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Is it possible to relate accommodative visual dysfunctions with neck pain?

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Short title: Accommodative visual dysfunctions and neck pain

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Abstract

The aim was to establish a relationship between conditions of accommodative visual dysfunctions and cervical complaints. Fifty-two participants were included. Variable: the value of accommodative amplitude(AA), positive and negative relative accommodation(PRA and NRA), accommodative response(AR) and accommodative facility(AF). Subjects were classified as accommodative insufficiency(AI), accommodative excess(AE) or normal. Neck disability measured with the Neck Disability Index(NDI), pain with Visual Analogue Scale(VAS), deep flexor muscle activity activation scored(AS) and performance index(PI)) and cervical range of motion. 24 subjects had AI, 25 AE and 3 normal values. We found a significant relationship of NRA with PI and with left tilt, AA right eye with right tilt and with left tilt, AA left eye with right tilt, AF left eye with PI and with left tilt (oscillating r between 0.28 and 0.33 $p<0.05$). In AF right eye, AI participants showed significant($P=0.03$) lower PI(median=3) values and greater($P=0.045$) pain(VAS median=4.7) than AE subjects (PI median=16;VAS median=0). In both groups, the PI values are decreased (median=8 and 9). Greater pain(VAS=3.2) and lower right rotation(median=63.3°) were found in the AE group than in AI participants(VAS=1.8 right rotation=69.7°). Conclusion:Accommodative excesses are related to low PI and AS, decreased mobility as well as greater functional disability and neck pain.

Key words: accommodation ocular, visual disorders, range of motion, neck pain, pain.

Introduction

The alterations of the visual system and musculoskeletal disorders are important public health problems that affect considerable proportions of the general population, at work, in their daily life and social life. The US National Occupational Safety and Health Institute (NOSHI) reports that more than 80% of people working with computers suffer from these complaints.[1]

The increase of new technologies implies visual and neck / shoulder musculature symptoms. On the one hand, the eyes are subjected to a continuous overexertion of accommodation and vergence, thus distance vision and the far-near-far exchange are exercised less. This abnormal situation produces a prolonged activation of the extrinsic and intrinsic muscles of the eye with distortion and imbalance in visual behavior, resulting in accommodative non-strabismic binocular dysfunctions.[2–10] The lack of efficiency of the visual system causes a diverse symptomatology, which includes eye strain and performance problems.[10,11] Similarly, this situation in the light of an abuse of distance at close quarters increases musculoskeletal complaints in the neck area, so that both visual symptoms and muscular complaints coexist at the same time.[12–14] Robertson et al.[15] state that with an ergonomic training program in the office, musculoskeletal and visual complaints decrease. Richter et al.[16] report the joint prevalence of visual and cervical/scapular symptoms and their association with occupational risk factors in a sample of professional users of information technology. Zetterberg et al.[17] report the coexistence of both symptoms in similar situations. Therefore, the possibility of a cross-dysfunction between the two systems is opened.

In the review carried out, that searches for relationships between accommodative dysfunctions and alterations in the neck, different authors state that an alteration of accommodative function is accompanied by an increase in muscle activity of the trapezius, which could cause an increase in pain in the neck area.[17–23] These studies do not look for the existence of possible accommodative anomalies or neck pain that could be present, the musculoskeletal disturbances that occur in the neck are analyzed, at the same moment that the condition of the neck is altered, by inserting positive and negative lenses mono and binocularly while the subject fixes a stimulus[17,19–23] or with the help of a photo-refractor during the focusing on a moving target located at 40 cm.[18] On the other hand, a methodology is not used that includes optometric tests which allow the evaluation of each parameter that has to be analyzed at the time of assessing the accommodative function. To define the state of the accommodative function, it is necessary to assess the monocular accommodative amplitude (AA), the monocular accommodative facility (AF) both in the phase with negative lenses, and in the phase with positive lenses and the accommodative response (AR) using the Nott retinoscopy, indirectly by assessing the positive and negative relative accommodation (PRA and NRA), binocular AA and binocular AF in both phases.[24]

In our study, we propose to evaluate the state of the accommodative function completely and exhaustively, by establishing the values of accommodative amplitude (AA), positive and negative relative accommodation (PRA and NRA), accommodative response (AR) and accommodative facility (AF), trying to determine whether there is a relationship between this accommodative function and the suffering of cervical complaints. That is, we establish which is the state of the accommodative function, according to the criteria of Scheiman and Wick[25] (normal, excesses and insufficiencies), comparing the neck complaints in those groups.

Materials and Methods

Design

A descriptive, cross-sectional, correlational study, conducted from April 1, 2016 until January 31, 2017 at the Faculty of Pharmacy, at the Optics and Optometry Titling facilities of the University of Seville was performed.

