and vergence disorder was made based of defined criteria (see Table 1.3. and 1.7). The results of their research is demonstrated in Table 1.10. They concluded that binocular disorders are more prevalent than accommodative dysfunctions or their combination (Garcia-Munoz et al., 2016).

Most of the studies had analyzed the prevalence of separate disorders. Thus, Brune and Eggenberger (2018) reviewed other studies where they noticed that prevalence of CI is increasing in the population with high rate of prolonged near work. In USA, prevalence of CI in children is estimated as 4.2-6%, in adults – 8.4% per 100,000 populations, and nearly 70% in older people (80-90 years old). In children younger than 10 years, CI was reported very rare (Brune & Eggenberger, 2018). Kirkeby (2014) described the study of Martinez-Thomson et al. (2013) where prevalence of divergence insufficiency esotropia was 10.6% in patients with adult onset strabismus (median age of patients was 74 years, with a range of 19 to 92 years) but the incidence of patients with DI was found to be 6%.

Table 1.10

Prevalence of accommodative and binocular dysfunctions in a study of Garcia-Munoz et al. (2016).

Dysfunction	**Patients**		**Prevalence**	**Patients with symptoms**
	Number	**%**	**95% confidence interval**	
Normal group	73	41.71	34.32–49.39	14
Refractive dysfunction	79	45.14	37.62–52.83	41
Accommodative and/or binocular dysfunction	23	13.15	8.52–19.07	23
Accommodative dysfunction	**4**	**2.29**	**0.63–5.75**	
AE	4	2.29	0.63–5.75	
Binocular dysfunction	**14**	**8.00**	**4.44–13.06**	
CI	6	3.43	1.27–7.31	
CE	4	2.29	0.63–5.75	
DE	1	0.57	0.01–3.14	
Basic exophoria	1	0.57	0.01–3.14	
Basic esophoria	2	1.14	0.14–4.07	
AD + BD	**5**	**2.86**	**0.93–6.54**	
CI + AI	2	1.14	0.14–4.07	
CI + AE	1	0.57	0.01–3.14	
CE + AI	1	0.57	0.01–3.14	
FVD + AI	1	0.57	0.01–3.14	
Total patients	175	100%		78

AI: accommodative insufficiency, AE: accommodative excess, CI: convergence insufficiency, CE: convergence excess, DE: divergence excess, FVD: fusional vergence dysfunction, AD: accommodative dysfunction, BD: binocular dysfunction.

Borsting et al. (2003) observed the prevalence of CI in 392 school age children (8 to 15 years old) from 2 public and 2 private schools in Southern California with no strabismus and minimal uncorrected refractive error. He used Modified Clinical Technic screening method. They observed that 55% had normal binocular vision with bigger exophoria at near than at far, and only 0.8% of them had exophoria with reduced fusional vergence. They concluded that prevalence of CI in his researched group is lower than in clinical population.

Wajuihian and Hansraj (2015) analyzed various studies about prevalence of CE and noticed that Shin et al. (2009) found 2.4% from 114 schoolchildren in South Korea (9 to 13 years old) with CE; Scheiman et al. (1996) had 7.1% of CE and significantly higher results with age and in black children than in white; Dusek et al. (2010) had 8.2% prevalence of CE in 328 clinical patients (6 to 14 years) in Austria; Dwyer and Wick (1995) reported 15% of 144 patients (7 to 18 years) having CE.

Table 1.11

The prevalence of accommodative insufficiency (AI) by age, gender and refractive errors in the study of Hashemi et al. (2019).

		AI %	(95% CI)
	Total	4.07	(2.61-5.52)
Gender	Female	6.04	(3.58-8.50)
	Male	2.01	(0.53-3.48)
Age (years)	18-19	2.59	(0.55-7.56)[a]
	20-21	4.45	(2.07-6.83)
	22-23	4.35	(1.55-7.15)
	24-25	4.08	(0.09-8.07)
Refractive errors (diopters)	Emmetropia	3.74	(1.88-5.61)
	Myopia	4.44	(2.07-6.81)
	Hyperopia	5.26	(4.79-16.32)

CI: confidential interval.
[a] The 95% CI was calculated using binominal distribution.

Specific study about AI was performed by Hashemi et al. (2019) in a student population in Iran at Shahrekord University. The aim of the researchers was to understand the prevalence of AI in relation to the age, gender, and refractive error. They did the basic optometric examination including binocular and accommodative tests: objective refraction (auto-refractometer and retinoscopy), subjective refraction to get the best visual acuity, heterophoria at far and near (alternated prism cover test at 6 m and 40 cm, respectively, using prism bar), amplitude of accommodation (Donders push-up method), monocular accommodative facility

and dynamic retinoscopy for near (40 cm). They excluded students with pathologic diseases, ocular traumas or ocular surgery in medical history. There were 713 students (21±2 years; 364 female). The prevalence of AI is demonstrated in Table 1.11.

Summary of studies on accommodative insufficiency as presented by Hashemi et al. (2019). **Table 1.12**

Author/s and year of study	Prevalence (%)	Target population	Type of population	Number of diagnostic signs
Hussaindeen et al. (2016)	0.2	School	Children	4
Scheiman et al. (1996)	2.0	Optometric clinic	Children	5
Lara et al. (2001)	3.0	Optometric clinic	Children and young adults	4
Hashemi et al. (2019)	4.1	University	Young adults	3
Porcar & Martinez-Palomera (1997)	6.2	University	Young adults	5
Rouse et al. (1999)	9.9	School	Children	2
Borsting et al. (2003)	10.5	School	Children	1
Dwyer (1992)	13.0	Optometric clinic	Children	3
	16.0			2
Abdul-Kabiret al. (2014)	31.8	School	Children	1
Paniccia & Angel Romero Ayala (2015)	39.0	Optometric clinic	Children	4
Abdi & Rydberg (2005)	61.7	NR	Children	1

NR: not reported

Table 1.13

Summary of studies on accommodative insufficiency with prevalence's (Wajuihian & Hansraj, 2015).

