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Professional paper

Simple Binocular Vision Examination on Synoptophore Determination of Normative Database of Healthy Adult Subjects Examination of Binocular Vision on Synoptophore

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A B S T R A C T

The main goal of our study was to determine the database of parameters of simple binocular vision (SBV) in healthy adult population. Next goal was to verify current data of particular parameters of SBV. Average subjective deviation for far of all 74 subjects was 2.78±3.65 cm/m, of women was 2.90±3.69 cm/m and only for men was 2.00±3.49 cm/m. According our measurements the positive fusion range of all subjects is 25.10±12.77 cm/m, negative fusion range –6.45±4.18 cm/m, accommodation convergence to accommodation ratio (AC/A) is 3.41±1.47 cm/m and subjective deviation with accommodation on 33 cm (with minus 3 D) is 13.02±5.23 cm/m. Further we proved statistically significant correlation between these parameters of SBV: Age and AC/A, SU-3 and AC/A, SU0 and SU-3, SU-3 and FS0 and FS-3. Knowledge of basic SBV parameters is important not only for ophthalmologist but also for optometrists.

***Key words**: simple binocular vision, synoptophore, fusion range, accommodation convergence*

Introduction

Simple binocular vision (SBV) is coordinated senso-motor activity of both eyes, which, together with fusion, leads to establishment of simple binocular space sense. Binocular vision is not inborn. Development of SBV is connected also with visual acuity. Newborn has not developed fixation and light source is fixated with non-coordinated conjugate eye movements. From 3rd month after the birth we can see central fixation of the newborn. Meanwhile we can also observe disjunctive eye movements like is convergence and divergence. From 4th month after the birth child is able to accommodate. In the third quarter of the first year child is able to fuse and at the end of the first year of life binocular vision is improving. Child is able to have stereoscopy vision[1].

We can divide conditions for normal development of SBV in the two main groups. First group, senso-motor, contains normal or nearly normal both eyes vision (i.e. good visual acuity), nearly the same size of retinal images of both eyes, common sensation with both eyes and good fusion ability. Second group (motor) consists of parallel eye vision direction for far, free movement of eyes in all directions and coordination of accommodation and convergence.

We can divide SBV in tree levels. It is superposition, fusion and stereovision. Superposition means ability to accept senses from both eyes. On synoptophore it means the coverage of one examination picture (e.g. lion) with the second (e.g. cage). The result is superposition or diplopia (crossed or uncrossed). Fusion is ability to connect sense from one eye with sense from the second eye. It is possible only if all sensor and motor predispositions are correct. We usually distinguish sensory fusion and motor fusion, when eyes must move to cross visual axes on fixation target. According to Duke-Elder[2] is normal fusion range in horizontal direction 30 degrees in convergence, 5 to 8 degrees in divergence and 3 to 6 degrees in vertical direction. Hurt and collective[3] set nearly the same values but in prismatic dioptres (cm/m). With mea-

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suring of range of fusion we try to find angle of convergence or divergence when SBV is broken. Also we can assess the power of fusion according to velocity and ability of SBV recovery. Fusion maintains SBV. Stereoscopic vision is possible only in certain limited 3-dimenzional space in front of and behind the fixation curve (horopter). It is so called Panum's area. According to Parks[4] the minimum of horizontal disparity, which cause stereoscopic vision is 14 seconds of arc. Quality of stereoscopic vision depends on quality and wide of range of fusion. That is the reason why is very important to know/measure this parameters of SBV.

Pathology of SBV is suppression, amblyopia and anomaly retinal correspondence (ARC). Suppression is the way, how to stop accept/see the sense from deviated eye. Amblyopia is decrease of visual acuity of the eye, which looks normal and is without signs of pathology. We usually distinguish these types of amblyopia: amblyopia ex anopsia, congenital, anisometropic, meridional, ametropical, relative and amblyopia by strabismus. According to degree of decrease of visual acuity we usually divide amblyopia to amblyopia gravis (visual acuity below 0.1), intermediate (from 0.1 to 0.3) and levis (from 0.4 to 0.8)[1]. ARC is sensor adaptation on motor anomaly by strabismus. The cause is placed in visual cortex of visual path not on the retina. In principal, fovea of leading eye and pseudo-fovea of the deviated eye gain common space localization and make new retinal image. We distinguish two forms of ACR: harmonic (HARK) and disharmonic (DARK). With HARK angle of anomaly is equal to objective angle of strabismus. With DARK angle of anomaly is smaller then objective angle of strabismus. When we want to check angle of anomaly (AA), we have to know the objective (OA) and subjective angle (SA). The smaller AA is the bigger is normal retinal correspondence (NRC).