Subjects

The selected population is made up of students, professors and administrative and service personnel of the University of Seville. The proposal for participation in the present study was sent via email to the entire university community of the Faculty of Pharmacy at the University of Seville. Those interested were a total of 70 subjects. All subjects were informed verbally and in writing. Once informed in depth of the investigation, four people refused to participate, leaving a total of 66 participants who gave their consent to participate in this research. To be included in the study, participants had to be between 18 and 39 years of age.

All subjects had at least 20/20 visual acuity with their best correction, absence of ocular motility defects, strabismus, nystagmus or amblyopia, and any ocular or systemic disease that could affect the results. Subjects who had undergone some type of ocular surgery or had a history of head trauma, cervical fracture or surgery in this area, persons with intellectual disabilities or any problems that prevented them from completing the Neck Disability Index, or who suffered any type of degenerative disease or neurological alteration, were excluded. Finally 14 subjects were excluded (Figure 1 is a flow chart of the study). The sample consisted of 52 subjects with a mean age of 25.9 years (Standard deviation (SD) of 6.4), from 18.0 to 39.0 years, and comprised of 29 (55.77) women and 23 (44.23) males (Table 1). Most of the subjects included in our research are university students 36 (69.2%), the rest had different occupations.

Variables

The variables used in our study by physiotherapists are: i) The cervical joint range measured with the cervical-range-of-motion (CROM) instrument,[26] in degrees (flexion, extension, right and left tilt and right and left, rotation); the condition of the deep flexor musculature, using the craniocervical flexion test (CCFT), with the Chattanooga™ stabilizer pressure biofeedback device (Chattanooga Stabilizer Group Inc., Hixson, TN);[27] the cervical disability assessed with the Neck Disability Index (NDI) questionnaire (range 0-50);[28] neck pain intensity was evaluated with the Visual Analogue Scale (VAS, range 0-10 cm). The variables that measure the state of the accommodative function are: 1) Accommodative Amplitude (Diopters, D) and Positive and Negative Relative Accommodation (D), they were evaluated with the ESSILOR MPH100E S / N 000104 phoropter; 2) Accommodative Response (D) is measured with the Welch Allyn retinoscope; 3) Accommodative Facility (cycles per minute, CPM) is quantified with ± 2 flipper lenses. From their analysis a new variable is determined, with which the global state of the accommodative function is described according to the criteria of Scheiman and Wick.[25] Three categories are defined therein: excesses (AE), insufficiencies (AI) and normal subjects.

Ethics

The research followed the tenets of the Declaration of Helsinki; informed consent was obtained from the subjects after explaining the nature and possible consequences of the study; and the Institutional Review Board of the University Hospital Virgen Macarena of the University of Seville approved the research.

Procedures followed

Once the informed consent was signed they were handed the Neck Disability Index (NDI) questionnaire (range 0-50),[28] which measures the cervical disability. Subsequently, pain intensity was evaluated with the Visual Analogue Scale (VAS, range 0-10 cm), as well as the state of the deep flexor muscle activity (Chattanooga TM stabilizer pressure biofeedback device) and the range of motion in the neck (CROM).

At the time of data collection, the assessors did not know the level of discomfort of the participants. This is established after the data processing. The physiotherapist was blinded regarding the optometric evaluation and vice versa.

A physiotherapist assessed in the subjects:

- The cervical joint range while sitting, through the cervical-range-of-motion (CROM) instrument.[26] Participants were asked to actively perform flexion, extension, right tilt (RT), left tilt (LT), Right rotation (RR) and left rotation (LR) movements, three times each, to find the mean of the measurements in degrees (º).
- The condition of the deep flexor musculature, using the craniocervical flexion test (CCFT), with the Chattanooga™ stabilizer pressure biofeedback device (Chattanooga Stabilizer Group Inc., Hixson, TN).[27] The CCFT is performed with the participant in a supine position with the neck in a neutral position (without a pillow). The device is positioned under the neck and against the occiput. It is inflated, once placed, to the 20 mmHg level. The patient makes a movement of the head as if they were saying "yes". A trained examiner observed and corrected any substitution of movements. Each individual was instructed to perform craniocervical flexion of the neck at five pressure levels (22, 24, 26, 28 and 30 mmHg), and hold the position firmly.If they achieved this, they had to relax the muscles and then repeat the movement for each position (obtaining the "activation score" (AS), depending on the pressure, with a range of 1 to 4). When the AS was established, we asked them to maintain the pressure, with minimal superficial muscle activity, performing 10 sustained 10-second repetitions. The number of repetitions is called "performance." A performance index (PI) was calculated by multiplying the AS by the performance.
- Neck pain case studies using this test show that the scores were less than 4 in AS and 10 in PI in patients with cervical disorders. These subjects present a neuromotor control with a deteriorated activation of the deep cervical flexor muscles. This deterioration seems generic to cervical pain disorders.[27,29]

All data were collected on a record sheet by another physiotherapist.

