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Research Article

Characteristics of Visual Dysfunctions in Individuals with Computer Vision Syndrome

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Abstract

Background: Although digital devices are ubiquitous, their prolonged usage can strain the visual system and lead to asthenopic symptoms, a condition known as computer vision syndrome (CVS). CVS is typically induced by vergence anomalies, accommodative dysfunction and/or refractive errors. Full assessment of visual system needed to treat people suffering from CVS.

Purpose: This study aimed to investigate the association between CVS and refractive, accommodative, and vergence anomalies in young adults.

Methods: A total of 141 young adults aged 16 - 38 years who spend 2 - 3h on computer screens per day were included. The severity of CVS was determined using the CVS questionnaire. Based on the severity of CVS, three groups were identified: asymptomatic, moderately symptomatic, and severely symptomatic. The clinical measurements included refractive, accommodation, and vergence systems.

Results: No significant association was found between the time spent in front of the computer screen and the total CVS score for all participants. Spherical and astigmatic refractive errors were not associated with CVS. However, among all accommodative tests, the amplitude of accommodation was associated with the severity of CVS. In addition, the mean values for the near point of convergence were clinically significant and increased with the severity of CVS, although this was not statistically significant.

Conclusion: The amplitudes of accommodation and near point of convergence were found to be the best clinical measurements for predicting the occurrence and severity of CVS. This suggests a higher incidence of "accommodative and/or "convergence insufficiency" among individuals with CVS.

Keywords: *Computer Vision Syndrome; Refraction; Astigmatism; Accommodation; Vergence; Binocular Vision*

Abbreviations

CVS: Computer Vision Syndrome; PFV: Positive Fusional Vergence; NFV: Negative Fusional Vergence; NPC: Near Point of Convergence

Introduction

Over the last decade, the use of electronic visual displays has dramatically increased. Most people have contact with these devices either for vocational or leisure purposes. It was found that approximately 97.8% of the American population aged 15 - 34 years reported

ownership of any type of computer [1]. Rideout., *et al*. [2] surveyed more than 2,000 children aged 8 - 18 years about media use and found that they spend almost 8 hours a day on computers and screens for both work and entertainment.

Since computer use has become a daily necessity for a wide range of age groups and occupations, it is important to consider the adverse effects of prolonged exposure to digital devices. Many studies have attempted to address the consequences of exposure to these devices [3] and it has been shown that most reported symptoms are related to vision. According to the American Optometric Association, the most common symptoms among digital device users are eyestrain, headaches, blurred vision, dry eyes, double vision, and neck and shoulder pain. These symptoms are collectively known as computer vision syndrome, which arise as a result of an individual's insufficient capabilities to perform visual tasks [4]. Thus, the occurrence of computer vision syndrome may reflect abnormalities or insufficiencies in certain visual system functions [5].

The proper and normal performance of the visual system depends on several factors, but the most important ones include the optical properties of the eye (i.e. refractive power) and oculomotor functions. Oculomotor functions involve the integrity of accommodation (i.e. the ability to focus an image on the fovea) and vergence systems (i.e. the ability to maintain a single binocular vision over a wide range of distances) [6]. Inappropriate oculomotor responses are considered primary factors leading to computer vision syndrome [7]. Such anomalies in the visual system cause visual and ocular symptoms such as headaches, blurred vision, eye strain, and diplopia. These symptoms are collectively referred to as "asthenopia" [8]. Asthenopia is one of the most common complaints among computer users. Various studies have found that computer users often experience these symptoms. For example, approximately 46% of computer users in India reported asthenopic eye symptoms, whereas 32% and 68% of computer users in Italy and Mexico, respectively, reported such symptoms [9-11].

Proper functioning of both accommodation and vergence systems is essential for clear and single vision while viewing a close object, such as when working on a computer. The exact etiology of computer vision syndrome is not clear; however, it can be observed when the ocular muscles get tired and/or the corneal surface dries. Using computers for a long time is thought to reduce the flexibility and ability of the oculomotor system owing to continuous changes in accommodative and vergence demands. This can cause eye strain and fatigue. Little information is available on how accommodation and vergence are affected during computer use or near work. A study found that prolonged near work on computer screens causes a small, temporary myopic shift [3]. The uncorrected astigmatic refractive errors of 0.50 to 1.00 D cylinder increased the level of symptoms after using computers [12,13]. Another study found that working on a computer tends to increase the amount of accommodative lag (i.e. inaccuracy in the amplitude of accommodation) when compared with paperwork, indicating that computer users need more accommodative effort on computer tasks than on hard copying [14]. Moreover, near-vergence ranges were found to significantly decrease after spending 8 hours on computers [15].

Based on previous studies, we hypothesized that computer users with computer vision syndrome might have abnormal clinical visual measurements.

Aim of the Study

This study aimed to explore the association between computer vision syndrome and refractive, accommodative, and vergence anomalies in young adult computer users.

