The results of objective accommodometry in eyes with concomitant strabismus

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Purpose. *This paper presents the results of objective accommodation measurements taken from patients with concomitant strabismus.* ***Materials and methods.*** *The experiment was performed on 32 patients (64 eyes) ranging from 5–26 years of age (in average 13.5±1.43 years old): 26 patients with esotropia (52 eyes), 2 patients with exotropia (4 eyes), and 4 patients with secondary strabismus. 8 of the patients (10 eyes) identified amblyopia of various degrees. 51 of the eyes exhibited hyperopia from 0.5 to 9.5 D according to spherical equivalent refraction, and 16 eyes exhibited myopia from 0.25 to 10 D. The control group consisted of 30 children with hyperopia (16 eyes), emmetropia (10 eyes), and myopia of various degrees (34 eyes) without strabismus. To determine specific indicators of objective accommodation — Binocular (BAR) and Monocular Accommodative Response (MAR), the options of consensual accommodation, as well as the resting state of accommodation (RSA) in concomitant strabismus — the open field autorefkeratometer Grand Seiko WR — 5100K was used. The degree of deviation was determined using the Hirschberg test and a handheld ophthalmoscope.* ***Results.*** *The MAR ranged between normal and drastically lower values averaging at -1.85±0.1 D. The BAR averaged at -2.23±0.1 D and was greater than the MAR in half of the measured cases (61.3%). The interocular difference in the BAR reached 2.95 D, averaging at 0.87±0.14 D. The interocular difference in MAR reached 0.85 D, averaging at 0.34±0.07 D. In the control group, BAR values were lower than MAR; the interocular differences consisted of 0.13±0.01 and 0.08±0.01 D, respectively. Highly amblyopic eyes had equal and drastically decreased BAR and MAR (average of -0.16±0.07 D); in the fellow eyes, BAR and MAR were higher -1.08±0.14 and -1.0±0.14 D, respectively. In esotropic eyes, RSA was higher in the misaligned eye, and in exotropic eyes, RSA was lower in the misaligned eye. The straight and concomitant responses were decreased: until -1.43±0.1 and -1.32±0.15 D respectively. In the control group, the straight and concomitant accommodative response was similar (average of -1.77±0.17 D in both cases).* ***Conclusion.*** *The results showed the characteristic changes in accommodative parameters as a result of heterotropia, not typical for orthotropic patients with various types of refraction.*

Ключевые слова: accommodation, accommodative response, concomitant accommodation, concomitant strabismus, resting tone of accommodation.

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It is well known that one of the important pathogenic factors of concomitant strabismus is the disruption of accommodation. In earlier studies of strabismus, a decrease of absolute volume, the disturbance of the related accommodation, and the occurrence of anisometropia have also been evident [1]. Research using laser stroboscopy methods has identified asymmetric changes in the resting state of accommodation [2]. Notably, the disturbance of the accommodation response and the disruption of the accommodation system as a whole have been described similarly to accommodative strabismus and to non-accommodative forms. At the same time, a decreased amplitude, accurate accommodation states, and increased micro fluctuations of amplitude associated with decreased contrast sensitivity in patients with monocular amblyopia have been identified. Multiple works have suggested the possible influence of irregular accommodation on the formation of amblyopia [3–7]. The phenomenon called "anti-accommodation" of an amblyopic eye is described to have an inverse correlation with accommodation of a healthy eye in patients with anisometropic amblyopia [8]. Some data has been presented on the decreased parameters of concomitant accommodation with strabismic amblyopia [9]. Attempts have been made towards functional treatment by impacting the accommodation state in patients with esotropia and heterophoria [8].

However, research studying the objective parameters of accommodation during strabismus was not been found in the literature.

PURPOSE

To analyze the results of objective accommodation measurement in patients with concomitant strabismus.

