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CLINICAL REPORT

Binocular Vision Changes in University Students: A 3-Year Longitudinal Study

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ABSTRACT

Purpose. The aim of this study was to investigate the changes in accommodation and binocular vision parameters during a period of 3 years and to evaluate their potential influence on the refractive changes observed over the same period of time in a population of university students in Portugal.

Methods. A 3-year longitudinal study was conducted comprising 118 young adults (34 males and 84 females; mean age: 20.6 ± 2.3 years). Examinations consisted of subjective refraction, dissociated phoria and vergences at distance and near vision, accommodative convergence/accommodative ratio, lag of accommodation, and the negative and positive relative accommodation.

Results. There were statistically significant differences between the first (2002) and the second examination (2005) relative to distance and near phoria, and break and recovery points for the base-in and base-out at distance vision. Statistically significant differences were also obtained for the blur and break points for the base-out, and for break and recovery points for the base-in at near vision. As regards accommodation parameters, we verified a statistically significant difference for all parameters measured. Comparing the baseline values of patients who suffered a myopic shift ≥0.50 D with those from patients who did not experience such a shift, we observed a statistically significant difference for the break value of the base-in at distance vision (equal to 12.2 ± 3.6 for the group without refractive error alteration and 15.8 ± 6.8 for the other group) and for the break value of the base-in at near vision (equal to 22.4 ± 5.2 and 24.8 ± 5.5 for the group without refractive error alteration and for the other group, respectively).

Conclusions. We observed significant changes in near heterophoria, fusional vergences, and positive relative accommodation. The break values of the base-in fusional vergence account as significant predictors of myopic shift in young adults.
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Key Words: binocular vision, accommodation, myopia progression, refractive changes, longitudinal study, university students

Evaluation of binocular vision, particularly heterophoria tests, is an important component of routine optometric examination. Several studies have provided normative values for binocular function in different populations.[1,2] There are only limited data available on binocular vision reporting the longitudinal alterations for large non-clinical populations.[3] Only one retrospective study has evaluated the longitudinal variations in binocular vision parameters over a period of 20 years.[4] However, there are no data about the variations of those parameters in young adult students at university level. This population represents a group of special interest because of a potential risk of developing late-onset or progression of myopia during university education. Results currently available showed substantial variability regarding this issue in different populations.[5–9]

Accommodative lag has been considered by several researchers as a potential precursor of myopia.[10–15] However, this theory is not supported by current research conducted by Mutti et al.[16] Regarding longitudinal variations of positive and negative relative accommodation (PRA and NRA, respectively), there is a lack of literature published concerning their potential impact on visual changes during late-onset and progression of myopia.

The goal of this study is to evaluate the longitudinal changes in binocular vision and accommodative parameters in a group of Portuguese science undergraduate students over a 3-year period and to evaluate their potential influence on refractive changes over the same period of time.

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MATERIALS AND METHODS

Subjects

In 2002, a sample of 150 first-year students (43 male and 107 female) from the School of Sciences (University of Minho, Braga, Portugal) was randomly selected from a total of 529 science students and evaluated at the Laboratory of Clinic Optometry. Criteria for exclusion from the study were diabetes mellitus or previous or present eye disease or injury. According to these criteria, seven subjects were not enrolled in the longitudinal study, two of them having keratoconus, three presenting high intra-ocular pressure values, and two with a history of previous strabismus surgery. The final sample consisted of 143 students [42 male and 101 female with a mean age of 20.6 ± 2.3 (years ranging from 18 to 28)]. After the 3-year period, 118 (82.5%) students remained in the study. Of the 25 students that did not complete the study (8 male and 17 female), 20 were had changed city and university, and the other 5 did not attend the final examination, and it was not possible to contact them again.

Study protocol followed the Declaration of Helsinki rules and was reviewed and approved by the Scientific Committee of the School of Sciences of the University of Minho (Portugal). After all procedures were explained, subjects signed an informed consent form before being enrolled in the study.