Once the physiotherapy assessment was finished, and after a 60-minute break, they were transferred to an adjoining room where a licensed optometrist performed an optometric examination. In this test, the accommodation was completely evaluated, assessing AA, AR, AF and PRA and NRA, whose purpose was to detect the presence of accommodative type dysfunctions. The classification used in our study was that defined by Scheiman and Wick, based on Duane's and that differentiates accommodative dysfunctions in accommodative insufficiency, accommodative excess, and accommodative infacility.[25,30] It is important to evaluate the different accommodative skills thus avoiding that any dysfunction that may be present could go unnoticed.[7,31,32]

The ESSILOR MPH100E S/N 000104 phoropter and Welch Allyn retinoscope were used.

The AA was measured by the minus lens method, as it is the one with the best repeatability,[33,34] adding negative lenses. The right eye (RE) and left eye (LE) were evaluated monocularly, followed by the assessment of both eyes (BE) together.

Measuring the accommodative response (AR) establishes the subject's plane of focus with respect to the accommodative target; that is, whether there is over- or under-accommodation. In clinical practice, rather than using the term accommodative response, it is common to consider the error of accommodation, which is the difference between the accommodative stimulus and the accommodative response. We use the term accommodative lag if this difference is positive (under-accommodation) and accommodative lead if the difference is negative (over-accommodation).[35] The AR was evaluated by means of the Nott retinoscopy technique, as it is the method with the highest repeatability.[35-39]

The AF assessment allows the evaluation of the ability of the visual system to perform sudden jumps of accommodation at a determined distance, effectively, progressively, quickly and comfortably, under monocular and binocular conditions.[40-48] The procedure described by Zellers was followed.[44]

Relative accommodation evaluates the patient's ability to increase and decrease accommodation in conditions where the demand for total vergence is constant. That is, it determines the maximum variations of accommodation stimulus that can be effected in near vision, maintaining optotype vision clear.

We speak of PRA, when referring to the maximum stimulation of the accommodation keeping the optotype clear and we speak of NRA when the relaxation of the accommodation is maximum, keeping the optotype clear.

It is important to study both NRA and PRA for the diagnosis of accommodative anomalies and their relationship with nonstrabismic binocular dysfunctions.[49,50]

Positive and negative relative accommodation were assessed using a visual acuity card situated at 40 cm and with the maximum plus for best visual acuity correction placed in the phoropter. While the patient fixated the horizontal line of 20/20 letters at 40 cm, the examiner added spherical lenses binocularly. Negative relative accommodation was measured first, adding plus lenses binocularly in 0.25 D steps at the rate of one step every 2 s 1 until the subject reported the first sustained blur. The net amount of plus added was recorded as plus to blur or negative relative accommodation. Then, the amount of plus was reduced or minus was increased binocularly in 0.25 D steps per 2 s over the refraction placed in the phoropter until the first sustained blur was again reported. PRA was recorded as the amount of minus lenses added over the subjective refractive examination.[49]

The measure of AA, AR, NRA and PRA is expressed in Diopters (D) and AF in cycles per minute (cpm).

Data Analysis

The data were analyzed with the SPSS 24 package for Windows (SPSS Science, Chicago, United States). The normality of our variables was verified with the Shapiro-Wilk test. A descriptive data analysis was developed, showing the count and proportion of each category in the qualitative variables and the mean and SD or in its defect the median and the first (Q1) and third (Q3) quartiles in the quantitative ones. Then the relationship between the variables considered was studied, calculating the

Pearson coefficient r and carrying out a simple and multiple linear regression analysis (using stepwise regression), showing the values of the coefficient of determination and unstandardized coefficient b. Finally, the values of disability, pain, mobility, AS and PI were compared in the groups in which we differentiated the subjects according to the Scheiman and Wick classification. When we considered two groups, Student t-tests or Welch t-test were used, as required, and for the variables that did not fit the normal, the Mann-Whitney U-test. When three groups of subjects were analyzed, the one-way Anova or Welch Anova were used, and when the variables were not distributed according to the normal, the Kruskal-Wallis test of was used, all complemented with tests of paired comparisons. The analyzes that were statistically significant or that approximated such statistical significance are shown. Groups that had a very small number of subjects for not providing significant comparisons are eliminated. All statistical tests were performed considering a 95% confidence interval (CI) ($P < 0.05$).

Results

The socio-demographic characteristics of the subjects, the mean values of the variables AA, ARN, ARP, RA and FA, as well as the classification of participants in AI, AE or normal values, and finally the values of the variables related to range of motion, pain, neck disability, and the state of the deep flexor muscle activity are shown in Table 1.

In the variables AF right eye and AF left eye, a subject could not complete the assessment, since he could not clarify positive or negative lenses, due to his accommodative alteration. In the variable AF both eyes, 6 subjects were lost due to the same reason.