Author/s and year of study	Country of study	Study setting	Age (years)	Sample size	Prevalence (%)
Borsting et al. (2003)	USA	School setting	8–15	392	17
Marran et al. (2006)	USA	School setting	11.5	299	4.7
Sterner et al. (2004)	Sweden	School setting	6–10	76	34
Abdi and Rydberg (2005)	Sweden	School setting	6–16	120	24.2
Abdi et al. (2008)	Sweden	School setting	6–16	216	11.1
Shin et al. (2009)	South Korea	School setting	9–13	114	18.3
Dwyer (1992)	Australia	Optometric practice	7–18	144	0.7
Dusek et al. (2010)	Austria	Optometric practice	6–14	328	0.6
Scheiman et al. (1996)	USA	University clinic	6–18	1650	2.3
Benzoni and Rosenfield (2012)	USA	University clinic	5–10	60	36
Helveston et al. (1985)	USA	School setting	N/A	1910	7–10
Wajuihian and Hansraj (2014)	South Africa	School setting	13–19	65	1.6
Moodley (2008)	South Africa	School setting	6–13	264	24
Metsing and Ferreira (2012)	South Africa	School setting	8–13	112	10
Wick and Hall (1987)	USA	School setting	6–12	200	25

Hashemi et al. (2019) demonstrated significant difference in prevalence of AI between men and women. The prevalence of AI in woman was 3 times higher (6%) than in men (2%). They observed no association between AI and refractive error or the age of the patients. In conclusion, they noticed that prevalence of AI in Iran is much lower (4.07%) than reported in other studies (see Table 1.12) (Hashemi et al., 2019). Similar analyses of other studies considering AI prevalence was performed by Wajuihian & Hansraj (2015) (see table 1.13).

If the results are compared, it can be seen that the prevalence of accommodative and vergence dysfunction differ in various studies due to different diagnostic criteria, the number of signs included, as well as due to population and, probably, also region analyzed. However, both types of dysfunctions are observed in children and young adults (a non-presbyopic group) even if they are not complaining. The most severe problems would be combinations of accommodative and vergence dysfunctions.

2. DATA AND METHODS

2.1. Participants

With the help of social internet resources, we invited students from various Universities in Baku, Azerbaijan, to participate in the research. 192 registered to eye examination (15-36 years old, male 42, female 150). All participants signed the informed consent form and the study was conducted in accordance with the tenets of the Helsinki Declaration. All participants had full eye examination (following the previously defined study protocol, see Appendix 2). All examinations were performed by four persons: the author of the master's thesis and two ophthalmologists Leyla Guluzade, Sabina Gurbanli, and Gunel Mammadova. Eye examination was performed in optometrist room in optic shop in Baku.

2.2. Methods

As the first step, special instruction (Appendix 1) and Protocol of eye examination (Appendix 2) were created. Instructions included the description of all methods of evaluation performed during examination.

Anamnesis

Examiner had to take information about name and surname of patient, age of patient, existing glasses or contact lenses, information about time and result of previous eye examination, demographic data, ocular history, medical history, drugs and medications, family ocular history, social history, review of systems (cardiovascular, endocrine, dermatological, psychiatric etc.), scope of questions about complains. During examination, we used questions mentioned in the Table 1.1.

Dominant eye and visual acuity

Dolman or Porta test to find motor dominant eye at the distance and Litinsky test to find motor dominant eye at near. To find sensory dominant eye, either red filter test or +2.00 D trial lens was used.

Corrected (if patient already used glasses or contact lenses) and non-corrected visual acuity was assessed for distance (5 m) and near (40 cm) using Snellen visual acuity charts.

Objective and subjective refraction

Objective refraction was found using Autorefractokeratometr POTEC 6000. After objective refraction, subjective refraction was assessed by indicating each step in the protocol: a power of lens which was used for fogging, result of refraction, result of binocular balance. Snellen visual acuity charts were used (projector POTEC 700). The visual acuity line was accepted if patient can read at least 3 letters from 5 in the line. For the classification of refractive errors, we used parameters presented in Table 2.1.

Table 2.1

Criteria for diagnosis of refractive error.

Refractive error (D)	
Myopia	≤-0.25 D
Hyperopia	≥+0.25 D
Astigmatism	≤-0.25 D
Anisometropia	At least -1.0 D difference between both eyes spherical equivalent (sphere + ½ cylinder)

Accommodation tests

Visual acuity at near was checked with the subjective refraction found for distance. Than amplitude of accommodation was measured monocularly with push-up method. Calculated amplitude of accommodation was compared to the minimum required accommodation amplitude as defined by the age of the patient (Hostettler formula A= 15 – 0,25 * (age of patient in years). Decreased amplitude of accommodation was considered if patient's amplitude of accommodation was 2.00 D below the calculated one.

To evaluate positive relative and absolute accommodation, minus-power lenses and for negative relative and absolute accommodation test – plus-power lenses in monocular and binocular viewing condition were used over his/her subjective refraction. We occluded one eye of patient, instruct to read two lines less than his/her best visual acuity at near on Snellen near vision chart. The same procedure was repeated for the other eye. Plus, or minus power lenses were gradually increased with 0.25 D steps every 3 seconds until patient will not be able to read presenting line. In case of blur, we waited 5 seconds and, if vision had not cleared up, we stopped test and recorded one step below of last blur point. Accommodation facility was measured binocularly an monocularly (in each eye) with the flipper ±2.00 D. Test was evaluated during 1-minute time were we counted how many cycles (patient has to start to read stimulus 2 step below his actual visual acuity for near) patient can afford.

Convergence test

The next in the protocol is convergence test were ruler and pen was used. This technique is also well known as pencil push-up test, and here the near point of convergence NPC (Break Point) and recovery point of convergence (Recovery Point) were registered. Convergence measurement was performed with the best refractive correction.

Maddox Test

To evaluate phoria, Maddox test with prism bar was used for distance and near, with and without correction. Cover test and prism cover test was used to check tropias and phorias. In order to understand how accommodation and vergence work together (to evaluate gradient AC/A ratio), Maddox test was also done with +2.00 D and then -2.00 D trial lenses. Exophoria was analyzed as a negative value and esophoria – as a positive value. According to the results of these tests, gradient and calculated AC/A ratio was found:

Gradient AC/A ratio: AC/A ratio = (D'-D")/-F

where D' – near phoria with additional lenses (pd), D" - near phoria without additional lenses (pd), F – power of additional lens (D); eso is plus and exo is minus.

Calculated AC/A ratio: AC/A ratio = PD(cm) + N(m)*(D"-D)

where PD is a pupil distance in centimeters, N – is near fixation distance in meter, D" – near phoria (pd) (eso is plus and exo is minus), D – far phoria (pd) (eso is plus and exo is minus).

Fusional Vergence

During this test, horizontal (BO to stimulate convergence and BI to stimulate divergence) or vertical (BU and BD to stimulate vertical vergence) prism bar was placed in front of one eye (in our case, we put prism in front of the left eye (OS)) and patient is asked to fixate on stimulus (two lines below the best visual acuity). The same procedure was repeated for near and far. The blur, break, and recovery points. To assess sensory status at distance, Red Filter Test and Worth 4 Dot test were used.