Synoptophore is instrument (Figure 1), which could be used by SBV disorders for therapeutic and diagnostic purpose. The main principal of synoptophore/haploscope is mechanical dividing of sense of right and left eye. First haploscope was used in 19th century by E. Hering. At the beginning of the 20th century C. Worth used this instrument for compensation of horizontal and vertical deviation by strabismus. M. Maddox, daughter of E. Maddox, defined usage of this instrument in 1931. She set 3 levels of SBV and their training. In Britain is this instrument usually known as synoptophore, but in USA as troposkop.

Synoptophore consist of the base, which connects horizontally movable arms. Base also contains chin and forehead rest and buttons for adjusting of intensity and frequency of the light sources, which are placed in movable arms. Arms also contains semitransparent plates and plus lenses (+8 D) for proximal convergence elimination. Rotation angle of arm is read from the scales in prismatic dioptres or in degrees of arc (1 deg of arc is approximately 2 cm/m). There is also scale on the arms for measuring of vertical deviations and fusion range. Synoptophore allows to measure also cycle-deviations. In addition we can examine eccentric fixation (EF) with Haidinger bundle if the instrument contains it. For SBV examination we usually use 3 types of pictures. Pictures are divides according to type (superposition, fusion and stereoscopy) and size (foveolar, macular and paramacular). For superposition we use dissimilar pictures (Figure 2), for fusion similar pictures (Figure 3) and for stereoscopy dissociated pictures (Figure 4)[5].

On synoptophore we examine patient's SBV with or without proper subjective correction. At first patient sit down on the chair behind the instrument and examiner set the proper pupillary distance on the scale. After that examiner checks corneal reflections (CR). All scales are set to zero position. At first we check and measure objective deviation (OD) of the eyes. Examiner alternatively

Fig. 1. Synoptophore.

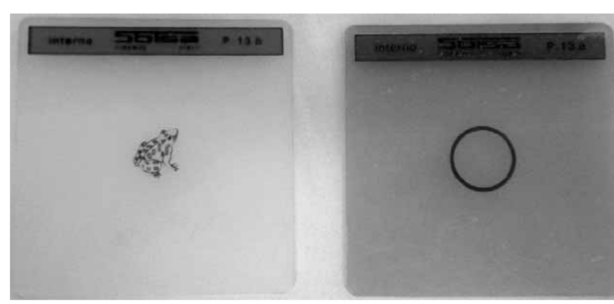

Fig. 2. Pictures for superposition.

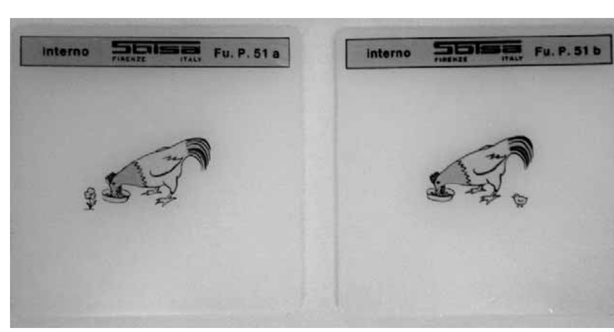

Fig. 3. Pictures for fusion.

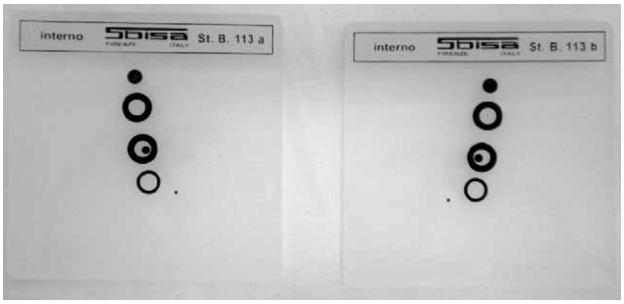

Fig. 4. Pictures for stereoscopy examination.

switches on and off the light in instrument's arms and moves with the arms to eliminate back movement of the eyes. Final move of the arm shows objective deviation in degrees of arc or in cm/m. After that we usually check subjective deviation (SD). SD is measured on the scale, when patient is able to see superposition of the dissimilar pictures. If there is the difference between OD and SD higher than 3 degrees of arc, it means that we probably find ARC. Retinal correspondence is also checked with method of Hering-Bielschowski after-images. After superposition we examine fusion. Patient should be able properly connect similar pictures. Afterwards we measure positive range of fusion with moving arms nasally and negative range of fusion with moving arms temporally. We look for so called blur points (BLP), break points (BRP) and recovery points (RP). The range of fusion should be the biggest in convergence direction and the smallest in vertical direction. At last we examine stereoscopic vision with dissociated pictures[6].