Relationship between accommodative visual dysfunctions and neck complaints

We have studied the accommodative Insufficiency/Excess relationship, with disability, mobility, AS, PI and VAS. In no case did we find statistically significant values, except for the relationship between:

1) NRA with PI (r = 0.30 P = 0.03 coefficient of determination = 0.090 unstandardized coefficient b = 0.015), and NRA with LT (r = 0.28 P = 0.046 coefficient of determination = 0.077 unstandardized coefficient b = 0.022). When performing the multiple linear regression analysis, using the stepwise method, the only variable that remained in the model was the PI, obtaining the same results as in the simple linear regression model between NRA and PI.

2) AA Right Eye with RT (r = 0.33 P = 0.02; coefficient of determination = 0.108 unstandardized coefficient b = 0.105) and AA Right Eye with LT (r = 0.29 P = 0.04; coefficient of determination = 0.084 unstandardized coefficient b = 0.078). On performing the multiple linear regression analysis, using the stepwise method, the only variable that remained in the model was RT, obtaining the same results as in the simple linear regression model between AA RE with RT.

3) AA Left Eye with RT (r = 0.32 P = 0.02; coefficient of determination = 0.102 unstandardized coefficient b = 0.098).

4) AF Left Eye with PI (r = 0.28 P = 0.04 coefficient of determination = 0.080 unstandardized coefficient b = 0.087) and with LT (r = 0.31 P = 0.03 coefficient of determination = 0.095 unstandardized coefficient b = 0.143). Once more, when performing the multiple linear regression analysis, using the stepwise method, only one variable remained in the model, that was LT, obtaining the same results as in the simple linear regression model between AF left eye and LT.

Disability, pain, AS and PI in subjects with AE, AI and normal values

The values of the variables of disability, pain, AS and PI in subjects with AE, AI and normal values (Table 2) are compared. In the case of AF Right Eye, statistically significant differences were obtained in the PI among subjects with a defect, that presented lower values and below the normality levels (established in 10 points), compared with individuals with excess, with normal PI levels. There were significant differences in the pain assessed with the VAS scale in the AF Left Eye, between subjects with insufficiency, when compared to subjects with excess, that showed ostensibly lower levels of pain.

Mobility in subjects with AE, AI and normal values

Regarding the range of motion (Table 3), RR in subjects with insufficiency following the Scheiman and Wick criteria, was significantly higher when compared to subjects with excess. In the AA Left Eye significant differences were found in flexion, with values lower in individuals with insufficiency than those considered normal, and also in RT where the subjects with insuffiency showed lower data than the normal subjects. Finally, we found that in the AF Both Eyes LT was significantly lower in the participants classified as normal than those who had an excess.

Discussion

Our study has as an objective the evaluation of the state of the accommodative function, determining the possible existence of anomalies of this function, and analyzing if there is a relationship between visual system and neck complaints.

The results show that in both groups, excess and insufficiency, established in the global variable determined according to the criteria of Scheiman and Wick, [25] PI values (medians of 8 and 9 points respectively) are slightly decreased which translates into a weakness of the deep flexor musculature, since the normative values are above 10. In relation to the pain variable, measured with the VAS scale, and considering the right cervical rotation movement, we found greater pain (3.2 cm) and lower motion (63.3º) in the AE group, compared to the AI group (1.8 cm and 69.7 °). That is, in subjects with accommodative excess the pain intensity was 1.4 cm higher than in the participants with insufficiencies, which represents a clinically relevant difference.[51]

When we analyze the variables, which in isolation evaluate some of the aspects related to the state of the accommodative function, we find that in AF the participants with excesses present less pain and higher AS and PI than those who have insufficiency. The difference in pain intensity, as measured by the VAS, is statistically significant, clinically relevant, and a substantially beneficial difference at clinical level (SCB).[51]

Considering NRA, parameter that helps the diagnosis of accommodative dysfunctions[49,52], it is confirmed that in the presence of such excess the subjects present less mobility. As for AA, it shows inconclusive results as subjects with normal values presented greater cervical range of motion and, however, greater pain and lower PI of the deep cervical musculature.

However, these results (AF, AA and NRA) are isolated clinical signs and although there are different criteria regarding the number of clinical signs that must be taken into account to define the state of the accommodative function, [10,32,49,52,53] we estimate that several clinical signs are required for an accurate assessment of this function. In addition, the mentioned comparisons are based on a reduced number of subjects, so these results should be considered with caution.

On the other hand, the findings described by Jull et al.[27] agree with our results since they conclude that subjects with neck pain disorders have an altered neuromotor control strategy during craniocervical flexion, characterized by reduced activity in the deep cervical flexors and increased activity in the superficial musculature. In our results, an AE is associated with a low AS and PI.