2.3. Diagnostic criteria

We analysed seeral studies and the diagnostic criteria they used. The best review of various criteria were presented in the study of Wajuihian (2019) (See Table 2.2).

Table 2.2

Range of normal for stereoacuity, accommodative and vergence measures for the study performed by Wajuihian (2019).

Clincial measures	Measurement techniques in Wajuihian (2019)	Range of normal in Wajuihian (2019)	Haines (presbyopes) (1941a, 1941b)*	Morgan (1944)*	Scheiman and Wick (13-30 y.o.) (2015)
Vergence measures	Raf rule/Push up				
Near point of convergence (cm)					
NPC break		5 to 10			2.5 ± 2.5
NPC recovery		6 to 13			4.5 ± 3.0
Heterophoria (pd)	Von Graefe				
Distance					
Lateral		2 eso to 2 exo	1 eso to 1 exo	ortho to 2 exo	1 ±2 exo
Vertical		ortho to 0.5	less than 1	N/A	N/A
Near					
Near lateral		2.5 eso to 6 exo	2 to 8 exo	3 ± 3 exo	3 ± 3 exo
Near vertical		ortho to 0.5	N/A		
Fusion vergence (pd)	Prism bars				
Base in break		12-23	19 to 25	19 to 23	13 ± 6
Base in recovery		8-17	8 to 18	10 to 16	10 ± 5
Base out break		16-35	17 to 28	18 to 24	19 ± 9
Base out recovery		11-24	12 to 22	7 to 15	14 ± 7
Accommodative parameters					
Amplitude of accommodation (D)	RAF rule, push up	12 to 18	Based on Donder's table	Based on Daune's table	Based on Hofstetter's min expected
Accommodative response (D)	MEM	Plano to 0.75	0.62 to 1.50	1.25 to 1.50	0.50 ± 0.25 (1 SD)
Binocular accommodative facility (cpm)	Plus lenses on phoropter	1.75 to 2.50	N/A	N/A	10 ± 5 (1 SD)
Negative relative accommodation (DS)	Minus lenses on phoropter	-2.00 to -3.00	1.75 to 2.25	1.75 to 2.25	2.00 ± 0.50 (1 SD)
Positive relative accommodation (DS)	±2.00 D flipper lenses	5 to 12	-1.50 to -2.75	-1.75 to -3.00	-2.37 ± 1.00 (1 SD)
AC/A ratio (pd/D)	Calculated	5 to 6.80			

* Retrieved from Wajuihian (2019). N/A – not specified.

Due to a bit different examination plan compared to the study of Wajuihian (2019), following criteria were used as described in Table 2.3 to specify the possible accommodative and vergence dysfunction.

Table 2.3

Dysfunction	Clinical signs
Accommodative spasm *Signs: All signs have to be presented*	1. Requires myopic correction 2. Corrected visual acuity is decreased at far and near 3. Refraction do not correspond to the uncorrected visual acuity 4. Reduced NR (≤1.50 D) and PR (≤1.25 D) 5. Fails BAF and MAF with ±2.00 D (<6 cpm) 6. Reduced NFV and PFV at near and far*
Accommodative excess *Signs: At least two signs have to be presented (3. - mandatory)*	1. Requires myopic correction 2. Reduced NR (≤1.50 D) or can be increased if had been overcorrected 3. Fails BAF and MAF with +2.00 D (<6 cpm) 4. Reduced NFV near* 5. Refraction do not correspond to the uncorrected visual acuity
Accommodative infacility *Signs: At least the first three signs have to presented*	1. Normal visual acuity (corrected and uncorrected) 2. Fails BAF and MAF with ±2.00 D (<6 cpm) 3. Reduced NR (≤1.50 D) and PR (≤1.25 D) 4. Reduced NFV and PFV at near*
Accommodative weakness *Signs: At least three signs (1. and 2. - mandatory) have to be presented*	1. Normal visual acuity (corrected and uncorrected) 2. Fails BAF and MAF with -2.00 D (<6 cpm) 3. Reduced PR (≤1.25 D) 4. Reduced PFV near*
Accommodative insufficiency *Signs: At least three signs (1. and 2. - mandatory) have to be presented*	1. Low AA (2.00 D less than the minimum defined by Hofstetter: 15 - 0.25 * age)** 2. Fails BAF and MAF** with -2.00 D (<6 cpm) 3. Reduced PR (≤1.25 D)** 4. Reduced PFV near* 5. Reduced visual acuity at near (with the best correction for far)
Basic esophoria *Signs: At least two signs (1. mandatory) have to be presented*	1. Esophoria of approximately equal magnitude (<5 pd diffrerence) at near and at far 2. Reduced NFV near and far* 3. Reduced PR (≤1.25 D) 4. Fails BAF with -2.00 D (<6 cpm)
Basic exophoria *Signs: At least two signs (1. mandatory) have to be presented*	1. Exophoria of approximately equal magnitude (<5 pd difference) at near and at far 2. Reduced PFV near and far* 3. Reduced NR (≤1.50 D) 4. Fails BAF with +2.00 D (<6 cpm)
Convergence excess *Signs: At least three signs (1. and 2. - mandatory) have to be presented*	1. Significantly larger esophoria at near (2-6 pd difference) than at far 2. Reduced NFV near* 3. High calculated AC/A (≥7/1) or graduated AC/A ratio (with -2.00 D) (>4/1) 4. Reduced PR (≤1.25 D) 5. Fails BAF with -2.00 D (<6 cpm)
Convergence insufficiency	1. Receded NPC (>8 cm) and/or RPC (>13 cm) 2. Significantly larger exophoria at near (4-6 pd difference) than at far

	3. Reduced PFV near*
Signs: At least three signs (1. or 2. mandatory) have to be presented	4. Low calculated AC/A (<3/1) or graduated AC/A ratio (with +2.00 D) (<2/1)
	5. Reduced NR (≤1.50 D)
	6. Fails BAF with +2.00 D (<6 cpm)
Divergence excess	1. Significantly larger exophoria at far (≥10 pd difference) than at near
Signs: At least two signs have to be presented	2. Reduced NFV far*
	3. High calculated AC/A (≥7/1) or graduated AC/A ratio (with -2.00 D) (>4/1) at far
Divergence insufficiency	1. Significantly larger esophoria at far (2-8 pd difference) than at near
Signs: At least two signs have to be presented	2. Reduced NFV far*
	3. Low calculated AC/A (<3/1) or graduated AC/A ratio (with +2.00 D) (<2/1)
Fusional vergence dysfunction	1. Orthophoria or low degree of eso or exophoria at far and near
Signs: At least three signs (1.-3. mandatory) have to be presented	2. Reduced NFV and PFV at near and far*
	3. Fails BAF with ±2.00 D (<6 cpm)
	4. Reduced NR (≤1.50 D) and PR (≤1.25 D)