All the various measurements were performed at each visit in the following order: refractive error measurement without cycloplegic, binocular vision measurements, accommodation measurements, cycloplegic instillation, and 30 min after refractive error measurements.

Refractive Error Measurements

The measurements at the first (2002) and second visit (2005) were performed by the first author (JJ) using the same equipment and methods as described below. Non-cycloplegic and cycloplegic refractive error was measured by monocular subjective refraction according to the protocol described in previous publications.[17–19] For the refractive state characterization, the cycloplegic refraction was used.

Binocular Vision Measurements

Binocular vision and accommodative parameters were evaluated under non-cycloplegic conditions and included horizontal phoria, fusional vergence ranges at distance vision (DV) and near vision (NV), PRA and NRA, accommodative convergence/accommodative demand ratio (AC/A) and accommodation lag (lag).

Direction and magnitude of the horizontal phoria were measured with the Von Graefe method at 6 m and 40 cm. While viewing a high contrast 20/25 column of letters of the Snellen chart, a fixed 6 Δ base-up prism was placed in front of the right eye and a 12 Δ base-in prism in front of the left eye using the Risley prism. Subjects were instructed to fixate the non-moving image and to keep the letter(s) clear at all times. The magnitude of horizontal prism was changed until the patient reported that the two images appeared "in vertical alignment," and the value was registered.

Risley rotary prisms were used to evaluate distance and near horizontal fusional vergence ranges. Approximately equal amounts of prism were introduced in front of each eye at a constant rate of approximately 2 Δ/s while the patient was looking at a high contrast 20/25 column of letters of Snellen characters at distance and near. Prisms were rotated until the subject first reported blur (blur value); further rotation was performed until diplopia occurred (break value). At this point, the amount of prisms was then increased by 3 Δ in each eye and subsequently reduced until the subject was just able to re-fuse the diplopic images (recovery value). As recommended by Rosenfield et al.,[20,21] distance base-in ranges were measured before base-out to avoid vergence adaptation.

The AC/A ratio was measured by the gradient method. Following the measurement of the near horizontal phoria, +1.00 lenses were placed in front of both eyes and the change in phoria value was determined. The difference between the two phoria measurements was recorded as the AC/A gradient value.

All measurements were performed twice and the mean value was then calculated.[21–23]

Accommodation Measurements

Accommodation lag was measured by dynamic retinoscopy [Monocular Estimate Method (MEM)] performed at 40 cm, with the result of the subjective examination placed in the trial frame. This method consists in an estimation of how far the reflex is from neutrality, and then very briefly (less than 1/2 s), a lens was put in front of the eye to confirm if the estimation was correct. The patient is viewing a target at the retinoscope plane. The target was a special near point card with a central hole surrounded by a circular series of letters. The near point card was the same design as the Bernell Corporation MEM card.

PRA and NRA were assessed while the patient was fixating the horizontal line of high contrast 20/20 letters at 40 cm. The NRA was determined by increasing plus lenses in 0.25 D steps until the patient reported the first sustained blur. At this point, the patient noticed that the letters were no longer appearing as sharp, clear, and legible as they were initially. The total amount of plus power added was recorded. The refractive value in the phoropter was adjusted to the value obtained before NRA measurements, making sure the letters were clear again. The PRA was measured by racking up minus lens power in 0.25 D steps until the patient reported the first sustained blur, and the total amount of minus power added was recorded. NRA was always measured first, followed by PRA.

Statistical Analysis

As noted by several authors,[24–28] the assimilation of data on the epidemiology of refractive errors is confounded by limitations and inconsistencies in technical and statistical procedures as well as in the definition of emmetropia and ametropia. Several investigators[29,30] have recognized that traditional clinical representations of refraction, including sphere, cylinder, and axis, are not adequate for quantitative analysis. For this reason, sphero-cylindrical refractive results were converted into vector representations by Fourier analysis, as recommended by Thibos et al.[31] In this notation, M represents the spherical equivalent; J0 and J45 represent the astigmatism. Positive J0 values represent with-the-rule astigmatism and negative values correspond to against-the-rule astigmatism. J45