In the study, we attach great importance to the evaluation of all aspects of the accommodative function to determine a specific accommodative diagnosis, through tests that present the highest repeatability. In some of the works reviewed, the relationships between visual symptoms and neck pain are studied by using questionnaires that we consider bound to a certain degree of subjectivity.[14] In other works, accommodative changes are evaluated with the help of a photo-refractor during the focus on a target in motion at 40 cm.[18] On the other hand, several authors have observed changes in focus induced by the insertion of positive and negative lenses mono and binocularly while the subject fixes a stimulus.[19-23,54] But in no case, do they measure each of the parameters that define the accommodation looking for dysfunctions and their relationship with the existence of cervical diseases.

There is a lack of consensus regarding the number of clinical signs that should be considered in the diagnosis of accommodative dysfunctions. Cacho et al. [52] provide a summary of several studies in which the number of diagnostic signs vary when defining an AI and conclude that in order to classify this condition, the values of accommodative response (AR) must be considered by means of MEM retinoscopy, monocular and binocular accommodative facility (MAF, BAF), positive and negative relative accommodation (PRA, NRA) and accommodative amplitude (AA). Sterner et al.[10] study accommodative amplitude (AA) in a group of children and determine that a monocular AA below 8.00 D together with a binocular AA below 11.00 D and the presence of symptoms can be a sufficient condition for the diagnosis of an AI. García et al.[49] found that high values of PRA are related to disorders associated with EA. There are authors who use the value of multiple clinical signs for the diagnosis of these anomalies, such as Porcar et al.[32] and Scheiman et al.[53]

In our study, we detected the existence of possible accommodative anomalies, based on the clinical signs defined by Sheiman and Wick,[55,56] and we established relationships between excesses, defects, subjects without accommodative alteration and state of the neck region, without causing of the evaluators an alteration of the accommodation. To carry out this classification, the tests used are grouped into a specific test group when they evaluate the same function directly or indirectly. It is a question of identifying the type of disorder based on the tests and the grouping of the results. This system developed by Scheiman and Wick is called Integrative Analysis[57] and is commonly used as a reference for the classification, diagnosis and treatment of accommodative disorders.[2,6,31,35,58-60]

The results of the present work seem to be in the same line as those obtained by different authors, who conclude that an alteration of accommodative function is accompanied by an increase in muscle activity of the trapezius, which could cause an increase in pain in the neck area.

In our literature review, we have found two trends that may explain the relationship between visual dysfunction and neck dysfunction.

A subject who has an AE presents unstable vision,[10,11,61] so they tend to adapt the head to achieve greater visual comfort, which forces them to adopt abnormal neck postures to compensate. A modification in the posture of the neck leads to an abnormal posture of the head in an attempt to maintain binocularity and optimize visual acuity,[62-65] which can cause musculoskeletal problems, resulting in neck pain. This postural adaptation would be good for improving vision, but it would lead to joint and muscular dysfunctions in the neck, thus giving rise to a cervical pathology if maintained over time. Seen this way, neck pain would be the consideration for the improvement of visual acuity. Cervical pathology can be the result of permanent compensation to the service of visual comfort, to paraphrase Richter, "the eyes steer the body".[1]

Other authors justify the neck-eye relationship, based on the innervation of both by the Sympathetic Nervous System (SNS). There is a double innervation of the ciliary muscle by the SNS and Parasympathetic Nervous System (PSNS),[66,67] the SNS tends to adapt the eye for the vision of distant objects and as such is opposed to the SNPS, which tends to adapt the eye to the vision of nearby objects, stimulating accommodation. There are several studies that demonstrate a predominant parasympathetic system versus a complementary sympathetic system.[68] The performance of the SNS in relation to accommodation is characterized by its inhibitory nature.[68] The role of the sympathetic innervation of the ciliary muscle can alleviate the accommodative excess caused by an abuse of near vision tasks. It is postulated that individuals with a deficit in sympathetic inhibition may be predisposed to develop accommodative anomalies.[69,70] On the other hand, the medullary center of the sympathetic pathway is the ciliospinal center of Budge (C6-D2). This center is located between the sixth cervical level and the second dorsal level. Hence the anterior roots of the spinal nerves allow the output of the first neurons to reach the cervical nodes. In this way, a cervical vertebral dysfunction can affect the ciliospinal center of Budget and the cervical nodes, affecting the SNS fibers of the ciliary muscle, causing an accommodative excess.[70-73]

For all these reasons, we think that our results confirm the relationship between the visual system and neck complaints, being based on those presented by other authors consulted and with the anatomophysiological arguments we present.

This justifies the examination of the visual system together with examination of the cervical spine. Faced with a cervical pathology, and especially when it includes headaches and eye strain, the physiotherapist should consider the assessment of the visual system in relation to the position of the head presented by the patient. And in the case of finding a relationship in the pathology, a combined eye-neck treatment and the referral to the optometrist should be considered.