* Normal values for FV (based on Scheiman and Wick, 2015)
PFV blur or break/recovery: near 19±9/14±7 pd; far 11±7/7±2 pd
NFV blur or break/recovery: near 13±6/10±5 pd; far 7±3/4±2 pd
** Required if accommodative insufficiency is monocular

The overall prevalence of accommodative and vergence dysfunctions were analyzed in all participant group, as well as separately for male and female and in three age groups (15-21 y., 22-26 y., 27-36 y.). For data presentation, percentage and the standard error of percentage was used. The difference between the percentage was compared and its statistical significance was analysed.

3. RESULTS

3.1. Prevalence of accommodative and vergence dysfunctions

At the beginning, refractive error distribution among participants was analysed. 148 or 77 ± 3% of participants were diagnosed some refractive errors and 44 (23 ± 3%) were emmetropic. Most of the participants (135 or 91 ± 2%) had myopia or myopia with astigmatism, and only 10 (7 ± 2%) participants had hypermetropia or hypermetropia with astigmatismus and 3 (2 ± 1%) had mixed astigmatismus. We noticed that 75 participants (39 ± 4%) had never used any glasses or contact lenses to correct their refractive error. 19 of them had complaints that could be related to their uncorrected refractive error because most of them had myopia or myopia with astigmatismus (spherical equivalent from -0.63 D to -3.75 D) and decreased visual acuity at far. Even those who did not complained had large variation of refractive errors: spherical equivalent from +0.75 D to -6.38 D with astigmatismus up to -2.50 D.

Table 3.1

Types and percentage of accommodative and vergence dysfunctions.

Dysfunction	Abbre-viation	Number	All participants		Only participants with accommodative and vergence problems	
			%	SE	%	SE
Accommodative dysfunctions						
Accommodative excess	AE	17	8.9%	2.1%	17.3%	3.8%
Accommodative weakness	AW	9	4.7%	1.5%	9.2%	2.9%
Accommodative insufficiency	AI	2	1.0%	0.7%	2.0%	1.4%
Vergence dysfunctions						
Basic esophoria	BE	5	2.6%	1.1%	5.1%	2.2%
Basic exophoria	BX	4	2.1%	1.0%	4.1%	2.0%
Convergence excess	CE	3	1.6%	0.9%	3.1%	1.7%
Convergence insufficiency	CI	14	7.3%	1.9%	14.3%	3.5%
Divergence excess	DE	0	0.0%	0.0%	0.0%	0.0%
Divergence insufficiency	DI	4	2.1%	1.0%	4.1%	2.0%
Fusional vergence dysfunction	FVD	4	2.1%	1.0%	4.1%	2.0%
Total		**62**	**32.3%**	**3.4%**	**63.3%**	**3.5%**

Following criteria described in Table 2.3, all participants were evaluated if there could be any accommodative or vergence dysfunction. Symptoms were not used as a criterion because there only ¼ of participants had complaints (23 ± 3%) that is a small part of participants. In addition, clinical and literature studies demonstrate that not all participants have complaints and not all participants relate some complaints to visual problems and will inform about them a visual specialist. Therefore, the diagnostic was based only on the results of visual function examination. A little bit more than a half of participants (51 ± 4%) was diagnosed some form

of the accommodative and vergence dysfunction. Results of the study are presented in Table 3.1 and Table 3.2. Table 3.1 includes types and prevalence of separate accommodative and vergence dysfunctions. Table 3.2 includes participants that had combined dysfunctions – both accommodative and vergence dysfunctions are presented.

The most dominant accommodative dysfunctions are accommodative excess and accommodative weakness. Accommodative excess was diagnosed mainly based on the reduced accommodative facility (both monocular and binocular one) and either decreased negative accommodation. 4 (out of 17 participants with accommodative excess) demonstrated increased negative accommodation that corresponded to overcorrection while performing subjective correction. Thus, larger attention should be made while assessing subjective correction with fogging method to ensure relaxation of accommodation. Accommodative weakness was mainly observed in patients who had never used glasses and during examination got their first prescription or needed stronger myopic prescription.

Table 3.2

Types and percentage of dysfunctions in participants that had both accommodative and vergence dysfunctions.

Dysfunction	**Abbre-viation**	**Number**	**All participants**		**Only participants with accommodative and vergence problems**	
			%	**SE**	**%**	**SE**
Accommodative weakness and divergence insufficiency	AW+DI	1	0.5%	0.5%	1.0%	1.0%
Accommodative insufficiency and basic exophoria	AI+BX	1	0.5%	0.5%	1.0%	1.0%
Basic esophoria and accommodative excess	BE+AE	2	1.0%	0.7%	2.0%	1.4%
Basic exophoria and accomodative excess	BX+AE	1	0.5%	0.5%	1.0%	1.0%
Basic exophoria and accommdoative weakness	BX+AW	1	0.5%	0.5%	1.0%	1.0%
Convergence excess and accommodative excess	CE+AE	2	1.0%	0.7%	2.0%	1.4%
Convergence insufficiency and accommodative excess	CI+AE	13	6.8%	1.8%	13.3%	3.4%
Convergence insufficiency and accommodative insufficiency	CI+AI	3	1.6%	0.9%	3.1%	1.7%
Divergence excess and accommdoation excess	DE+AE	2	1.0%	0.7%	2.0%	1.4%
Divergence insufficiency+accommodative excess	DI+AE	4	2.1%	1.0%	4.1%	2.0%
Fusional vergence dysfunction+accommodative excess	FVD+AE	6	3.1%	1.3%	6.1%	2.4%
Total		**62**	**18.8%**	**2.8%**	**36.7%**	**3.5%**

Two of participants who were diagnosed to have accommodative insufficiency, had it only in one eye that was amblyopic eye. There were 46 participants, who had decreased AA: 2.00 D below the minimum value for the age as defined by Hofstetter (33 participants in both eyes and 13 participants in one eye). However, to make a diagnosis accommodative insufficiency, most of the studies (Hashemi et al., 2019; Hoseini-Yazdi et al., 2015) required more than one criterion. Thus, following out criteria, only 3 participants had one or more criteria in addition to a decreased accommodative amplitude.

