DIFFICULTIES IN DIAGNOSIS OF NON-STRABISMIC BINOCULAR AND ACCOMMODATION DEFECTS

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SUMMARY

The aim of the paper is to inform about the current approach to the diagnosis of non-strabismic binocular and accommodative disorders. A large number of studies quote high occurrence of them in both clinical and nonclinical populations. They also point out the presence of a diagnosis deficiency or insufficient diagnosis within the optometric and ophthalmological practice. The representation in population depends not only on race and age, but also on the methodology of diagnostic tests, and the chosen diagnostic criteria in particular. For the purpose of division of binocular and accommodative disorders there are several classification systems. The widespread classification facilitates a better understanding of a great spectrum of symptoms, assignment of the characteristic signs, and decision about appropriateness and choice of treatment types.

Key words: heteroforie, binocular disorders, accommodative disorders, fusional vergence, convergence insufficiency, convergence excess

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Binocular and accommodation disorders

Binocular disorders lead to a failure of fusion or an inability to maintain comfortable bifoveolar fixation [27]. The etiology of non-strabismic binocular disorders is attributed to deficiencies in the relationship between accommodation and binocular interaction [25]. These deficiencies and associated symptoms are primarily worsened by extended visual demands, concentrated tasks at close distances such as reading, writing or work on a computer.

In the case of accommodation disorders, the visual system is not capable of clearly and effectively focusing on objects at various distances, which may lead to the formation of blurred retinal images accompanied by characteristic symptoms [26]. Accommodation disorders include accommodative insufficiency, ill-sustained accommodation, accommodative paralysis, accommodative infacility and accommodative excess [23, 12].

Several authors assert that binocular disorders occur ordinarily in optometric practice [6, 15, 20]. Ciuffreda even states that in optometric practice, non-strabismic binocular and accommodation disorders (of a non-pathological character), with the exception of refractive errors, are the most common visual disorder [3]. Only a complex evaluation of binocular and accommodative functions, furthermore for measurement of refractive error, can ensure that these disorders do not remain unnoticed during a routine examination [14].

Symptoms of binocular and accommodation disorders

Patients with a non-strabismic binocular and/or accommodation disorder state a wide range of symptoms [3, 18]. The symptoms in the case of binocular disorders include defocussed vision, diplopia, ocular discomfort during or immediately after close up work, frontal head pain, nausea, general drowsiness, loss of concentration, feeling of heavy eyelids, general fatigue and a feeling of pulling of the eyes [3]. In the case of accommodation disorders, defocussed distance and/or near vision often occurs during or immediately after close up work, headache, poor concentration and difficulty reading. Scheiman and Wick present a broad overview of symptoms which are attributed to individual types of binocular and accommodation disorders. Such a division eases diagnosis and decision on the suitability and type of treatment [23].

Headaches are stated among the frequently stated symptoms of binocular disorders. It is possible to consider their connection with binocular disorders once other potential causes of headaches have been eliminated. Of importance are the characteristics of the pain, such as location, type of pain, duration and linkage with certain visual tasks. For example, hyperphoria may be linked with occipital headache, whereas horizontal heterophoria (HTP) has a tendency to lead to headaches in the frontal region [7]. In the case of exophoria these frontal headaches occur during concentrated visual attention, in the case of esophoria even one day after concentrated work.

Significance of measurement

The symptoms of binocular disorders create discomfort, worsen the effectiveness of close up work, and may have an influence on studying results, intellectual development and overall quality of life [27]. Conditions connected with learning problems appear to be closely linked with binocular disorders. Hoffman stated that more than 85 % of children with a learning disability who were referred for an optometric examination had a non-strabismic binocular and/or accommodation disorder [10]. Furthermore, several children who have problems with reading or suffer from dyslexia have binocular and/or accommodation disorders [21].