Similarly, optometrists or ophthalmologists should divert the patient to the physiotherapist when anamnesis, symptomatology or adaptation of the head-neck cause them to suspect a neck disorder.

Suggestions for future research

Given the relationship between both systems, visual and cervical, it would be an option in future research to propose an intervention through a visual therapy program in subjects with accommodative dysfunctions and neck pain, since visual therapy has proved to be a useful treatment option in subjects with accommodative anomalies,[74-79] and assess whether there are changes in possible neck dysfunctions.

Regarding the limitations of our study, it is important to emphasize the small sample size, which should make us carefully consider the results presented. In future research, we propose to increase this sample size.

The results obtained in the present work seem to affirm that relationships are established between the presence of accommodative dysfunctions and the suffering of neck complaints. The accommodative excesses seem to be related to low levels of activation score and performance index of the deep muscles of the neck, less mobility of the neck, as well as greater functional disability and neck pain.

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Competing interests

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Figure legend

Figure 1. Flow chart of the study.

Table legends

Table 1. Description of the characteristics of the sample (n = 52)

Table 2. Differences in NDI, AS, PI and pain evaluated with the VAS scale among subjects with insufficiency and accommodative excess according to the Scheiman y Wick classification, and among subjects with AA of both eyes normal and insufficient, and among subjects with AF of the right eye and AF of the left eye insufficient, normal and in excess, and AF both eyes excess and normal.

Table 3. Differences in flexion, RT, LT and RR among subjects with insufficiency and accommodative excess according to the Scheiman and Wick classification, among subjects with AA of the left eye normal and insufficient, NRA insufficient,

normal and in excess, and AF both eyes excess and normal.

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Figure 1. Flow chart of the study.

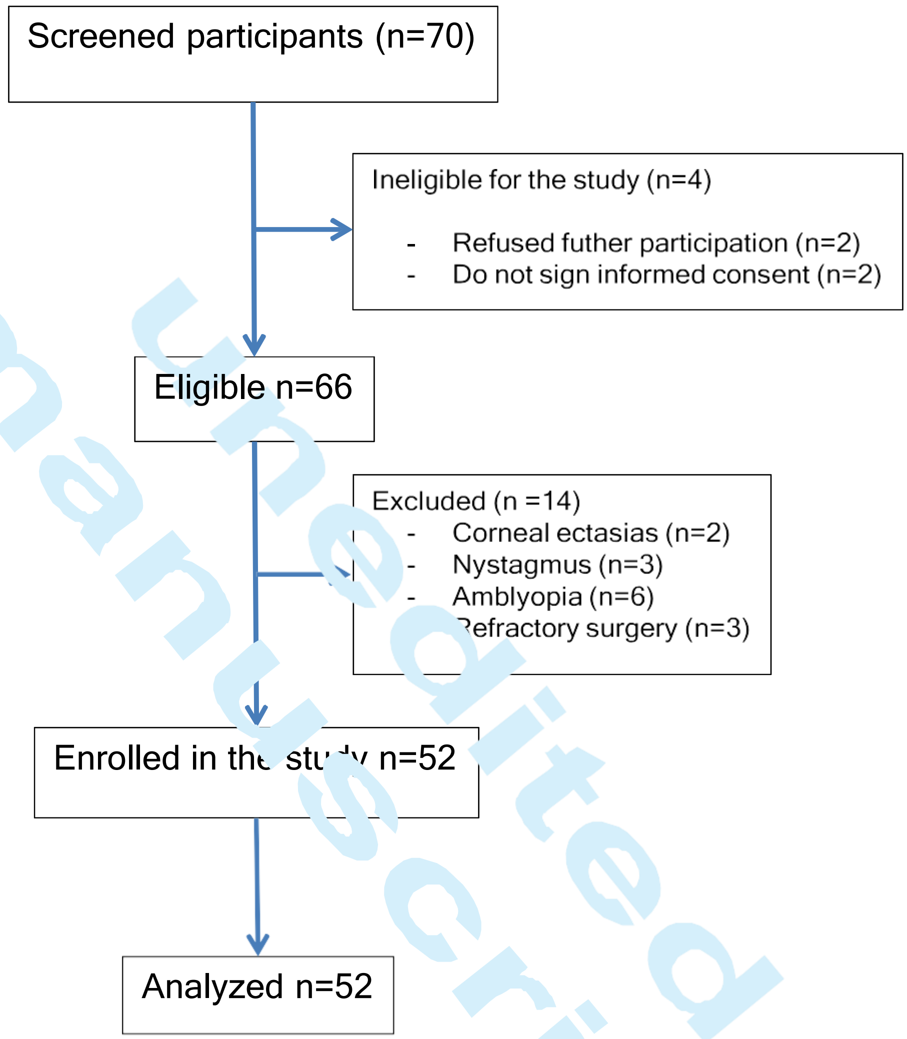

Table 1. Description of the characteristics of the sample.