The most common form of vergence problem was convergence insufficiency (30 participants – 16 ± 3%). Some participants even demonstrated near point of convergence worse than 20 cm (maximum 25 cm). Only 10 of them complained. Only one demonstrated suppression during fusional vergence assessment. Convergence insufficiency has a high prevalence not only as a separate problem but also in combination with accommodative excess. Accommodative excess was noticed also in combination with basic esophoria, basic exophoria, convergence excess, divergence excess, divergence insufficiency, and fusion vergence dysfunction.

Total number of participants who had accommodative dysfunctions (separately and mixed) (64) very close to number of students who had vergence dysfunctions (separately and mixed) (70). The number of participants with diagnosis of AI, BE, BE, CI, DI, DE (separately and mixed) was not performed for these problems.

3.2. The effect of gender and refraction type on the prevalence of accommodative and vergence dysfunction

In order to get more information about prevalence of each dysfucntion and relative to the gender and age of participant, three age groups were analyzed. *Group 1* included participants from 15 to 21 years old, *Group 2* – from 22 to 26 years old, and *Group 3* – from 27 to 36 years old. In addition, they were separately analyzed by the gender – female and male, accordingly. It was found that distribution of accommodative and vergence dysfunctions are not affected by the gender and age of the participant (see Table 3.3). All three groups show not statistically significant differences *($p > 0.05$).* For example, participants who had refractive error but never been corrected had statistically insignificant variations in gender and age *($p > 0.05$).* Type of refractive error also had no statistical significance neither comparing it in separate age groups, nor by gender *($p > 0.05$).*

Table 3.3

Distribution (number) of refractive errors and accommodative and vergence dysfunction by gender and age groups.

	Age groups		
	Group 1	**Group 2**	**Group3**
Female (total)	68	56	26
Refraction	52	44	19
Myopia, myopia with astigmatismus or mixed astigmatismus	47	42	19
Hyperopia and hyperopia with astigmatismus	5	2	0
Emmetropia	16	12	7
Never glasses glasses/contact lenses	28	17	11
Accommodative dysfunctions	11	8	2
Vergence dysfunctions	11	8	9
Combined dysfunctions	13	11	4
Male (total)	19	12	11
Refraction	14	10	8
Myopia, myopia with astigmatismus or mixed astigmatismus	12	10	7
Hyperopia and hyoperopia with astigmatismus	2	0	1
Emmetropia	4	2	3
Never glasses glasses/contact lenses	9	4	6
Accommodative dysfunctions	1	4	2
Vergence dysfunctions	3	1	2
Combined dysfunctions	5	1	2

4. DISCUSSION

It was noticed in this research that the 51 ± 4% of student's population in Baku, the capital city of Azerbaijan had accommodative and vergence dysfunctions. The most common were accommodative excess and convergence insufficiency. The result of this research is partially very similar to some other studies. Lara et al. (2001) had approximately the same age group of population (265 participants with the age of 20.75 ± 5.78 years) and found that prevalence of general accommodative dysfunction is 9.4% where the dominant one is AE (6.4%). The prevalence of participants with general vergence dysfunctions was also similar to ours, but types of disorders and their prevalence was different. There are many points that can make difference in results between similar study's: different age groups, different diagnostic criteria, different regions, difference in tests and methods used during examination. If we compare our methods exactly with study Lara et al. (2001), we can see that our results are almost similar. The difference between type of vergence disorder probably can be explained with the accommodative and vergence disorders diagnostic criteria and the testing procedure because CI and CE usually depend on accommodative anomalies. For example, we did not used dynamic retinoscopy in our research for the reason of limited time and low experience of our ophthalmologist in retinoscopy, especially dynamic retinoscopy.

Also, very interesting to compare our results with study of Garcia-Munoz et al. (2016), were we see similar prevalence of same types of disorders. The authors did not count the prevalence of disorders which were very small for the group of 175 participants instead of our study where we did. On other side, the authors describe that sample of their groups cannot represent all university population. They compared their results with other authors which did similar studies and come to conclusion that difference between results arises for the reason of population difference. Most of the studies were performed on clinical population which have higher prevalence compare to the general population. We also have to notice that our results are not representing all university students, nor the population of Baku or Azerbaijan. But based on these results, we can consider the possible variation of reviewed problems in the student population.

Another interesting research was done by Hossein-Yazdi et al. (2015) in Iran, Mashad University of Medical Science. During research, they used almost the same methods and criteria that we used in our study. They did the research on optometry clinic population and choose 83 participants (21.3 ± 3.5 years) for the study. 14.5% of the participants had specific binocular and accommodative symptoms. Accommodative and vergence dysfunctions were found in 19.3% of patients, from which the most common was AE and CI: AE was 4.8% and CI – 3.6%. They also compared symptomatic and asymptomatic patients for these disorders. We did not

compare symptomatic and asymptomatic patients, but we will refer to the general statistic of disorders from their study. They found the prevalence of accommodative dysfunction in 7.2% population, and convergence dysfunction in 12.1% of the examined patients. If we compare with our results, we can see that proportion of people with accommodative and vergence dysfunctions in our study is significantly higher (accommodative dysfunctions 14.6 ± 2.5% and binocular dysfunctions 17.7 ± 2.8%). As well we separately analyzed also those where accommodation dysfunction was combined with vergence dysfunction (18.8 ± 2.8%). We can explain this difference by the fact that we examined participants who used glasses and those who did not previously used any glasses. But in the study of Hossein-Yazdi et al. (2015), all participants used glasses previously. Another reason of difference can be that they did research for less type of disorders than we did.

Of the 192 participants examined, we had 77 ± 3% (148 participants) with refractive errors from which 115 (60 %) were female, and 33 (17 %) were male. As we divided all patients into the groups, we can make comparison of results according to their age and gender, and come to the conclusion that type of refractive errors in these groups do not depend on the gender and age of participants. The main problem which we see during research is the number of participants with not corrected refractive errors. We can notice that participants in Group 3 are more often using correction and we think that the reason of that is their age. They faced with the vision problems before and which reduced they abilities in daily work or activities. Participants in this age group (Group3) are living in the capital city (Baku) and have job, which allows them to have glasses if it is necessary. Another reason of problem with high prevalence of not corrected participants in our study is that most of them come from regions of our country, where is less possibilities to have medical examinations due to low medical service level. As we noticed, some of them even do not know that they have reduced visual acuity.