MATERIAL AND METHODS

32 patients (64 eyes) ranging from 5–26 years of age (in average 13.5 ± 1.43 years old) were studied: 26 patients with esotropia (52 eyes), 2 patients with exotropia (4 eyes), and 4 patients with secondary strabismus. 8 of the patients (10 eyes) identified amblyopia of various degrees. 51 of the eyes exhibited hyperopia from 0.5 to 9.5 D according to spherical equivalent refraction, and 16 eyes exhibited myopia from 0.25 to 10 D. The control group consisted of 30 children with hyperopia (16 eyes), emmetropia (10 eyes), and myopia of various degrees (34 eyes) without strabismus.

The degree of deviation was determined using the Hirschberg test and a handheld ophthalmoscope.

The Binocular (BAR) and Monocular Accommodative Response (MAR), the resting state of accommodation (RSA), and the concomitant accommodation were measured using the binocular, open field autorefkeratometer Grand Seiko WR — 5100K. Distant refraction was measured as the patient focused their gaze at a distant point (5 m away). Given the resulting data, a spherical or cylindrical lens was placed into the trail frame, correcting all appearing anomalies of the refraction. The Objective Accommodation Response (OAR) (the dynamic refraction of an emmetropizing eye), the Binocular Accommodative Response (BAR) (in the presence of strabismus — with both eyes open), and the Monocular Accommodative Response (MAR) was measured as the patient focused their gaze at a point 33 cm away. The fellow eye was physically blocked for the MAR measurement.

Direct (DA) and Concomitant (CA) Accommodation were measured following the methodology developed at the Helmholtz Moscow Research Institute of Eye Diseases [10, 11] using the binocular open field autorefkeratometer Grand Seiko WR — 5100K. In the case of completely corrected ametropia and divided visual fields, an object was shown to only one eye at a 33 cm distance. The OAR of this eye (Direct Accommodation, DA) and its fellow, which was not fixated on any near object (Concomitant Accommodation, CA), was measured.

The RSA was identified following the methodology developed at the Helmholtz Moscow Research Institute of Eye Diseases [12]. The study consisted of measuring the refraction of each eye in dark conditions (dark visual adaption or "dark focus") by isolating the patient from any light elements with the use of a hood. Also, the refraction was determined under induced cycloplegic conditions by instilling 1% Cyclopentolatum twice with a 15 minute break in between. The resting state of accommodation was calculated using the formula RSA = RD – RC, where RD is equal to the refraction in conditions of complete darkness ("dark focus accommodation") and RC is equal to the refraction in conditions of induced cycloplegia. RSA is positive when the refraction in darkness is stronger than in conditions of induced cycloplegia, and it is negative for the reverse circumstance; a positive RSA is denoted by a "minus" sign, whereas, a negative RSA is denoted by a "plus" sign.

RESULTS

As shown in Table 1, MAR ranged from normal (greater than -2.6 D) to drastically lower (-0.06 D) values and averaged at -1.85 ± 0.1 D. In 50% of the eyes, MAR was less than -2.0 D. BAR averaged at -2.23 ± 0.1 D and was greater than MAR half of the time (61.3%) ($p < 0.01$ between BAR and MAR). The maximum values of BAR at -5.0 D were greater than the usual at the given distance, which is equal to -3.0 D. In the control group, BAR was less than MAR for eyes with various degrees of hyperopia and weak myopia.

70% of the measurements in the case of unilateral strabismus and in the case of alternating strabismus were significant and sometimes exhibited asymmetric interocular differences of BAR and MAR. The asymmetry might have resulted in cases where the MAR was greater in one eye and the BAR was greater in the fellow eye.

The interocular difference of BAR reached 2.95 D, averaging at 0.87 ± 0.14 D. The interocular difference of MAR reached 0.85 D, averaging at 0.34±0.07 D ($p < 0.01$ between interocular differences of BAR and MAR). Only four of the patients with interocular differences of BAR and MAR exhibited unilateral strabismus; the rest were alternating.