TABLE 1.
Descriptive statistics and statistical significance of changes in refractive error, binocular vision, and accommodative parameters during a 3-year period (n = 118 university students)

	1st exam (mean ± SD)	2nd exam (mean ± SD)	Change (mean ± SD)	p
Refractive error (D)				
M	0.04 ± 1.49	−0.25 ± 1.72	−0.29 ± 0.38	0.000
J0	0.12 ± 0.25	0.10 ± 0.24	−0.02 ± 0.16	0.435
J45	−0.05 ± 0.18	−0.04 ± 0.21	−0.01 ± 0.10	0.935
Binocular Vision				
Phoria (Δ)				
PhDV	−0.4 ± 2.6	−0.9 ± 3.0	−0.5 ± 2.2	0.004
PhNV	0.4 ± 5.4	−1.2 ± 5.4	−1.6 ± 4.1	0.000
Vergences (Δ)				
BrBIDV	13.0 ± 4.6	10.7 ± 3.7	−2.3 ± 3.4	0.000
ReBIDV	5.2 ± 2.1	6.0 ± 2.4	0.8 ± 2.8	0.007
BlBODV	13.1 ± 5.7	12.0 ± 5.6	−1.1 ± 6.4	0.343
BrBODV	23.8 ± 8.8	22.1 ± 8.5	−1.7 ± 8.5	0.025*
ReBODV	8.0 ± 5.4	10.6 ± 6.5	2.6 ± 5.7	0.000
BlBINV	15.8 ± 5.1	13.9 ± 6.0	−1.9 ± 5.3	0.030
BrBINV	22.9 ± 5.4	19.6 ± 5.6	−3.3 ± 4.8	0.000
ReBINV	11.5 ± 4.6	11.8 ± 4.9	0.3 ± 5.3	0.312
BlBONV	19.7 ± 8.2	20.6 ± 8.0	0.9 ± 10.3	0.659
BrBONV	29.7 ± 9.0	28.0 ± 9.6	−1.7 ± 7.6	0.044
ReBONV	13.7 ± 7.6	15.9 ± 8.6	2.2 ± 9.2	0.045
AC/A	4.4 ± 2.2	3.9 ± 2.1	−0.5 ± 2.8	0.081
Accommodation (D)				
Lag	1.12 ± 0.42	1.44 ± 0.50	0.32 ± 0.47	0.010
PRA	2.21 ± 0.42	2.31 ± 0.48	0.10 ± 0.40	0.010
RNA	2.33 ± 1.40	2.99 ± 1.33	0.66 ± 1.35	0.000

*Statistical analysis performed with Student's t-test, other parameters' statistical analysis performed with Wilcoxon test.

PhDV, phoria distant vision; PhNV, phoria near vision.

BrBIDV, break value base-in vergences at distant vision; ReBIDV, recovery value base-in vergences at distant vision; BlBODV, blur value base-out vergences at distant vision; BrBODV, break value base-out vergences at distant vision; ReBODV, recovery value base-out vergences at distant vision.

BlBINV, blur value base-in vergences at near vision; BrBINV, break value base-in vergences at near vision; ReBINV, recovery value base-in vergences at near vision; BlBONV, blur value base-out vergences at near vision; BrBONV, break value base-out vergences at near vision; ReBONV, recovery value base-out vergences at near vision.

represents astigmatism with an oblique orientation (intermediate axis values).

Myopia was defined as $M \leq -0.50$ D, emmetropia as $M > -0.50$ D and $< +0.50$ D, and hyperopia as $M \geq +0.50$ D. Only the right eye was used for statistical analyses concerning monocular visual parameters.

Data were analyzed using the statistical package SPSS version 14.0 (SPSS, Chicago, IL). After normal distribution and equality of variances were assessed with the Kolgomorov-Sirmnov test and Levene test, respectively, the statistical significance of differences between first and second exams was assessed by parametric or non-parametric tests (paired sample t-test and Wilcoxon test, respectively). The level of significance was established at $\alpha \leq 0.05$.