Among participants, there is a significant dominance of female. We cannot investigate here in this study why less males participated, but we can presume that if the proportion were the same then the results would not change significantly. Since in many other proportions they mostly coincide. Or, we can presume that if they did not accept the invitation and did not take the opportunity to be examined for free, they do not know about their vision problems or do not want to use glasses considering that the glasses can limit activity in some way (glasses wearing discomfort during active life). Of course, we as optometrists can give them solution, like contact lenses or glasses from light and flexible materials, but we cannot reach them yet.

We also see from the statistic and have already noted this before, that the level of accommodative and vergence problems we have is higher than on other studies, because the proportion of those who are not corrected is very high. The persons who need the correction

but do not have it, use their accommodative and vergence abilities more than emmetropes, and in long period of time, disorders can occur or get worse. Thus, not wearing glasses puts high pressure on accommodative and vergence system. This could be the reason why combined cases where both accommodative and vergence dysfunctions are so many in the present study.

In conclusion, we can specify that the prevalence of accommodative and vergence dysfunction can depend on the diagnostic criteria that can make it complicated to compare different studies. However, our research had demonstrated that the prevalence of accommodative and vergence dysfunctions is quite high among students (15-36 years old) and therefore optometrists and ophthalmologists should pay larger attention on the assessment of accommodation and vergence during vision examination even if patients do not complain.

CONCLUSIONS

1. In the student population in Baku, Azerbaijan, the prevalence of accommodative and vergence dysfunctions is 51 ± 4%. Compared to other countries in the same region as Azerbaijan, this prevalence is higher than previously described by Hossein-Yazdi et al. (2015) in Iran because of difference in studied population and variety of accommodative and vergence dysfunction types.
2. In the student population in Baku, Azerbaijan, the most common accommodative dysfunction is accommodative excess and the most common vergence dysfunction is convergence insufficiency. There were 8.9 ± 2.1% participants with accommodative excess and 7.3 ± 1.9%. participants with convergence insufficiency, as well as 6.8 ± 1.8% participants with combination of both dysfunctions.
3. In the student population in Baku, Azerbaijan, 39 ± 4% of participants had never used any glasses or contact lenses to correct their refractive error that can also increase the number of accommodative and vergence dysfunctions. The possible reason could be the low medical service level in the regions outside Baku, the capital city of Azerbaijan.
4. The distribution of accommodative and vergence dysfunctions among students is not related to their age or gender.

FINAL WORDS

During our research, we concluded that university students in Baku have high prevalence of accommodative and vergence problems in comparing to other studies from other countries. As we mentioned before, we think that this is the problem of not wearing the glasses. What we can do with this situation? We can make many different steps in order to reduce the prevalence of these disorders. As the first step, we can spread simple information materials about vision exams in the schools, universities, places with high traffic of people, trams, busses, trains. As the second, we should improve knowledge of medical staff in the schools, improve knowledge of parents, especially on a pregnancy period. Together with the Association of Opticians and Optometrists, we should refer to the government structures in order to activate processes to inform population about the need for regular – at least once a year – eye examinations especially for children.

During our study, we had problem with retinoscopy procedure because we did not have enough instruments and our ophthalmologists are not very experienced on it. But this procedure is very important on the evaluation of accommodative and vergence functions. Therefore, additional training of staff involved in the vision care should be done in a future to improve possibility to diagnose accommodative and vergence problems.

ACKNOWLEDGEMENT

I want to convey my thanks to my supervisor Aiga Svede for the helps to increase my education level, to help me with my thesis and support me all the time. I started my thesis with my another supervisor Ilze Ceple and we did a lot of work at the beginning, and I regret my thanks to her, too. During research, ophthalmologists Leyla Guluzade, Gunel Mammadova, and Sabina Gurbanova helped me to evaluate practical part of this research and for this I regret my many thanks to them. Also, I regret all the patients (students) who participated in this research.

Many thanks to the reviewer of this thesis for reading this thesis and all the comments.

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APPENDIX 1

The translation of the instructions for the methods used in the study protocol.

Wearing RX

We need to check patient existing glasses (if there is one) and indicate Diopters and distance between focuses of lenses. Patient can have 2 or more glasses. We need to check all of them.

Case History

We need to ask patient about his/her health (demographic data, ocular history, medical history, drugs and medications, family ocular history, social history, review of systems (cardiovascular, endocrine, dermatological, psychiatric etc.))

Complains

We need to ask patient about his/her complains. If we suspect something according first complains, we need to ask more question to clarify the questions which is more interesting for us. But need to be very careful in order not to confuse patient and not make him/her worried. If the patient says that there are no complaints, we need to ask specific questions based on their case history and work/studies., e.g. how many hours per day you use computer or do you have prolonged near work? Do you experience eye fatigue, double vision, blurring? If yes, for how long have you had these complaints? When are they more pronounced? After how long do these complaints appear? Ask specific questions! It is sometimes easier for the patient to say, that there are no complaints. Or sometimes patients (especially children) do not know that their complaints are real and that others don't feel the same way!

Dominant eye

Here we can use Dolman or Porta test. For near we can use mirror test or Litinsky test. To check sensory dominant eye, we have to use Red Filter on front of right eye and ask patient about color of dot on the screen. If he sees dot on white color it means the dominant eye is left, if dot become rose or red it means the dominant eye is right. The patient might not always say that the dot is red or white (if the dominance is not very high). You can try switching the lens to the other eye and ask when the dot is more red- when it is in front of the right eye or when it is in front of the left eye. Sensory dominance can also be checked using + lenses: both eyes looking at letters that are 3 rows bigger than the best visual acuity. +2.50 D lens is put in front of right eye (left eye is without the lens), and after that in front of the left eye (right eye is without the lens). Patient reports, when does the lens make the vision worse (when it is in front of the right eye or when it is in front of left eye). That eye is the dominant!

Visual Acuity

Here we need to check patient visual acuity without glasses and with patient existing glasses. VA have to be measured for distance and near with and without glasses.

Objective refraction

For this procedure we need to use Refractokeratometer and rewrite all information in the protocol. If you do cycloplegic examination, please indicate that in the protocol.

Subjective refraction

Here we need to use fogging and indicate in protocol which lens power was used and which visual acuity was reached. It is necessary to give to patient best and comfortable visual acuity during refraction exam. Result have to be recorded in protocol.