In a recent study, Vaughn et al. demonstrated that children with a larger number of visual symptoms had poorer study results than those with less occurring symptoms [24]. Symptoms in connection with accommodation and binocular disorders may have a negative influence on performance of children in schools, and comprehension of written texts also declines [21]. Furthermore, these children experience unnecessary frustra-

tion and develop low self-esteem, which may lead to them avoiding reading and close up work. Further stated negative consequences of binocular disorders include the potential correlation of convergence insufficiency (CI) and attention deficit hyperactivity disorder (ADHD), anxiety, emotional and social problems [27]. Shin et al. in their study drew the conclusion that binocular and accommodative functions should be tested in all school pupils who have visual problems or learning difficulties [21]. A study by Porcar and Martinez-Palomera detected a high incidence of accommodation and binocular disorders also in university students, at 33 % [17].

Although the incidence of these disorders may differ according to the diagnostic criteria, particular characteristics of the population or used clinical methods, these dysfunctions have been found to be far better predictors of academic success than race and socio-economic factors, which are recognised predictors of academic education [21]. From this it ensues that an improvement in the quality of these visual capacities could have a positive influence on improving study results in children.

According to Razavi et al., the incidence of binocular disorders is one of the main problems following keratorefractive surgery (KRS), and some of these disorders could result in persistent complications after KRS [18]. Binocular problems may be manifested after KRS, primarily in patients with poor balance of binocular vision [9]. As opposed to correction of refractive error with glasses, patients with myopia after KRS will converge and accommodate more, and patients with hypermetropia will converge and accommodate less [16]. Because it is possible to expect that convergence and accommodation after KRS will be the same as upon wearing contact lenses, this is a further reason to apply evaluation of binocular vision in cases where complaints characteristic of binocular disorders appear in patients upon correction with contact lenses. Normative values of the parameters of diagnostic tests for assessing binocular functions will help detect high risk patients for the development of these problems following KRS [18].

Incidence of binocular and accommodation disorders

The majority of studies confirm a high incidence of binocular and accommodation disorders within the population. Representation of disorders within the population and the distribution of the individual types are dependent upon the characteristics of the examined sample, the used method and above all on the selected diagnostic criteria.

Scheiman et al. studied the clinical population aged up to 18 years. Immediately after refractive errors, binocular disorders were the most widespread disorder in 14 % of the population, with accommodation disorders in 5.4 % [22]. Of the individual types of disorders there was a predominance of convergence excess (CE) 7.1 %, followed by CI at 4.6 %, accommodative insufficiency (AI) 2 % and accommodative excess (AE) 1.8 %. Upon diagnosis, criteria were used which took into consideration a number of characteristics for the individual types of disorders.

According to a study by Hokoda, for accommodation disorders in symptomatic non-presbyopic patients the incidence of AI is 9.2 %, accommodative infacility 5.1 % and accommodative spasm 2.5 % [11]. For binocular disorders the study by Borsting et al. shows the incidence of at CI 17.3 % and CE at 0.8 % [1].

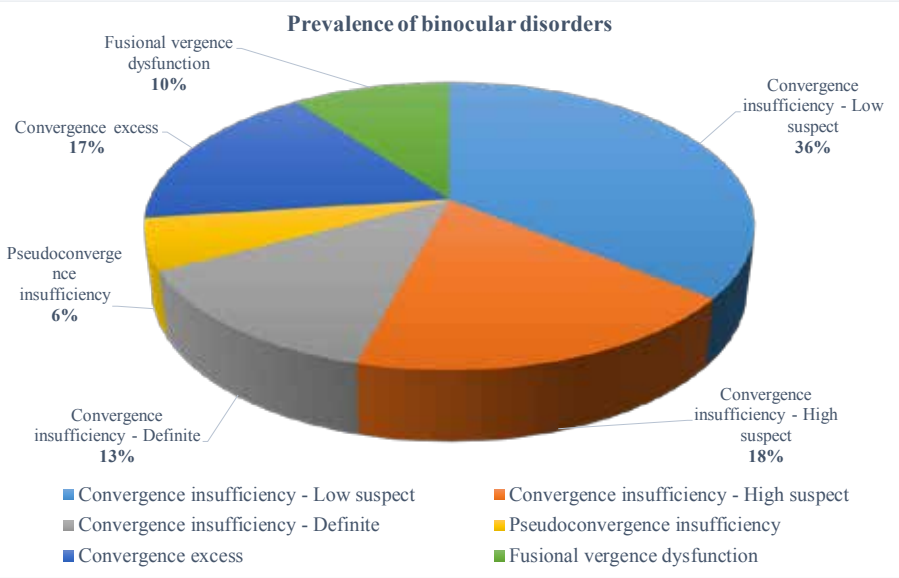
The distribution of types of binocular and accommodation disorders varies according to the different studies. An overview of the results of the frequently cited studies is presented in table 1. Graph 1 presents the distribution of types of binocular disorders for the recent study by Wajuihian and Hansraj conducted in 2015.