We can also analyze heterophoria on synoptophore[7]. Instrument allows to measure values of relative convergence and accommodation, wide/power of fusion for far and for near and accommodation convergence to convergence ratio (AC/A), which significantly influences quality of SBV. Certain portion of convergence corresponds with certain portion of accommodation. This relationship is expressed also in graphic way with co called Donder's line (see Graf 1). The increase of accommodation on synoptophore is possible due to addition of minus lenses. We measure AC/A gradient (AC/Ag). Figure 5 shows heterophoria analysis of young adult hypermetrop without eye pathology. Pupilary distance was 5.8 cm and SD for far is 6 cm/m. SD for near (33 cm with minus 3 D) should theoretically be 18 cm/m. But we measured 19 D and it means, that AC/Ag is 4.3 cm/m to 1 D of accommodation (4.3:1).[6]

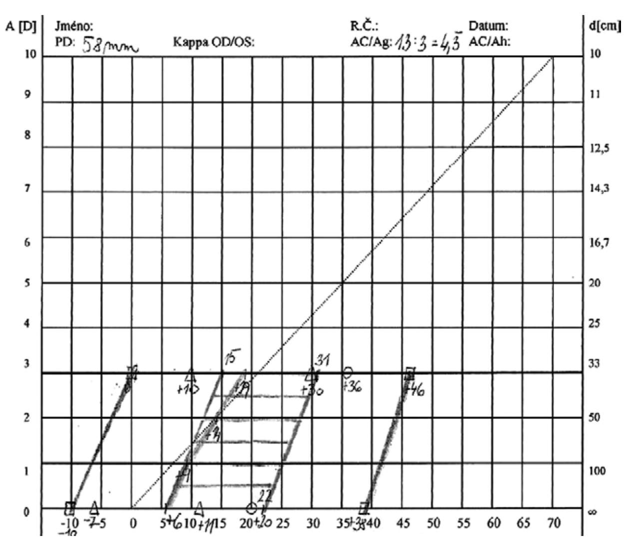

Fig. 5. Heterophoria analysis of young hypermetrop without eye pathology[6].

Material and Methods

We examined SBV of 74 subjects on synoptophore (64 women, 10 men). All subjects were healthy (without eye pathology). Ametropes wore their habitual correction. All examinations were done without pharmacology tools (e.g. atropin) in standardized light conditions in different day time. We used Sbisa synoptophore.

We got together results from 74 patients. Values were measured in cm (pupillary distance) and in prismatic dioptres (cm/m – angle of deviation, fusion range). Data were count and processed with statistical program STATISTICA (StatSoft CR) version 10 and with MS EXCEL version 2007. We used normality tests (Lilliefors, Shapiro-Wilks) for testing of data normality. We proved abnormal data distribution so we used non-parametric test (Spearman correlation test). But in comparing of male and female data, there was normal data distribution, so we could use parametric T-test for comparison. Statistical level of significance was set on p=0.05.

TABLE 1
AVERAGE PARAMETERS OF SINGLE BINOCULAR VISION (SBV) OF ALL SUBJECTS

Parameters of single binocular vision	Value ± standard deviation and unit
Pupillary distance (PD)	6.02±0.29 cm
Subjective deviation for far (SU0)	2.78±3.65 cm/m
Far nasal blur point (BLP0)	19.04±9.48 cm/m
Far nasal break point (BRPN0)	25.10±12.77 cm/m
Far temporal break point (BRPT0)	–6.45±4.18 cm/m
Far nasal recovery point (RPN0)	10.54±8.04 cm/m
Far temporal recovery point (RPT0)	–1.3±3.71 cm/m
Subjective deviation for near (SU-3)	13.02±5.23 cm/m
Near nasal blur point (BLP-3)	35.54±12.20 cm/m
Near nasal break point (BRPN-3)	42.09±15.14 cm/m
Near temporal break point (BRPT-3)	–0.90±6.77 cm/m
Near nasal recovery point (RPN-3)	24.06±12.23 cm/m
Near temporal recovery point (RPT-3)	8.01±7.90 cm/m
Accommodation convergence to accommodation ratio (AC/A)	3.41±1.47 cm/m
Far fusion range	31.56±12.30 cm/m
Near fusion range	42.74±15.30 cm/m