RESULTS

There were no significant differences in the baseline refractive error, binocular vision, and accommodation of the 25 students lost to follow-up when compared with the 118 that were examined after 3 years (33.3 months, ranging from 30 to 38 months).

Table 1 displays mean (mean ± SD) values of the M, J0, and J45 components of refraction, and the accommodation and the binocular vision parameters at the first and second examination during the 3-year period. Average change and statistical significance are also represented.

Longitudinal Variation of Refractive Parameters

For the refractive state, we only found a statistically significant trend for the M component toward more negative values ($p < 0.001$); conversely, no significant change was observed for the components J0 and J45 ($p = 0.435$ and $p = 0.935$, respectively). This means that the astigmatic error did not register any clinical or statistically significant change during this period of time in this population.

The prevalence of myopia at baseline was 22%, emmetropia 28.8%, and hyperopia 49.2%. The mean change in the refractive error was −0.29 ± 0.38 D, and 22% of the population experienced a change in refractive error of at least −0.50 D. After 3 years,

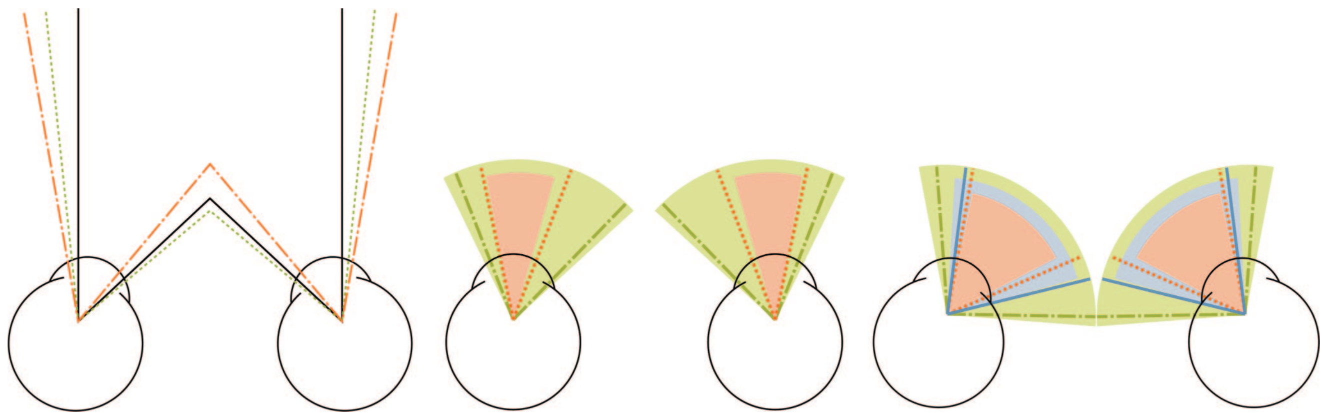

FIGURE 1.

A, Schematic representation of the DV and NV phoria variations from the first (green color) to the second examination (orange color). B, Schematic representation of the DV vergences for the first (solid surface) and the second examination (lines). The green color represents the break values and the orange color the recovery values. C, Schematic representation of the NV vergences for the first (solid surface) and the second examination (lines). The blue color represents the blur values, the green color represent the break values and the orange color the recovery values. A color version of this figure is available at www. optvissci.com.

the prevalence of myopia and emmetropia increases to 27.1% and 33.1%, respectively and hyperopia prevalence decreases to 39.8%.

Longitudinal Variation of Binocular Vision and Accommodative Parameters

Regarding binocular vision parameters, we verified a statistically significant difference between the first and the second examination relative to DV and NV phoria, and for the break and recovery points for the base-in and base-out at DV. Statistically significant differences were also observed for the blur and break points for the base-out, and for the break and recovery points for the base-in at NV.