DIAGNOSIS

The issue of correction of binocular vision disorders has become a regular component of optometric conferences and seminars, and an ever greater number of professionals are focusing on this issue in their practice. A contribution is also made here by the availability of modern instrument equipment that several centres have at their disposal. Despite this, however, the approach to the issue in question is only partial in the majority of practices, and the actual causes of the aforementioned complaints may be overlooked, resulting in incorrect choice of solution. In evaluating the condition of binocular vision, often only one degree thereof is used. The

Table 1 Occurrence of binocular disorders to various studies

Occurrence of binocular disorders to various studies											
Authors of the study	Year of study	Country of study	Age	Sample size	Occurrence						
					Convergence insufficiency				Convergence excess	Fusional vergence dysfunction	Total binocular disorders
					Low suspect	High suspect	Definite	Total			
Wajuihian and Hansraj	2015	South Africa	13-19	1211	11,8%	6,0%	4,3%	22,1%	5,6%	3,3%	31,0%
Dusek et al.	2010	Austria	6-14	328	-	-	-	5,2%	8,2%	-	13,4%
Borsting et al.	2003	USA	8-15	392	-	12,7%	4,6%	17,3%	-	-	17,3%
Rouse et al.	1999	USA	9-13	453	8,4%	8,8%	4,2%	21,4%	-	-	21,4%
Scheiman et al.	1996	USA	6-18	1650	-	-	-	5,3%	8,2%	0,4%	13,9%
Dwyer	1992	Australia	7-18	144	-	-	-	33,0%	15,0%	-	48,0%
Some studies use division convergence insufficiency according to the diagnostic criteria - Low suspect, High suspect a Definite convergence insufficiency [27, 6, 22, 1, 5, 19].											



Graph 1 Prevalence of binocular disorders (Wajuihian and Hansraj, 2015) [27]

presence of heterophoria (HTP) and the determination of the directional type and size are generally measured above all in the case that characteristic symptoms are stated. In the case that the finding also corresponds to the symptoms, this concerns decompensated HTP [7]. Classification of HTP into compensated and decompensated HTP is clinically very important. Compensated HTP is considered to be a physiological condition which does not cause any symptoms. In order to detect decompensated HTP, it is essential to have knowledge of a wide range of symptoms of binocular disorders, their characteristics and diagnostic criteria. In practice often only the size and direct of HTP to distance is measured, without verifying its capacity for compensation. As a result binocular disorders may be easily overlooked in patients, and the stated complaints associated with a different cause. Fig. 1 presents the basic classification of HTP according to compensation, fixation of distance and direction of deviation.

Upon assessing accommodative functions, near visual acuity and available amplitude of accommodation (AA) is routinely checked. However, an adequate AA value does not eliminate the possibility of accommodation disorder [23]. In such a case there may be a problem with ill-sustained accommodation, with accommodative infacility or inability to relax accommodation. In the case of complaints characteristic of accommodation defects it is necessary a more complex evaluation of the accommodation system using further tests is required.