TABLE 2
AVERAGE PARAMETERS OF SINGLE BINOCULAR VISION (SBV) OF ALL WOMEN

Parameters of single binocular vision	Value ± standard deviation and unit
Pupillary distance (PD)	5.97±0.29 cm
Subjective deviation for far (SU0)	2.90±3.69 cm/m
Far nasal blur point (BLP0)	19.08±9.69 cm/m
Far nasal break point (BRPN0)	25.20±12.99 cm/m
Far temporal break point (BRPT0)	–6.21±4.26 cm/m
Far nasal recovery point (RPN0)	10.50±7.89 cm/m
Far temporal recovery point (RPT0)	–1.13±3.72 cm/m
Subjective deviation for near (SU-3)	12.93±5.01 cm/m
Near nasal blur point (BLP-3)	35.14±12.35 cm/m
Near nasal break point (BRPN-3)	42.59±14.94 cm/m
Near temporal break point (BRPT-3)	–0.82±6.91 cm/m
Near nasal recovery point (RPN-3)	24.30±11.82 cm/m
Near temporal recovery point (RPT-3)	8.34±7.92 cm/m
Accommodation convergence to accommodation ratio (AC/A)	3.34±1.49 cm/m
Far fusion range	31.42±12.54 cm/m
Near fusion range	43.12±15.04 cm/m

TABLE 3
AVERAGE PARAMETERS OF SINGLE BINOCULAR VISION (SBV) OF ALL MEN

Parameters of single binocular vision	Value ± standard deviation and unit
Pupillary distance (PD)	6.32±0.31 cm
Subjective deviation for far (SU0)	2.00±3.49 cm/m
Far nasal blur point (BLP0)	18.00±0.00 cm/m
Far nasal break point (BRPN0)	24.50±11.86 cm/m
Far temporal break point (BRPT0)	–8.00±3.43 cm/m
Far nasal recovery point (RPN0)	10.77±9.56 cm/m
Far temporal recovery point (RPT0)	–2.44±3.67 cm/m
Subjective deviation for near (SU-3)	13.60±6.76 cm/m
Near nasal blur point (BLP-3)	44.00±0.00 cm/m
Near nasal break point (BRPN-3)	38.90±16.87 cm/m
Near temporal break point (BRPT-3)	–1.40±6.13 cm/m
Near nasal recovery point (RPN-3)	22.60±15.17 cm/m
Near temporal recovery point (RPT-3)	5.66±7.77 cm/m
Accommodation convergence to accommodation ratio (AC/A)	3.86±1.27 cm/m
Far fusion range (FS0)	31.50±11.22 cm/m
Near fusion range (FS-3)	40.30±17.53 cm/m

Results

Average age of 74 non-pathological subjects was 24.82 years (max. 28, min. 22, SD 2.5 years). We measured these average parameters of SBV from all subjects (Table 1). From only women (n=64, average age 24.82±2.5 years) we measured these average parameters of SBV (Table 2). From only men (n=10, average age 25.90±1.10 years) we measured these average parameters of SBV (Table 3). Further we proved, from basic data set (men and women), statistically significant correlations between some parameters of SBV with help of non-parametric test (Spearman test, see Table 4). In the next part of work we divided part of data set according to refractive error. We got 9 emetropes, 4 hypermetropes and 10 myopes. With help of parametric T-test we compared these data to prove statistically significant differences (see Table 5). Finally we divided basic data set according to gender (64 women and 10 men) and with help of parametric T-test we tried (with respect to data asymmetry) to prove differences (see Table 6).

Discussion

The main goal of our study was to set normative database of standard parameters of SBV. Currently many of authors show different values of parameters of SBV (fusion range, AC/A and so on).