Mean values (mean ± SD) obtained for the DV phoria for the first and second exams were −0.4 ± 2.6 Δ exophoria and −0.9 ± 3.0 Δ exophoria, respectively. At NV, the mean values were 0.4 ± 5.4 Δ esophoria and −1.2 ± 5.4 Δ exophoria for the first and second exams, respectively. Thus, mean variation for NV was −1.6 ± 4.1 Δ. Contrary to DV phoria, the NV phoria changed from esophoria to exophoria (Fig. 1A).

For the vergence ability (blur/break/recovery points) at DV, we found average values of −/13.0/5.2 for the base-in at the first visit and −/10.7/6.0 at the second; for the base-out situation average values were 13.1/23.8/8.0 at the first visit and 12.0/22.1/10.6 at the second one.

For the base-in break point in DV, a reduction between the first and second examination of 2.3 ± 3.4 Δ and an increase of 0.8 ± 2.8 Δ in the recovery value were observed. We also detected a reduction in the interval between the break and recovery points from the first to the second examination with a mean difference of 3.1 Δ. For the base-out at DV, a statistically significant difference between the first and second examination for the break and recovery points was also observed. The break point value decreased by 1.7 ± 8.5 Δ, and the recovery value increased by 2.6 ± 5.7 Δ (Fig. 1B).

In NV, the mean values for the base-in vergences were (15.8/22.9/11.5) at the first examination and (13.9/19.6/11.8) at the second examination; base-out values were (19.7/29.7/13.7) at the first visit and (20.6/28.0/15.9) at the second one.

Base-in blur and break points in NV displayed an average reduction between the first and second examination of 1.9 ± 5.3 Δ and 3.3 ± 4.8 Δ, respectively. For the base-out vergences, a statistically significant difference between the first and second examination for the break and recovery points was observed. The break point value decreased by 1.7 ± 7.6 Δ, and the recovery value increased by 2.2 ± 9.2 Δ (Fig. 1C).

Concerning accommodation parameters, we verified a statistically significant difference for all parameters measured. The mean values (mean ± SD) obtained for the lag of accommodation for the first and second examination were 1.12 ± 0.42 D and 1.44 ± 0.50 D, respectively. For the NRA and PRA, we found an increase from the first to the second examination. The NRA in the first examination was 2.21 ± 0.42 D and 2.31 ± 0.48 D in the second examination. For the PRA, we observed an increase of 0.66 ± 1.35 D from the first (2.33 ± 1.40 D) to the second examination (2.99 ± 1.33 D). AC/A did not show any statistically significant difference between the two exams.

Refractive Predictors of Binocular Vision Changes

We have also investigated how the binocular vision system and accommodation could be influenced by both the refractive error conditions and the variations in refraction occurred during the 3-year period (myopic shift). The results are presented in Table 2. We did not find any statistically significant differences between the refractive change (variations in the spherical equivalent ≥0.50 D in myopic direction) and the variation occurred for any of the binocular vision or accommodative parameters.

The refractive state obtained in the first examination did not show any influence on the binocular vision system or accommodation with the exception of the break value of the base-out vergences at DV [$p = 0.017$ (analysis of variance with the Bonferroni post hoc test)]. The value obtained for the hyperopes was 26.1 ± 7.6 Δ, 20.9 ± 9.1 Δ for the emmetropes, and 22.7 ± 9.8 Δ for the myopes.

TABLE 2.
Descriptive statistics and statistical significance of changes in refractive error, binocular vision and accommodative parameters from the patients with a refractive alteration ≥0.50 D and <0.50 D (n = 118 university students)