In patients with greater degrees of amblyopia (3 patients), the values of BAR and MAR were drastically lowered in the amblyopic eyes, and in all these cases, BAR was equal to MAR (averaging at -0.16 ± 0.07 D). In the fellow eyes, the BAR and MAR values were greater (averaging at -1.08 ± 0.14 D and -1.0 ± 0.14 D, respectively), however, they also differed slightly from one another. In the control group, the myopic, hyperopic, and emmetropic cases all exhibited interocular differences less than 0.5 D, consisting of 0.08 ± 0.01 D for MAR and 0.13 ± 0.01 D for BAR. In eyes with strabismus, these values were equal to 0.34 ± 0.14 D and 0.87 ± 0.14 D, respectively; the difference between the groups was significant ($p < 0.01$).

Dark focus or dark visual adaption and RSA were measured in 3 patients with esotropia. In 5 eyes, RSA was negative (averaging at +1.2 ± 0.13 D), identifying the anisotony of accommodation. One of the patients had a negative RSA value on the straight eye corresponded with a positive RSA value (-0.4 diopters) on the turned eye with amblyopia; on the contrary, the objective accommodation response was distinctly lower on the turned eye (-0.16 diopters) and almost matched the norm on the straight eye (-1.94 D). In the case of esotropia, RSA was greater in the turned eye, but it was less, in the case of exotropia. In the control group, a negative RSA was noted in

Table 1. Objective Accommodative Response (D) in eyes with concomitant strabismus and in the control group (M±m)

Indicators		Average value, D	Maximum value D,	Minimum value, D	Notes
Objective Accommodative Response in eyes with concomitant strabismus					
MAR, n=64		-1.85±0.1	-3.0	-0.06	<-2.0 in 50%
BAR, n=64		-2.23±0.1*	-5.25	0	50% BAR>MAR by 0.97 D. 22% BAR<MAR by 0.3 D. In 28% – asymmetry: in one eye BAR>MAR, in the paired eye BAR<MAR
MAR interocular difference, n=64		0.34±0.7**	0.85	0	in 71% cases
BAR interocular difference, n=64		0.87±0.14***	2.95	0	in 65% cases
Objective Accommodative Response (D) in control group eyes					
BAR	Hyperopia, n=16 Emmetropia, n=10	-2.41±0.1	-2.88	-1.25	BAR<MAR by 0.2 D
	Myopia of low, medium, and high degree, n=34	-1.91±0.1	-2.88	-0.02	BAR>MAR by 0.09 D
MAR	Hyperopia, n=16, Emmetropia, n=10	-2.61±0.1	-2.94	-1.5	
	Myopia low, medium, and high degree, n=34	-1.82±0.1	-3.0	-0.53	
Interocular difference MAR	All refractions, n=60	0.08±0.01	-1.0	0.01	in 37% cases
Interocular difference BAR	All refractions, n=60	0.13±0.01	-1.0	0	in 25% cases

Note: n – number of eyes, * — the difference between BAR and MAR is significant, p<0.01; ** — the difference between interocular differences of MAR in the main group and in the control group is significant, p<0.01; *** — the difference between interocular differences of BAR in the main group and in the control group is significant, p<0.01.

5% of eyes with myopia and in 40% of eyes with medium and high degrees of hyperopia (Table 2).

The indicators of concomitant accommodation are presented in table 3.

The average direct and concomitant response to the -3.0 D accommodation task was decreased to -1.43±0.1 diopters and -1.32±0.15 diopters, respectively. The individual values ranged between the average (-2.8 D), the maximum (-3.62 D), and the lack thereof. Notably, the asymmetrical values of the direct and concomitant accommodation averaged 0.78±0.28 D reaching 1.93 D in some instances. A negative state of concomitant accommodation was identified in one of the patients (+0.8 D when measuring direct accommodative response of the opposite eye with -1.44 D). In the control group, the direct and concomitant accommodation responses were equal (in average, -1.77±0.17 D in both cases). The difference between the values of the direct accommodation response in the fellow eyes (interocular difference RSA) was minimal, with an average of 0.05 D. The asymmetry of the direct and concomitant accommodation in the fellow eyes of hyperopic, emmetropic, low myopic, and mild myopic cases was insignificant and uncertain (averaging at 0.08±0.01 D).The difference between this indicator with the analogous indicators found in eyes with strabismus (0.76±0.28 D) was highly reliable (p<0.01). In the highly myopic case, this diffe-rence reached 0.27±0.04 D, and it reached a maximum of 0.48±0.1 D in eyes with anisometropia.