Materials and Methods

Participants

This cross-sectional, descriptive, and analytical study was conducted at the Department of Optometry, College of Applied Medical Sciences, King Saud University in Riyadh, Saudi Arabia. A total of 141 participants (54 males and 87 females) aged 16 - 38 years who

spent at least 2 - 3 hours a day working on a computer were enrolled in this study. The inclusion criteria were best-corrected visual acuity of 20/20 (6/6) or better at both distance and near in each eye and self-reported good health. Participants with both distant or near strabismus, presbyopia, suppression, or amblyopia in one or both eyes were excluded. Individuals with ocular and/or neurological diseases were excluded to prevent a selection bias.

Measurements and procedures

This study consisted of six stages that all participants had to go through. First, participants completed the "computer vision syndrome questionnaire" which assessed eye comfort, dryness, and other symptoms [16]. The computer vision syndrome questionnaire is a valid and reliable tool used in eye examinations and consists of 16 symptom questions that measure the frequency and intensity of each symptom. In addition, the computer vision syndrome questionnaire detects the manifestation of each and overall symptoms (Computer vision syndrome score) in computer users. For questions rating the frequency (i.e. how often the symptom occurs), the participants answered by selecting one of the following options: never (defined as the symptom not occurring at all), occasionally (defined as sporadic episodes or once a week), or often or always (defined as two or three times a week or almost every day). The intensity of each symptom was graded as 0 (never occurring), 1 (moderate), or 2 (intense). Finally, the total computer vision syndrome score was obtained by multiplying the sum of the symptom frequency by the symptom intensity. A score ≥ 6 points indicated that the participant had computer vision syndrome [16].

Second, participants' ocular and neurological medical histories were obtained to determine their eligibility criteria. Third, the best optically corrected visual acuity was measured monocularly and binocularly using a standardized Snellen visual acuity chart. The magnitude and type of refractive errors were recorded for each participant. The cover and Worth four-dots tests were performed at both distance and near to determine whether the participants had strabismus, suppression, and/or amblyopia. Fourth, subjective refraction was performed and recorded for each eye if the participants could not achieve a visual acuity of 6/6 in one or both eyes.

Fifth, the accommodation system was evaluated using clinical measurements, including the amplitude of accommodation, accommodative accuracy, and accommodative facilities, both monocularly and binocularly. The amplitude of accommodation was measured monocularly while the participants wore their best optical correction using the minus lens-add method. The test was performed by adding a -0.25 D lens step while the participant was fixating on a 20/30-line, equivalent to an N5 size target at 40 cm. Measurements were recorded when the participant reported complete blurring. Monocular estimated method retinoscopy was used to evaluate accommodation accuracy. The participants were asked to read a text of 20/30 line, equivalent to the N5 size at a 40 cm. Accommodative facility evaluates the dynamics of the accommodative response, and it was measured with ±2.00 D binocular flipper lens at 40 cm working distance while participants read a text of N5 size monocularly and binocularly. Participants were asked to clear the reading text every time the lens flipper was switched. The number of complete cycles was counted for 1 minute.

Sixth, the vergence systems were assessed using clinical measurements, including the amount of horizontal heterophoria at distance and near, the near point of convergence, horizontal fusional vergence amplitude at distance and near, the vergence facility, and a stereoacuity test at near. The amount of horizontal heterophoria was measured subjectively at both distance and near using the Von Graefe technique. Participants were asked to fixate on a 20/30 vertical line, both far (6 m) and near (40 cm). Eye dissociation was achieved by inducing 3 Δ base-down to one eye and 12 Δ base-in to the other eye, which then gradually decreased until the participant reported vertical alignment of the two lines. The prism step technique was employed to measure both positive and negative horizontal fusional vergence amplitudes at 40 cm and 6 m, respectively. Participants viewed a 20/30 vertical line at an appropriate distance while the number of prisms gradually increased in front of one eye. Negative fusional vergence was measured first by increasing the number of prisms in the base-in direction, followed by positive fusional vergence, which was measured by placing the prism in the base-out direction. The number of prisms increased gradually until the participants noticed the first blur, break, and recovery points. The NPC was measured using the

Royal Air Force rule at the primary gaze by moving the single dot target along the scale towards the eye until the participant noticed a double. A vergence facility test is designed to evaluate the ability of the system to respond over time. A prism flipper of 3 Δ base-in/12 Δ base-out was used in front of one eye while the participant binocularly fixated on a 20/30 vertical line at 40 cm. The participants were asked to clear the line and attempt to keep it fused each time the prism flipper was switched. The number of complete cycles was counted for 1 min. Finally, contour (i.e. local) stereoacuity was measured in seconds of arc using the Titmus fly test while the participants wore polaroid filters at a distance of 40 cm.

All participants provided written informed consent before participating in the study, which was approved by the Research Ethics Committee of King Saud University and Specialized Medical Center Hospital. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Data analysis

The participants were classified into three groups based on the severity of their total computer vision syndrome scores. The first group comprised participants with a total score < 6 and was considered the "asymptomatic group" with 49 participants. The second group had a total score between 6 and 15 and was considered the "moderately symptomatic group" with 69 participants. The third group had a total score > 15 and was considered the "severely symptomatic group," which included 23 participants. The means and standard deviations of the demographic data are presented in table 1.