	Refractive error alteration <0.50 D (mean ± SD)	Refractive error alteration ≥0.50 D (mean ± SD)	p
Refractive error (D)			
M	−0.15 ± 0.17	−0.78 ± 0.49	0.000
J0	−0.02 ± 0.17	−0.02 ± 0.15	0.960
J45	−0.01 ± 0.09	0.03 ± 0.08	0.092
Binocular Vision			
Phoria (Δ)			
PhDV	−0.4 ± 2.4	−0.8 ± 2.8	0.278
PhNV	−1.6 ± 4.2	−1.5 ± 3.9	0.858
Vergences (Δ)			
BrBIDV	−2.3 ± 2.8	−2.0 ± 5.0	0.493
ReBIDV	0.8 ± 2.7	0.4 ± 2.9	0.741
BlBODV	−1.3 ± 6.4	1.1 ± 6.2	0.232
BrBODV	−2.0 ± 8.4	−1.1 ± 9.0	0.658*
ReBODV	2.0 ± 5.8	3.0 ± 5.6	0.446
BlBINV	−2.1 ± 5.5	−0.8 ± 4.2	0.446
BrBINV	−3.4 ± 4.8	−2.9 ± 4.9	0.539
ReBINV	−0.1 ± 5.1	2.1 ± 6.1	0.584
BlBONV	0.4 ± 11.1	0.4 ± 0.9	0.334
BrBONV	−1.7 ± 7.5	−1.6 ± 7.8	0.562
ReBONV	1.8 ± 9.2	1.7 ± 9.5	0.670
AC/A	−0.5 ± 3.1	−0.5 ± 1.9	0.448
Accommodation (D)			
Lag	0.28 ± 0.45	0.44 ± 0.51	0.079
PRA	0.12 ± 0.42	0.03 ± 0.33	0.357
RNA	0.68 ± 1.35	0.63 ± 1.36	0.765

*Statistical analysis performed with Student's t-test, other parameters' statistical analysis performed with Wilcoxon test.

TABLE 3.
Descriptive statistics and statistical significance from the values at the 1st exam for the refractive error, binocular vision and accommodative parameters from the patients with a refractive alteration ≥0.50 D and <0.50 D (n = 118 university students)

	Refractive error alteration <0.50 D (mean ± SD)	Refractive error alteration ≥0.50 D (mean ± SD)	p
Refractive error (D)			
M	0.32 ± 1.00	−0.95 ± 2.33	0.002
J0	0.12 ± 0.24	0.11 ± 0.28	0.960
J45	−0.05 ± 0.18	−0.04 ± 0.21	0.887
Binocular Vision			
Phoria (Δ)			
PhDV	−0.2 ± 2.5	−1.2 ± 2.9	0.220
PhNV	0.5 ± 5.6	0.2 ± 4.6	0.807
Vergences (Δ)			
BrBIDV	12.2 ± 3.6	15.8 ± 6.8	0.012
ReBIDV	5.0 ± 1.9	5.9 ± 2.6	0.148
BlBODV	12.9 ± 5.3	13.5 ± 6.8	0.959
BrBODV	23.9 ± 8.9	23.7 ± 8.6	0.969
ReBODV	8.0 ± 5.7	7.9 ± 4.8	0.606
BlBINV	15.3 ± 4.8	17.5 ± 5.6	0.142
BrBINV	22.4 ± 5.2	24.8 ± 5.5	0.041
ReBINV	11.6 ± 4.6	10.9 ± 4.5	0.509
BlBONV	20.0 ± 7.8	18.6 ± 9.6	0.688*
BrBONV	29.4 ± 9.2	30.7 ± 8.6	0.606
ReBONV	13.5 ± 7.5	14.7 ± 8.0	0.514*
AC/A	4.5 ± 2.4	4.0 ± 1.6	0.598
Accommodation (D)			
Lag	1.14 ± 0.41	1.08 ± 0.45	0.268
PRA	2.18 ± 0.41	2.32 ± 0.44	0.111
RNA	2.31 ± 1.34	2.39 ± 1.65	0.575

*Statistical analysis performed with Student's t-test, other parameters' statistical analysis performed with Wilcoxon test.

Predictors of Myopic Shift

In Table 3, we present a comparison of the baseline values of patients who suffered a myopic shift equal or higher than −0.50 in their spherical equivalent refraction with those from patients who did not experience such a shift, we observed a statistically significant difference for the break value of the base-in at distance vision (equal to 12.2 ± 3.6 for the group without refractive error alteration and 15.8 ± 6.8 for the group with a refractive error alteration ≥0.50 D) and for the break value of the base-in at near vision (equal to 22.4 ± 5.2 and 24.8 ± 5.5 for the group without refractive error alteration and for the group with a refractive error alteration ≥0.50 D, respectively).