Table 2. The Resting State of Accommodation (diopters) in Eyes with Strabismus and in the Control Group (M±m)

Indicators	Average value, diopters	Maximum value, diopters	Minimum value, diopters	Notes
Resting State of Accommodation (diopters) in eyes with strabismus				
Resting state of accommodation, n=64	+0.95±0.09	-0.4	+2.25	Negative RSA in 83% of eyes, asymetrical in monolateral strabismus, higher in esoptropic strabismus, lower in exotropic strabismus
The Resting State of Accommodation (diopters) in the control group				
Resting state of accommodation (Hyperopic low degree, Emmetropic, Myopia low, mild and high degree), n=50	-0.88±0.15	-1.5	+0.1	Negative in 5% of eyes, symmetrical
Resting state of accommodation (Hyperopic mild and high degree), n=10	-0.35±0.13	-0.95	+0.68	Negative in 40% of eyes, symmetrical

Note: n — number of eyes.

Table 3. Indicators of concomitant accommodation (diopters) in eyes with strabismus and in the control group (M±m)

Indicators	Average value, diopters	Maximum value, diopters	Minimum value, diopters	Notes
Concomitant accommodation in eyes with strabismus				
Direct accommodation response *	-1.43±0.10	2.8	-0.06	Interocular difference between the direct accommodation responses and the concomitant accommodation responses in 80% of the cases
Concomitant accommodation response*	-1.32±0.15	-3.62	+0.8	
Difference between the direct accommodation response and the concomitant accommodation response**	0.76±0.28	1.93	0.06	Asymmetry in 100% of the direct and concomitant accommodation response
Concomitant accommodation in the control group				
Direct accommodation response*	-1.77±0.17	-2.88	-0.15	Interocular difference between the direct accommodation response averaged 0.05 diopters; concomitant accommodation response – 0.17 diopters. Asymmetry in the direct accommodation response and the concomitant accommodation response was only in the highly myopic and anisometropic eyes
Concomitant accommodation response*	-1.77±0.17	-3.25	-0.25	
Difference between the direct accommodation response and the concomitant accommodation response(Hyperopic, Emmetropic, Myopia low and mild degree) **	0.08±0.01	0.2	0	
Difference between the direct accommodation response and the concomitant accommodation response(Myopia high degree) **	0.27±0.04	0.61	0.12	
Difference between the direct accommodation response and the concomitant accommodation response(anisometropic myopia) **	0.48±0.1	1.25	0.16	

Notes: n — number of eyes; * — direct accommodation response — accommodation of the focused eye, concomitant — not focused; ** — the correlated fellow eye value of concomitant accommodation was deduced out of the value of direct accommodation; specifically, the direct accommodation response from OD was compared with the concomitant accommodation response from OS and vice versa.

Earlier, the inconsistency of the direct and concomitant accommodation of the fellow eyes during high myopia and, especially, during anisometropic myopia was revealed, and we suggested to use these symptoms for diagnostic purposes [10]. We believe that this work's results on high values of asymmetrical direct and concomitant accommodation in fellow eyes of strabismus eyes non-accidentally supports the pathogenetic role of concomitant strabismus in the disturbance of the accommodation-vergence balance, and the given data should be further used for prognosis and determining treatment.

CONCLUSION

For the first time, object accommodometry carried out in eyes with concomitant strabismus revealed changed characteristics in the binocular, monocular, direct, and concomitant accommodation response and the resting state of accommodation which was unusual for orthotropy in any type of refraction. The given data supports the significant role of concomitant strabismus in the disturbance of accommodation and can further suggest using objective accommodometry in the complex treatment-diagnosis measurements of the given ophthamological conditions.

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