Socio-demographic characteristics, n (%) (n = 52)	
Sex,	
Male	23 (44.2)
Female	29 (55.8)
Age, years	25.9 ± 6.4*
Height, m	1.7 ± 0.1*
Weight, kg	70.4 ± 13.9*
Body Mass Index (BMI), kg/m^2	24.7 ± 4.2*
Profession, n (%)	
Professor	3 (5.8)
Student	36 (69.2)
Laboratory Technician	1 (1.9)
Physiotherapist	2 (3.8)
Administrative	2 (3.8)
Hotelier	2 (3.8)
Optometrist	2 (3.8)
Nurse	1 (1.9)
Musician	1 (1.9)
Transporter	1 (1.9)
Pharmacist	1 (1.9)

* Mean and SD is shown.

Characteristics of the variables that define accommodation				
Characteristic	Mean ± SD	Classification of subjects according to normative values n (%)		
		Insufficiency	Normal	Excess
Insufficiency/Excess Accommodative	-	24 (46.2)	3 (5.8)	25 (48.1)
AA Right Eye, D (n = 52)	8.3 ± 2.7	28 (53.8)	22 (42.3)	2 (3.8)
AA Left Eye, D (n = 52)	8.5 ± 2.6	27 (51.9)	23 (44.2)	2 (3.8)
AA Both Eyes, D (n = 52)	8.2 ± 2.6	28 (53.8)	23 (44.2)	1 (1.9)
NRA, D (n = 52)	2.4 ± 0.8	21 (40.4)	23 (44.2)	8 (15.4)
PRA, D (n = 52)	-2.3 ± 1.8	26 (50.0)	11 (21.2)	15 (28.8)
AF Right Eye, cpm (n = 51)	10.2 ± 4.4	6 (11.8)	39 (76.4)	6 (11.8)
AF Left Eye, cpm (n = 51)	9.9 ± 4.8	10 (19.6)	34 (66.7)	7 (13.7)
AF Both Eyes, cpm (n = 46)	10.18 ± 4.57	2 (4.3)	35 (76.1)	9 (19.6)
AR, D (n = 52)	0.1 ± 0.5	3 (5.8)	12 (23.1)	37 (71.2)

Characteristics of variables that define disability, mobility, activation score, performance index and cervical pain	
Characteristic (n = 52)	Mean ± SD
NDI, 0-50	5.7 ± 5.8
AS	5.1 ± 3.1
PI	14.1 ± 15.6
VAS, 0-10 cm	2.7 ± 2.7
Flexion, degrees	52.4 ± 10.9
Extension, degrees	65.9 ± 14.2
RT, degrees	41.6 ± 8.5
LT, degrees	46.2 ± 10.2
RR, degrees	66.7 ± 10.3
LR, degrees	70.9 ± 11.1

SD: Standard Deviation. BMI: Body Mass Index. AA: Accommodative Amplitude. NRA: Negative Relative Accommodation. PRA: Positive Relative Accommodation. AF: Accommodative Facility. AR: Accommodative Response. D: Diopters. CPM: Cycles per minute. NDI: Neck Disability Index. VAS: Visual Analogue Scale (pain intensity). AS: Activation Scored of deep cervical musculature. PI: Performance Index of deep cervical musculature. RT: Right Tilt. LT: Left Tilt. RR: Right Rotation. LR: Left Rotation.

Table 2. Differences in NDI, AS, PI and pain evaluated with the VAS scale among subjects with insufficiency and accommodative excess according to the Scheiman y Wick classification, and among subjects with AA of both eyes normal and insufficient, and among subjects with AF of the right eye and AF of the left eye insufficient, normal and in excess, and AF both eyes excess and normal.