Divišová[1] presents AC/A value in healthy population from 2 to 5 cm/m of accommodation convergence to one

TABLE 4
CORRELATION BETWEEN SOME AVERAGE PARAMETERS OF SINGLE BINOCULAR VISION (SBV)

Parameter 1	Parameter 2	Number N	Spearman R	p-value	Correlation
Age	AC/A	74	0.273	0.018	YES
SU0	AC/A	74	–0.103	0.378	NO
SU-3	AC/A	74	0.717	0.000	YES
PD	SU0	74	–0.226	0.052	NO
SU0	SU-3	74	0.559	0.000	YES
SU0	FŠ0	74	0.182	0.118	NO
SU-3	FŠ-3	74	0.260	0.024	YES
FŠ0	FŠ-3	74	0.585	0.000	YES

SU0 – Subjective deviation for far; SU-3 – Subjective deviation for near; PD – Pupillary distance; AC/A – Accommodation convergence to accommodation ratio; FS0 – Far fusion range; FS-3 – Near fusion range

TABLE 5
DIFFERENCES BETWEEN SOME PARAMETERS OF SINGLE BINOCULAR VISION ACCORDING TO REFRACTIVE ERROR (T-TEST)

Parameter 1	Parameter 2	t-value	p-value	Difference
EM-ACA	HY-ACA	–0.539	0.600	YES
EM-ACA	MY-ACA	–0.685	0.502	YES
HY-ACA	MY-ACA	0.090	0.929	YES
EM-BRPN0	HY-BRPN0	0.046	0.963	YES
EM-BRPN0	MY-BRPN0	–0.423	0.677	YES
HY-BRPN0	MY-BRPN0	–0.327	0.748	YES
EM-BRPN-3	HYBRPN-3	0.738	0.475	YES
EM-BRPN-3	MY-BRPN-3	0.059	0.953	YES
HY-BRPN-3	MY-BRPN-3	–0.497	0.628	YES
EM-BRPT0	HY-BRPT0	–1.983	0.072	YES
EM-BRPT0	MY-BRPT0	–1.507	0.150	YES
HY-BRPT0	MY-BRPT0	0.741	0.472	YES
EM-BRPT-3	HY-BRPT-3	–1.271	0.229	YES
EM-BRPT-3	MY-BRPT-3	–0.397	0.695	YES
HY-BRPT-3	MY-BRPT-3	0.711	0.490	YES
EM-SU0	HY-SU0	–1.423	0.182	YES
EM-SU0	MY-SU0	–0.614	0.547	YES
HY-SU0	MY-SU0	1.006	0.333	YES
EM-SU-3	HY-SU-3	–1.956	0.076	YES
EM-SU-3	MY-SU-3	–1.178	0.254	YES
HY-SU-3	MY-SU-3	0.792	0.443	YES

EM – emetropia; HY – hyperopia; MY – myopia; SU0 – Subjective deviation for far; SU-3 – Subjective deviation for near; AC/A – Accommodation convergence to accommodation ratio; BRPN0 – Far nasal break point; BRPN-3 – Near nasal break point; BRPT0 – Far temporal break point; BRPT-3 – Near temporal break point

TABLE 6
DIFFERNCES BETWEEN SOME PARAMETERS OF SINGLE BINOCULAR VISION ACCORDING TO GENDER (T-TEST)

Parameter 1	Parameter 2	t-value	p-value	Difference
PDZ	PDM	–3.714	0.000	NO
SU0Z	SU0M	0.726	0.469	YES
BRPN0Z	BRPN0M	0.160	0.872	YES
BRPT0Z	BRPT0M	1.256	0.212	YES
SU-3Z	SU-3M	–0.379	0.712	YES
ACAZ	ACAM	–1.045	0.299	YES
FŠ0Z	FŠ0M	–0.255	0.798	YES
FŠ-3Z	FŠ-3M	0.540	0.590	YES

Z – women; M – men; SU0 – Subjective deviation for far; BRPN0 – Far nasal break point; BRPT0 – Far temporal break point; SU-3 – Subjective deviation for near; FS0 – Far fusion range; FS-3 – Near fusion range

accommodation dioptre. But she notes that values can be more diffused. Values of horizontal fusion range (in our case BRPN0) are in healthy population according to Divišová[1] from 15 to 25 cm/m and negative fusion range (in our case BRPT0) from –6 to –12 cm/m. Divišová[1] further states: »There are higher both these values in practice, especially in convergence direction«. But our average data do not correspond with this: BRPN0 = 25.10±12.77 cm/m a BRPT0 = –6.45±4.18 cm/m. Divišová further reminds that values of fusion range may differ according to age, attention and training, size of fusion objects and according to examination method. »On synoptophore there is usually higher fusion range for near than for far, because of instrument/psychological convergence«, write Divišová.