Division of binocular disorders

Binocular disorders are described according go the type of HTP measured for distance and near vision [23]. The original classification of strabismus developed by Duan was later modified by Tait for the division of non-strabismic binocular disorders. Here binocular disorders are divided into CI, CE, divergence insufficiency and divergence excess. The classification does not contain a diagnosis of dysfunction of fusional vergence, and in addition does not reckon with the same sizes and types of deviation for distance and near vision. Dysfunction of fusional vergence is a condition in which pronounced HTP is not present in distance or near vision, but the scope of horizontal fusional vergences is reduced for convergence and divergence. These further types of binocular disorders are included in the extended classification by Wick, which is based on a consideration of HTP for distance vision (tonic vergence) and the ratio between accommodative convergence and ac-

Obr. 1 Klasifikace heteroforií dle způsobu kompenzace, fixační vzdálenosti a směru odchylky (Evans, 2007)

commodation (AC/A ratio). The nine possibilities of diagnosis of non-strabismic disorders of binocular vision are divided on the basis of the AC/A ratio into 3 main categories (Table 2). A large contribution to this division is the allocation of a group of symptoms, traits and recommended procedure for treatment for each type of binocular disorder.

Division of accommodation disorders

The classification of accommodation by Duke Elder and Abrams is an extension of the original classification by Donders [23]. It incorporates AI, ill-sustained accommodation, AE, accommodative infacility and accommodative paralysis.

Measurement of binocular and accommodative functions

Binocular

Heterophoria

The starting point for an evaluation of binocular functions is an assessment of vertical and horizontal HTP in distance and near vision [18]. Heterophoria in distance vision is a reflection of tonic vergence and is measured when the patients fixes on a remote object with prevented fusion, relaxed accommodation and corrected refractive errors [23]. Tonic vergence means the binocular response which is maintained by the extraocular muscles. HTP in near vision is based on the AC/A ratio. Patients who experience symptoms in connection with binocular stress may have entirely normal HTP in distance and near vision [8]. The etiology of these symptoms is more complex, and as a result if such symptoms are present a complex view of binocular functions is appropriate.

Fusional vergence

Fusional vergences provide information about the patient's capacity to compensate for deviation [2]. In the past the rules for correction of binocular disorders were compiled on the basis of the ratio between the size of HTP and fusional vergence (FV). For example, Sheard's criterion states that in the case of comfortable binocular vision, FV upon HTP should be at least double the value of the size of the deviation [23]. A study by Worrell et al. detected that upon a comparison of prismatic correction prescribed according to Sheard's criterion as against correction without prisms, the application of prisms was not preferred by all patients [28]. It is important to know that it is possible to have normal ranges of FV and still have a disorder of the binocular system [18]. As a result it is appropriate to use supplementary tests for evaluation of binocular functions.

Indirect evaluation of fusional vergences

It is possible to evaluate the function of FV also by an indirect method. These tests include near point of convergence (NPC), negative and positive relative accommodation (NRA and PRA), binocular accommodative facility (BAF), vergence facility test (VFT) and tests for accommodative response [23]. Upon measurement by NPC we determine the nearest point at which the client sees the test under the conditions of simple binocular vision [13]. We refer to the location where loss of simple binocular vision first occurs as the break point, and the location where joining of an image first takes place as the recovery point. NRA and PRA evaluate the capacity for smooth disaccommodation and accommodation in pronounced changes of accommodation demand upon unchanged vergence. VFT assesses the capacity for facility of convergent and divergent FV. Even in the case of sufficient scopes of FV, BAF and VFT may detect a reduced facility of vergence. This may also provide information about the condition referred to as dysfunction of fusional vergence, which is characterised as an incapacity of the fusional binocular system to alter the demand for vergence quickly and precisely in time [27]. The capacity for FV is also indirectly documented by tests for accommodative response, which include monocular estimation

Table 2 Classification of binocular and accommodative disorders.