Characteristic		NDI, 0-50		Activation Score		Performance Index		VAS, 0-10 cm	
		Median (Q1 ; Q3)	*P* value	Median (Q1 ; Q3)	*P* value	Median (Q1 ; Q3)	*P* value	Median (Q1 ; Q3)	*P* value
Accommodative Insufficiency / Excess	Insufficiency (n = 24)	[illegible] (1.2 ; 8.7)	0.89*	6.0 (2.0 ; 8.0)	0.85*	9.0 (4.0 ; 16.0)	0.83*	1.8 (0.0 ; 4.5)	0.21*
	[illegible]ess (n = 25)	[illegible].0 (1.[illegible]0.0)		4.0 (2.0 ; 8.0)		8.0 (4.0 ; 19.0)		3.2 (0.0 ; 6.0)	
AA Both Eyes	[illegible]ufficie[illegible] (n = 28)	5.0 ([illegible]; 10.[illegible]	0.07*	5.0 (2.0 ; 6.0)	0.62*	9.0 (4.0 ; 22.5)	0.56*	2.2 (0.0 ; 4.0)	0.85*
	Norm[illegible] (n = [illegible])	2.0 (1.0 ; [illegible]		6.0 (2.0 ; 8.0)		8.0 (2.0 ; 16.0)		2.8 (0.0 ; 6.0)	
AF Right Eye	Insufficiency ([illegible]6)	9.5 (0.7 ; 15.2)	0.[illegible]	2.0 (0.0 ; 4.5)	0.08†	3.0 (0.7 ; 6.5)	**0.03†**	5.6 (0.3 ; 6.8)	0.21†
	Normal (n = [illegible]9)	[illegible]0 (1.0 ; 9.0)		6.0 (2.0 ; 8.0)		10.0 (4.0 ; 16.0)		2.6 (0.0 ; 5.4)	
	Excess (n = 6)	[illegible] (0.7 ; 5.7)		[illegible].0 (2.0 ; 10.0)		16.0 (5.0 ; 47.5)		1.2 (0.0 ; 3.1)	
AF Left Eye	Insufficiency (n = 10)	[illegible].0 (3[illegible]	0.15†	5[illegible](0.0 ; [illegible]	[illegible].41†	7.0 (1.7 ; 13.0)	0.19†	4.7 (0.7 ; 6.5)	**0.045†**
	Normal (n = 34)	2.5 ([illegible]0 ; 8.2)		4.[illegible](2.0 ; [illegible])		8.0 (4.0 ; 16.5)		2.8 (0.0 ; 5.4)	
	Excess (n = 7)	3.0 (0.0 ; [illegible]		6.0 (4.0 ; [illegible]0.0)		12.0 (6.0 ; 40.0)		0.0 (0.0 ; 2.4)	
AF Both Eyes	Normal (n = 35)	4.0 (1.0 ; 10.0)	[illegible].51[illegible]	4.0 (2.0 ; 8.0)	[illegible]6*	8.0 (4.0 ; 16.0)	0.24*	3.5 (0.0 ; 6.0)	0.06*
	Excess (n = 9)	4.0 (0.5 ; 6.0)		[illegible].0 (3.0 ; 9.0)		12.0 (6.0 ; 32.0		0.0 (0.0 ; 3.1)	

* U de Mann-Whitney test was.
† Kruskal-Wallis ANOVA test was used.
AA: Accommodative Amplitude. AF: Accommodative Facility. NDI: Neck Disability Index. [illegible]: Vis[illegible]l Analogue Scale (pa[illegible] inte[illegible]). Q1: First quartile. Q3: Third quartile.

Table 3. Differences in flexion, RT, LT and RR among subjects with insufficiency and accommodative excess according to the Scheiman an d Wick classification, among subjects with AA of the left eye normal and insufficient, NRA insufficient, normal and in excess, and AF both eyes excess and normal.

Characteristic		Flexion		RT		LT		RR	
		Mean (SD)	*P* value	Mean (SD)	*P* value	Mean (SD)	*P* value	Mean (SD)	*P* value
Accommodative Insufficiency / Excess	Insufficiency (n = 24)	52.7 (9.2)	0.92*	40.7 (7.0)	0.59†	46.2 (9.9)	0.90†	69.7 (63.3 ; 74.0)‡	**0.03§**
	Excess (n = 25)	52.3 (12.6)		42.0 (9.6)		45.8 (10.8)		63.3 (56.0 ; 70.0)‡	
AA Left Eye	Insufficiency (n = 27)	49.3 (10.7)	**0.03†**	38.4 (7.6)	**0.006†**	44.2 (10.6)	0.19†	67.6 (10.1)	0.46†
	Normal (n = 23)	55.9 (10.5)		44.9 (8.6)		47.9 (9.8)		65.4 (10.9)	
NRA	Insufficiency (n = 21)	51.8 (54.5)	0.32‖	41.7 (8.4)	0.21‖	47.7 (10.0)	0.07‖	66.0 (8.2)	0.91‖
	Normal (n = 23)	54.5 (10.3)		43.2 (8.8)		47.5 (9.8)		67.1 (13.0)	
	Excess (n = 8)	47.8 (11.1)		37.0 (7.3)		38.6 (9.5)		67.7 (6.2)	
AF Both Eyes	Normal (n = 35)	51.4 (11.1)	0.36†	40.4 (8.9)	0.16†	44.1 (10.7)	**0.018†**	66.4 (9.6)	0.61†
	Excess (n = 9)	55.2 (10.9)		45.0 (7.3)		53.5 (8.1)		64.4 (12.9)	

* Welch t test was used.

† Student t-test was used.

‡ Median and first and third quartiles (Q1 ; Q3) are shown.

§ Mann-Whitney U-test was used.

|| One way ANOVA was used.

SD: Standard Deviation. RT: Right Tilt. LT: Left Tilt. RR: Right Rotation. AA: Accommodative Amplitude. NRA: Negative Relative Accommodation. AF: Accommodative Facility.