Binocular balance

Need to place +0.50 D in front of each eye and start cover test. Ask patient which eye sees better (short letter bar on the screen, usually 2 lines up his visual acuity). If there is significant difference need to blur better eye until patient either notices balance between both eyes or better eye becomes worse. If dominant eye sees better and difference is +0.25 D, we keep balance with no changes. Instead of fogging and cover test, we can use prismatic lenses 3 pd in front of each (BU and BD) eye. The result of binocular balancing should be recorded in the protocol and necessary changes should be made in refraction.

Near vision acuity with distance correction

Keep distance refraction lenses and check patient near visual acuity monocularly and indicate the results in the protocol. After this, start to use additional lens (only if the visual acuity at near is reduced) until patient will reach the best and comfortable visual acuity for near (best is 1.0 on Snellen chart).

Dynamic Retinoscopy

The key to the technique is the neutralization of the retinoscopic reflex that occured when the patient accommodated on a target placed on the retinoscope. Two methods can be used: MEM and Nott.

Monocular Estimate Method (MEM):

Target: Near target attached to the retinoscope at 40 cm distance. Patient sees it binocularly. The letters have to be read out loud. Patients must wear their distance correction.

If the movement is *with* add "+ lenses" and for *against* movement add "- lenses" till the reflex is neutralized – no movement is observed. The lens is added only to one eye and for a very brief period of time (less than 0.5 seconds). If you get final power in '- lenses', then the patient is over-accommodating which means the patient has lead of accommodation. If you get final power in'+ lenses', then the patient is under-accommodating which means the patient has lag of accommodation.

Nott Method:

Target: Near target at subjects 40 cm distance. Here we can ask patient to read loudl Snellen visual acuity chart for near. Patient sees the target binocularly. Patients must wear their distance correction. Retinoscope is kept alongside of the target and the movement of the reflex is observed. If the movement is *against*, then the patient is over-accommodating. Move the retinoscope towards the patient till you get neutral point while keeping target fixed. The distance between the neutral point and the target will be converted into diopters. The resultant dioptric value is the magnitude of lead of the accommodation.

$$\textbf{focal length in mm} = \frac{1000}{\textbf{diopter}}$$

If the movement is *with*, then the patient is under-accommodating. Move the retinoscope away from the patient till you get neutral point while keeping target fixed. The distance between the neutral point and the target will be converted into diopters. The resultant dioptric value is the magnitude of lag of the accommodation. Result of test has to be recorded in the protocol.

Amplitude of Accommodation

The test have to be done monocularly. Give the patient near visual acuity chart and ask him/her to read 1-2 rows less than the best visual acuity (40 cm). Then the chart is moved

toward the patient until he/she report the blur. The distance from his/her eye till the visual acuity chart is measured (in meters). This point is named Punctum Proximum. Amplitude of accommodation is calculated: AA=1/distance. Do not perform tests for presbyopic patients because they will not be included in the study. Result of this test for each eye have to be recorded in the protocol.

Positive/Negative relative accommodation

For this test, we have to add minus lenses with step 0,25 D until patient can't read 0,8 (at 40 cm). Result will be PRA. For NRA we have to use plus lenses with step 0,25 D until patient can't read 0,8 (at 40 cm). Result will be NRA. Test have to be done monocularly.

Accommodation Facility

Have to use ±2.00 D flipper and ask patient to read visual acuity chart. Hold +2.00 D in front both eyes (with the best correction for distance) and ask him/her to say "read" when he/she will be able to read (ask him to read loud) 0,8 (40 cm). Then switch to -2.00 D and again ask him/her to read. We have to repeat this switching every time when patient is able to read, during 1 minute, and count how many cycles we did. Number of cycles (+/-) is recorded in the protocol. The test have to be done binocularly and monocularly. ±2.00 D flipper must be used if PRA and NRA are higher than 2.00 D. If PRA and NRA are less than 2.00 D, make the test only monocularly with ±2.00 D flipper and if it still doesn't work, measure accommodation facility using Wick method. Be sure that the distance hasn't changed during the testing.

Convergence

Hold pen or pencil in front of face of patient at 40 cm distance or more, ask him/her to focus on this target while you move it toward the patient. Ask patient to inform you when he/she will see double. Need to measure distance from eye of patient to the point were vision become double and then move the target away from the patient and ask patient to inform you when single vision recovers. If the patient report that he/she sees blurred, then you continue moving the target towards the patient until it gets double. Both numbers have to be recorded in the protocol. Sometimes vision does not get double or blur. In this case we need to catch the point when non dominant eye will lose the fixation and recover fixation on target. While performing the test, look at the patient's eyes! Sometimes when there is suppression the patient might not see blur, but you will see that there is no convergence (one eye is starting to diverge).

Binocular vision

Here we can place red filter on front of right eye, switch on the white dot on the screen, and ask patient the color of the dot. If patient have BSV, he has to see dot in pink color. Second test is Worth Test. Over distance refraction we need to put red (on right eye) lens and green lens on the left. Then give Worth test on distance and ask patient what he/her seen on the screen.

If patient sees all four figures, there is binocular single vision. Also we need to do binocular test for near vision. Here we can use the Lang Two Pencil Test. The patient is asked to place a pencil on top of one being held vertically by the examiner. It is conventional to do the test with either eye in turn and then with both eyes together, the aim being to assess the accuracy or otherwise of the positioning shown by the patient.

Maddox test

Need to place on front of distance corrected right eye of patient Maddox lens (line on lens horizontal), stay on 5-meter distance with light source and ask patient if he seen line and light. Need to ask if line cross the light, if not were the line positioned according the light. If the line not crossing the light, we need to put on front of other eye the prizm bar and find with which prizm and with which position (BI and BO) the line cross the light. Same manipulation has to done with vertically oriented Maddox lens and use BU and BD prizm bar. Both manipulation has to be repeated for near distance, and after it for non-corrected eyes also for distance and near. Result have to be recorded in the protocol.

Cover test

We have to take occluder and start to cover and uncover each eye of patient when he/she is looking at distance (5 m) on the target (figure "A" on the screen). Here we need to check if patient have tropia or not. Result have to be recorded in the protocol.

AC/A ration calculation

AC/A ratio= PD(cm)+N(m)*(D"-D)

Where PD is a pupil distance in centimeters, N - is a near fixation distance in meter, D"- near phoria (eso is plus and exo is minus), D- far phoria (eso is plus and exo is minus)

3-10 Exophoria, Low AC/A- Convergence insufficiency

8-3 Esophoria, Low AC/A- Divergence insufficiency

3-6 Esophoria, High AC/A- Convergence excess

10-5 Exophoria, High AC/A- Divergence excess

Result have to be recorded in the protocol.