Classification of binocular and accommodative disorders			
Binocular disorders			
HTF at distance / AC/A ratio	HTF with low AC/A ratio	HTF with normal AC/A ratio	HTF with high AC/A ratio
Orthophoria at distance	Convergence insufficiency	Fusional vergence dysfunction	Convergence excess
Esophoria at distance	Convergence insufficiency	Basic esophoria	Convergence excess
Exophoria at distance	Divergence insufficiency	Basic exophoria	Divergence excess
Vertical HTF			
Accommodative disorders			
Accommodative insufficiency			
Ill-sustained accommodation			
Accommodative excess			
Accommodative infacility			
Paralysis of accommodation			
Classification of binocular disorders based on the heterophoria at distance and at near. Heterophoria at near is given by the ratio between the accommodative convergence and accommodation - AC/A ratio. In case that the AC/A ratio is normal, heterophoria is equal at distance and at near - basic esophoria or basic exophoria [23].			

Table 3 Overview of the diagnostic criteria for convergence insufficiency

Overview of the diagnostic criteria for convergence insufficiency					
Authors of the study		Lara et al.	Wajuihian and Hansraj	Porcar and Martinez-Palomera	Dwyer and Wick
Year		2001	2015	1997	1995
Diagnostic criteria		Need to be present signs 2-4 and two of 5-8	Low suspect CI - 1 sign, High suspect CI - 2 signs, Definite - min. 3 signs	Symptoms associated with reading. Signs below.	Present both signs.
Signs					
1	HTF	-	Exophoria at near	-	Orthophoria at distance or a very low degree of esophoria or exophoria at distance with substantial exophoria at near.
2	Exophoria at near	> 6 pd	Exophoria at near ≥ 4 pd greater than far	> 6 pd	-
3	Positive FV at near	≤ 11/14/3 (at least one of three - blur/break/recovery)	Fails Sheard's criteria or poor positive FV ≤ 15 pd for break.	Reduced positive FV	-
4	NPC	>10/17.5 cm (break/recovery)	≥ 7.5/10.5 cm (break/recovery)	Receded NPC	-
5	AC/A ratio	<3/1 (calculated AC/A ratio)	-	<3/1	<3.7/1 (calculated AC/A ratio)
6	BAF	≤ 3 cpm (with ± 2 D flipper; cpm - cycles per minute)	-	-	-
7	MEM retinoscopy	< + 0.25 D	-	-	-
8	NRA	≤ 1.5 D	-	-	-
Only the study from Wajuihian a Hansraj has more diagnostic conditions with respect to convergence insufficiency diagnostic groups. Pd - prism diopter. [27, 6, 14, 17]					

method retinoscopy (MEM) and fused cross-cylinder (FCC) [13]. In the case of presbyopic clients it is possible to use tests that do not require the necessary AA value such as NPC and VFT for indirect evaluation of FV.

In a study by Dusek et al. from 2010, a group of 825 subjects with reading difficulties was observed, in comparison with a control group of 328 subjects [5]. No statistically significant difference between the two groups was demonstrated for refractive errors, or for the size or direction of heterophoria in distance vision. On the other hand, a statistically significant difference was determined for exophoria in near vision, AA, accommodative facility, NPC and the AC/A ratio. This study confirms the significance of complex measurement of binocular functions, not only measurement of the level and direction of HTP in distance vision.

Table 4 Distribution of the convergence insufficiency groups [27]

Distribution of the convergence insufficiency groups according to diagnostic criteria (Wajuihian a Hansraj 2015) - n = 1201		
Group of CI	n	Occurrence
Low suspect	141	11,8%
High suspect	72	6,0%
Definite	51	4,3%

Accommodative

Accommodation must be assessed under monocular conditions [23]. This eliminates any influencing of the results of tests with regard to dependency on applicable binocular disorders. The tests in this category incorporate AA, monocular NRA and PRA, monocular accommodative facility (MAF), MEM and FCC. Tests under binocular conditions can be used for evaluation of the accommodation system only in the case that the binocular system is unchanged. For example, low PRA values under binocular conditions may point to AI or a problem in esophoria and low negative FV. Most often a push-up test is used for measuring AA upon evaluation of accommodative capacity in optometric practice. However, an adequate AA value does not eli-

minate the possibility of accommodation disorder [23]. In such a case there can quite easily be a problem with ill-sustained accommodation, with accommodation infacility, or with inability to relax accommodation. In the case of complaints it is appropriate to supplement measurement with further tests.