Hromádková[8] in her publication writes that normal range of positive horizontal fusion is 30 degrees of arc (i.e. nearly 60 cm/m), negative fusion is 8 degrees of arc (i.e. 16 cm/m) and vertical fusion range is 3 degrees of arc (6 cm/m). We think, according our results, that these values are a bit higher than is usual (240 % of our average positive and 266 % of our average negative fusion range). The range of fusion also depends on size of examination pictures. With big/wide pictures we can find fusion range from –3 to 25 degrees of arc. We used pictures in macular size. According to Hromádková fusion range with these pictures should be from –2 to +15 degrees of arc. We can say, that these values nearly corresponds with our results (BRPN0 = 25.10±12.77 cm/m a BRPT0 = –6.45±4.18 cm/m). So we conclude that setting of type of used method and size of used examination picture is very important information by examination of SBV.

Range of fusion we can also measure with prismatic lenses or bars. Patient fixate light source on 5 meters. We gradually add prisms. Positive range of fusion is measured with prisms base out and negative range of fusion with prisms base in. We increase prisms until comes diplopia. According to Hromádková[8] healthy adult subjects should have positive fusion range from 25 to 40 cm/m, negative fusion range from 8 to 10 cm/m and vertical fusion range from 3 to 4 cm/m. These values also correspond with our measurements on synoptofor (BRPN0 = 25.10±12.77 cm/m a BRPT0 = –6.45±4.18 cm/m), although they were measured with different method.

Author Adamek[9] found on data set from 132 patients differences between range of fusion on right and left eye. Total 35.6% of patients had difference between fusion range of right and left eye for near by convergence, 34.4% of patients had difference between fusion range of right and left eye for far by convergence and 65.6% of patients had difference between fusion range of right and left eye. We did not check differences between fusion ranges of our subjects' eyes.

The quality of SBV is measured with measuring of vergence facility (VF). We put alternatively 12 cm/m with base out and 3 cm/m with base in and count the cycles per minute. Standard value of VF for near (1/3 m) is according to Melville[10] 12±4.2 cm/m. Author Melville but not proved correlation between VF and quality of SBV in his study.

Author Sharma[11] in his study of 20 normal healthy subjects with visual acuity 6/6 without refractive errors studied quality of SBV, which is disturbed by objects of difference size (aniseikonia). Sharma on synoptophore measured 15.2 cm/m of adduction vergence (positive fusion range) and 5 cm/m of abduction vergence (negative fusion range). With another special polarization instrument (5 meters of exanimation distance) Sharma measured adduction vergence from 2 to 6 cm/m (with average 2.92 cm/m) and abduction vergence from 1 to 3 cm/m (with average 2.16 cm/m). Values of positive and negative range of fusion measured on synoptophore by Sharma are only 11%, respective 35% of our data. Sharma[11] found that 70% of patients are able to accept 30% of aniseikonia and wider fusion range do not significantly influence increase of this ability.

Conclusion

Knowledge of basic SBV parameters is important not only for ophthalmologist but also for optometrists, who are able to influence these parameters in the way of comfortable SBV and clear vision. The most frequent optometric methods are proper sphere-cylindrical correction, prismatic correction and visual training.

In our study we set the normative average data of SBV parameters, which were measured on healthy adult emetropes and ametropes with habitual correction. We found how parameters influence each other (age – AC/A, SU-3 – AC/A, SU0 – SU-3, SU-3 – FS-3 and FS-0 – FS-3). All SBV parameters differ on statistically significant level, when we compared them with respect to refractive state or gender. Our results are probably negatively influenced by small number of subjects in group of men.

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ISPITIVANJE BINOKULARNOG VIDA NA SINOPTOFORU KOD ODREĐIVANJE BAZE PODATAKA U POPULACIJI ZDRAVIH SUBJEKATA

S A Ž E T A K

Glavni cilj ovog rada jeste izraditi bazu podataka binokularnog vida na sinoptoforu u zdrave populacije odraslih. Kod naših mjerenja pozitivne fuzije pokazalo se u svih ispitanika 25,10±12,77 cm/m,dok je negativna fuzija iznosila –6,45±4,18 cm/m, dok je AC/A (akomodacijska konvergencija spram akomodacijskoj vrijednosti), iznosila 3,41±1,47 cm/m, dok je subjektivna devijacija spram akomodaciji na 33 cm (sa minus 3D) iznosila 13,02± cm/m. Zaključuje se da su vrijednosti u bazi podataka vrlo bitne, kako za oftalmologe, tako i za optometriste u praksi.