Stereovision

Near vision test:

STEREOTEST – CIRCLES. This is a graded series, which tests fine depth discrimination. Within each square are four circles. Only one of the circles has a degree of crossed disparity. It should appear forward of the plane of reference for those having normal fusion. The design of a circle within a circular window establishes a constant distance from test object to reference plane. Variation in this distance will influence the ability to judge relative

depth. To equate this test with other stereopsis tests, a factor to compensate for different distances from test object to reference plane must be considered.

Start with No. 1. Say to the patient: “Look at each of the four circles and tell me which one seems to come out closer to you--top, bottom, right or left.” Continue until patient gives up trying, or makes two successive mistakes.

SCORING - Refer to chart below. Record the level of stereopsis at the last one chosen correctly. If the patient makes one mistake, then gets the next one right, go back and have him try the missed one again to determine if he can achieve this level of stereoscopic discrimination, or just guessed the more difficult one.

STEREOTEST -- CIRCLES

1 Bottom 800 Seconds

2 Left 400 Seconds

3 Bottom 200 Seconds

4 Top 140 Seconds

5 Top 100 Seconds

6 Left 80 Seconds

7 Right 60 Seconds

8 Left 50 Seconds

9 Right 40 Seconds

Result has to be recorded in the protocol.

Fusional Vergence

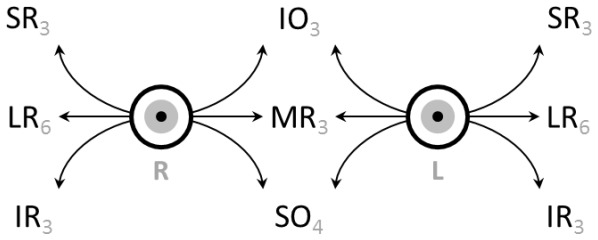
Here we need to use prism bar. The test has to performed with subjective refraction. Demonstrate distance target on the screen (5 m). Target can be the short vertical line from letters (two lines below the best visual acuity). Place prism bar in front of the eye (start with BI and after do the same with BO) and ask patient to tell you when target will blur or double. Wright in the protocol the prims power when the patient noticed blur, double and recover points. Repeat the same manipulation with short horizontal line of letters and use BU and BD prism bar. Both manipulation has to be performed also for near (40 cm).

Versions

Here we are checking the eye movements. We need to present small target in front of the face of the patient and start to slowly move the target up then back to center, then down and up to center and see if both eye are following the target in the same direction. Same manipulation has to be performed to the right and left, and then move target in diagonals direction. Six extraocular muscles facilitate eye movements: lateral, medial, inferior and superior rectus

muscles, and inferior and superior oblique muscles. The muscles, when contracting, cause movement of the eyeball, by pulling the eyeball towards the muscle.

Result has to be recorded in the protocol. If there are any limitations of the movements, we should indicate which muscle failed.



According to the results of the tests we need to wright diagnose of disorders and prescribe glasses or/and contact lenses, prescribe vision training if necessary, send to the ophthalmologist if we see disorders which could have pathological reason.

APPENDIX 2

Study protocol for the full eye examination.

Date ..../..../....

First name	**Surname**	**Year of birth**

Wearing Rx

Distance	OD.....D sph	.....D cyl	ax.....	PD.....mm
	OS .....D sph	.....D cyl	ax.....	
Near	OD.....D sph	.....D cyl	ax.....	PD.....mm
	OS .....D sph	.....D cyl	ax.....	

Case history

Complaints *(Chief complain, secondary complaints)*

Ocular dominance Sensory: Distance..... Near.....
Ocular dominance Motor: Distance..... Near.....

Visual acuity

Distance	V	OD nc..... cc.....	Near	V	OD nc..... cc.....
		OS nc..... cc.....			OS nc..... cc.....

Refraction

Objective refraction. Cycloplegia Y/N .....

Refracto meter	OD.....D sph	.....D cyl	ax.....	PD.....mm
	OS .....D sph	.....D cyl	ax.....	

Subjective refraction

OD Fog D..... V..... sph..... Fog.....CDT ax..... V.....sph.....cyl..... ax..... V.....

OS Fog D..... V..... sph..... Fog.....CDT ax..... V.....sph.....cyl..... ax..... V.....

Bin V.....

Binocular balance

OD cc.....D sph .....D cyl ax..... V..... Bin V.....
OS cc.....D sph .....D cyl ax..... V.....

Distance-corrected near visual acuity OD..... OS..... OU.....

Dinamic Retinoscopy ..... **OD**..... **OS**.....

Amplitude of Accommodation **OD**..... **OS**.....

Positive/Negative accommodation OD...../..... D sph OS...../.....

AF OD..... **OS**.....
AF Bin.....

Convergence BRP.....**REC**..... Test 1.....

Binocular vision: ..... **Test 1** .....
Binocular vision: ..... **Test 2** .....

Maddox test Distance cc..... Prizm..... Distance nc..... Prizm.....
Near cc.....Prizm..... Near nc..... Prizm.....

Cover test..... Distance cc.....Prizm..... Distance nc..... Prizm.....
Near cc.....Prizm..... Near nc.....Prizm.....

AC/A ratio +2.0D. ..... **-2.0** .....

Stereovision Distance ..... Near ..... Test ...../.....

Fusional Vergence

Distance				Δ BI	Distance				Δ BU (OD/OS)
				Δ BO					Δ BD (OD/OS)
Near				Δ BI	Near				Δ BU (OD/OS)
				Δ BO					Δ BD (OD/OS)

Versions
.....
.....
OD  OS 

Rx

OD.....D sph .....D cyl ax..... Prism ax..... PD.....
OS .....D sph .....D cyl ax..... ax.....

ADD OU..... OD..... OS.....

Diagnosis:

Follow-up **OPTOMETRIST** **Signature**

The Master Thesis "The prevalence of accommodative and vergence dysfunctions in Azerbaijan" is developed at the Faculty of Physics, Mathematics and Optometry of the University of Latvia.

I certify with my signature, that the research has been conducted independently, all information sources used in the Master Thesis have been mentioned in the reference list, and the submitted electronic copy of the Master Thesis corresponds to the printed version.

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The Master Thesis is submitted at the Department of Optometry and Vision Science_____

Dean's authorized person: Una Plauka (_____)
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The Master Thesis is defended in the session of the State Examination Commission of the Professional Master's Study Programme "Optometry".

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