DIAGNOSTIC CRITERIA

The incidence of binocular and accommodation disorders varies in different studies. Potential causes of these differences include the influence of ethnicity, age, methodology of the tests and selection of diagnostic criteria [25]. Daum in his study diagnosed AI only on the basis of a single characteristic, which was reduced AA value [4]. When a subject had AA lower than the lower limit for the expected accommodation value with regard to age, this was classified as AI. Representation of AI was high within the sample of accommodation disorders, at 80 %. Lara et al. in their study used a number of characteristics as the diagnostic criterion for accommodation disorders [14]. For AI there were reduced or erroneous results in the tests AA, MAF, BAF, MEM or PRA. Representation of AI in the sample of accommodation disorders was at the level of 32 %. A diagnostic criterion with a larger number of characteristics also influences the incidence of binocular disorders. Rouse stated that upon the use of a larger number of characteristics for the diagnosis of CI, the frequency of the disorder was lower [19]. This assumption could be applied also to further binocular and accommodation disorders [14].

Examples of diagnostic criteria for convergence insufficiency

Convergence insufficiency is stated as the most common binocular disorder. It concerns a non-strabismic binocular anomaly characterised by an incapacity for precise convergence or maintenance thereof by the pair of eyes for a longer time in the case of performance of tasks close up [27]. Upon use of a classification with a single-characteristic criterion such as remote NPC, the incidence for various studies is within the range of 5.2–33 %. Upon the use of more characteristics, incorporating exophoria, NPC and positive FV, the incidence is lower. A condition upon occurrence of at least 2 characteristics is considered clinically significant CI. Table 3 presents the diagnostic criteria used for CI in various studies. Table 4 contains a distribution of groups of CI according to the number of diagnostic characteristics used in the study by Wajuihian and Hansraj from 2015.

CONCLUSION

Routine examination of sight mostly does not contain measurement of binocular and accommodation disorders, the occurrence of which we may expect in one quarter of the clinical population. The fact is that precise sphero-cylindrical correction may of itself significantly improve reduced binocular functions. Dwyer and Wick stated in their study that the success of treatment of binocular and accommodation disorders by precise correction of refractive error depends on the type of refractive error, age and type of binocular disorder [6]. The highest success rate was achieved in the case of hypermetropic astigmatism (79 %) and the lowest in the case of myopic patients (20 %). The authors state that there is a 50 % chance that binocular and accommodation disorder will be resolved passively by wearing precise correction of the refractive error. However, there remains a considerable percentage of patients in whom complaints may persist even despite precise correction of refractive error, due to binocular and accommodation disorders. In the case of identification of binocular and accommodation disorders, the generally recognised approach is to evaluate them 1-3 months after prescription of sphero-cylindrical correction in order to determine whether or not further treatment is required [6]. The success rate for curing non-strabismic binocular and accommodation disorders is very high [3]. The success rate for accommodation disorders is 80–100 %, and for binocular disorders 70–100 %.

List of abbreviations

AA	amplitude of accommodation
AC/A	accommodative convergence to accommodation ratio
AE	accommodative excess
AI	accommodative insufficiency
BAF	binocular accommodative facility
CE	convergence excess
CI	convergence insufficiency
FCC	fused cross-cylinder
FV	fusional vergence
HTP	heterophoria
KRS	keratorefractive surgery
MAF	monocular accommodative facility
MEM	monocular estimation method retinoscopy
NPC	near point convergence
NRA	negative relative accommodation
PRA	positive relative accommodation
VFT	vergence facility test

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