DISCUSSION

Longitudinal Variation of Refractive Parameters

The refractive trends observed in the present study are in agreement with other previous studies demonstrating that the prevalence of myopia increases in young adults exposed to high educational demands over several years.[32–34] These issues have been extensively discussed in a previous report recently published addressing the biometric changes associated with the refractive error change in young university students.[19]

Changes in Binocular Vision and Accommodative Parameters

However, longitudinal changes in binocular vision and accommodation are not as frequently found in the literature, and they may be found to play an important role in the onset and progression of ametropia. In a study carried out by Porcar and Martinez-Palomera,[2] 21.5% of university students presented anomalies of the binocular visual function. In this longitudinal study, we detect a great variability in binocular vision function. For example, of the 14 parameters under investigation in the present study, 10 have displayed statistically significant differences after a 3-year period. It was well known that a statistically significant result is not always associated with a clinical significant difference. Along the discussion, the authors will try to clarify which parameters suffered a clinically significant variation to differentiate from those whose differences were statistically significant but not clinically significant.

There was an exophoric trend at distance and near vision, and this variation was more significant at near with a mean change from esophoria to exophoria, whereas at distance there was an increase in the already exophoric condition at the beginning of the study. Different studies support this trend as being an attempt of the visual system to compensate for a more intensive demand in near visual tasks.[2,35–40] In a longitudinal study published by Spierer and Hefetz[4] in 1997, they reported an increase of the esophoria by 0.9 Δ for DV and a change towards an increase in the exophoria by 0.6 Δ for NV during a period of 20 years. In that work, baseline values were obtained from people between 18 and 23 years old, and the patients presented an esophoria of 0.9 Δ on average for DV and 2.7 Δ of exophoria for NV. Changes in DV phoric status are different from those observed in our study. Such a discrepancy could be due to the long time elapsed between the two examinations (20 years), and factors such as presbyopia and weakness of the extraocular muscles could probably play a role in explaining this trend towards esophoria.[41]

A recent work presented by Palomo et al.[21]which used the Von Graefe method showed similar values to those obtained in our study for the phoria at DV and NV.

Another possible explanation for the different values obtained in different works could be the method of measurement. The use of a Maddox rod to measure lateral phorias has the drawback that the subject may view the streak of light as being closer than the light source distance, in such a way that Maddox rod phorias tend to overestimate esophoria.[21] On the other hand, the use of Von Graefe causes a more profound disturbance of the vergence system than Maddox wing. Perhaps, the fusional demand of prism dissociation which is applied in von Graefe's technique is more disruptive of fast fusional vergence than the instantaneous dissociation with the Maddox wing.[42]

Regarding negative vergence break point, our values are on average 5 Δ higher than those obtained by Palomo et al. In our study, we have measured a decrease in the break and an increase in the value of recovery, both in the base-in and base-out at distance and near vision. In clinical terms, this means that there is a decrease in the ability to sustain binocular vision without diplopia, and at the same time, an increase in the ability to recover fused binocular vision after a diplopic condition.

There were no statically significant changes in the AC/A relationship, which is in agreement with previous studies.[43–45] There are several methods to determine the AC/A ratios.[23,45–48] Recently, Escalante and Rosenfield showed that the best clinical method to determine the AC/A ratios is the Modified Thorington method. However, the expected mean difference between AC/A measurements using this method and the Von Greafe gradient method with +1.00 D lens was <0.50 Δ/D. The authors concluded that it is possible to obtain a more stable accommodative response by giving precise instructions to the subject to ensure that the target remains clear at all times.[23] Rosenfield et al. noted that the reliability of AC/A measurements assumed the gradient method will relay on the accuracy of heterophoria measurements.[49,50]

Different studies support a relationship between lag of accommodation and the development of refractive error.[10,51,52] However, there is lack of statistical values regarding the longitudinal variation of this parameter in young adults. In our study, accommodative lag increased significantly during the 3 years. Average values are in agreement with those reported by other investigators in cross-sectional studies.[14,53] This variation was expected as the patients are aging over this 3-year period.

Values of relative accommodation (PRA and NRA) are normal according to the normative values for a population of young adults. There was a statistically significant change during the 3 years, which was more important for the PRA. Thanks to the close relationship between relative accommodation and vergence ability, an increase in the values of PRA and NRA could be expected because of the decrease in the break values for base-out and base-in vergence. Overall, these facts demonstrate a weakness of the accommodative system, which could act as a potential factor to promote the development of refractive error according to the feedback theories of Hung and Ciuffreda.[54–59]

Binocular vision and accommodation parameters showed great variability during the 3-year period of the study. Seventy percent of all parameters under investigation presented significant variations. According to different studies,[23,40,42,51,60–62] there are two major factors that affect the binocular vision and accommodation parameters: methods of measurements and the visual system itself.

Reliability of different methods of measurement of binocular vision and accommodation has been investigated over the last 50 years. More recently, several research reports[63–67] have elucidated different sources of intertechnique and interexaminer variability. The authors acknowledge these limitations, and conclusions drawn from this study and other similar studies must be taken with some reserve with regard to the statistical changes obtained. As an alternative, we will highlight the clinically significant changes observed rather than deriving conclusions from single quantitative statistical data.

In clinical terms, it was important to highlight the changes from esophoria to exophoria in NV and the decrease of the interval between the break and recovery points for the NV and DV vergences. The variations observed in the interval between the break and recovery points suggest a weakness of the vergence system. The changes verified in the NV phoria were clinically significant not only for the value of prism variation but also essentially for the variation from esophoria to exophoria. This variation was interpreted by some authors as an adaptation to the visual stress in near vision.[57,68,69]

Considering the accommodation parameters, we would like to highlight a clinical significant variation (0.66 D) in the PRA suggesting an increase in the accommodative response despite the increase in the age of the subjects. This finding is in agreement with the results of Garcia et al.[70] who found that the accommodative excess is associated with high values in the PRA.

Refractive Predictors of Binocular Vision Changes

Neither the baseline refractive error nor the refractive error alteration between both exams determined any significant changes in binocular vision parameters. There was a trend towards higher values of break value for distance base-out vergence in hyperopes compared with emmetropes and myopes.

Predictors of Myopic Shift

Two studies published by Goss and Jackson[36,71] concluded that those patients who become myopes presented higher values of base-out prism (higher convergence ability). Accommodation parameters did not display any significant difference between refractive conditions. Many studies obtained a relationship between the accommodation and binocular vision parameters with the myopia progression.[10,14,45,52,53,72,73] In the present study, we did not find any difference in the pattern of change in those parameters between the group of people who experienced a refractive error change equal or great than 0.50 D (all patients experienced a change towards higher levels of myopia) compared with the remaining elements of the sample who did not experience such a myopic shift.

We also evaluated the ability of baseline values of binocular vision and accommodation parameters to predict any myopic shift over the 3-year period. Only the break value of the base-in at distance and near showed a statically significant difference between patients who displayed such myopic shift (higher values of the aforementioned parameters) and those who did not. With the exception of the work of Goss and Jackson,[71] there is not any current reference in literature on the potential influence of the binocular vision parameters on progression of ametropia in young populations. Goss and Jackson evaluated the middle-point of the clear vision interval and concluded that patients displaying a myopic trend showed a middle-point more convergent than those who remained emmetropes. Our values also demonstrate that the fusional vergence is the only parameter with an apparent influence on myopia progression, and this issue warrants further interest on studies evaluating the potential influence of binocular vision parameters on refractive stability in childhood and adulthood.

In summary, the results of the present work suggest that when analyzed in clinical terms, they show significant changes in near heterophoria, fusional vergences, and PRA. The break values of the base-in fusional vergence could act as a predictor of a myopic shift in young adults.

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