Variable		Asymptomatic	Moderately Symptomatic	Severely Symptomatic
Sample Size (N)	Female (%)	28 (57%)	44 (64%)	8 (35%)
	Male (%)	21 (43%)	25 (36%)	15 (65%)
Age (mean ± SD)		23.75 ± 3.73	24.09 ± 5.36	24.53 ± 5.90
Hours Spent (mean ± SD)		9.21 ± 3.53	9.44 ± 2.56	7.63 ± 2.42
CVS Total Score (mean ± SD)		3.43 ± 1.23	9.36 ± 2.35	19.73 ± 4.37

Table 1: *Participants' characteristics are listed as mean ± standard deviation values for the asymptomatic, moderately symptomatic, and severely symptomatic groups (N = 141)*

CVS: Computer Vision Syndrome; SD: Standard Deviation.

To determine the prevalence of participants having normal and abnormal measurements in each group, a cut-off point was selected for each clinical test, including refractive, accommodative, and vergence tests. The cut-off point was used to classify whether a specific measurement fell within the normal clinical range. The selection criteria for each test are listed in table 2.

Category	Test	Diagnostic Criterion for Abnormal Values
Refractive Errors	Spherical Refractive Errors	Myopia or hyperopia ≥.50 diopter sphere (D)
	Astigmatism	Astigmatism ≥ 0.75 diopter cylinder (DC) in minus cylinder notation
	Anisometropia	.75 D difference in spherical equivalent of refraction between both eyes
Accommodative Measurements	Amplitude of Accommodation	≤ 2.00 less than [Amplitude of accommodation = 15 - (1/4 age)]
	Accommodative Accuracy	< 0 D, or > +.75 D
	Monocular Accommodative Facility	< 11 cycles per minute
	Binocular Accommodative facility	< 8 cycles per minute

Vergence Measurements	Phoria at Distance	> 3 Prism base-in (Exophoria)
	Phoria at Near	> 6 Prism base-in (Exophoria)
	Positive Fusional Vergence at Distance (Break Point)	< 19 Δ base-out
	Negative Fusional Vergence at Distance (Break Point)	< 7 Δ base-in
	Positive Fusional Vergence at Near (Break Point)	< 21 Δ base-out
	Negative Fusional Vergence at Near (Break Point)	< 19 Δ base-in
	Near Point of Convergence (NPC)	> 7.5 cm
	Vergence Facility	< 12 cycles per minute
	Stereoacuity	> 60 seconds of arc

Table 2: *Diagnostic criteria for abnormal values for all clinical tests.*

The normality of the data for refractive errors (spherical and astigmatic power), accommodative measurements, and vergence measurements was assessed using the Shapiro-Wilk test. The results indicated that the data for refractive errors and accommodative measurements were normally distributed, whereas the data for vergence measurements were not normally distributed.

Different methods were used for the data analyses. First, a one-way analysis of variance (ANOVA) was used to directly compare groups for both refractive and accommodative measurements, whereas the non-parametric Kruskal-Wallis test was used for vergence measurements. The post-hoc Bonferroni test was then used for pairwise multiple comparisons between the groups. Second, the chi-squared test (X^2) was used to compare the number of participants with normal and abnormal measurements for each clinical test among all groups. Third, a non-parametric Spearman's correlation test was used to assess the correlations between the total computer vision syndrome score and different clinical measurements for all participants. All data were analyzed using the Statistical Package for the Social Sciences version 28 software.

Results and Discussion

Association between spent time and total score of CVS

The normality of data was tested for both the time spent in front of the computer (hours per day) and the total computer vision syndrome score for all participants using the Shapiro-Wilk test. The results showed that the time spent in hours was normally distributed (P = .016), but the total computer vision syndrome score was not (P = .190). Therefore, correlations between these two variables were tested using the non-parametric Spearman's correlation test. The results showed that these two variables were not significantly correlated (P = -.102, P = .228).

Comparisons between the groups

Mean values, standard errors of the mean (std. error), and 95% confidence intervals for refractive errors, accommodative measurements, and vergence measurements for each group are summarized in table 3. For spherical and astigmatic refractive errors, direct comparisons between the groups using a one-way ANOVA showed no significant differences in either spherical refractive (F = .448, P = .640) or astigmatic errors (F = 1.408, P = .248) between the groups. For accommodative tests, direct comparisons between the groups using a one-way ANOVA showed that the differences between the groups were not significant in most tests. The differences were only significant for the accommodation amplitude (F = 6.152, P = .003). As computer vision syndrome becomes severe, a lower amplitude of accommodation can be exerted by the participant. Pairwise multiple comparisons were performed using the Bonferroni post-hoc test. The post hoc test showed that the difference was significant only between the asymptomatic and severely symptomatic groups. Figure 1 shows the mean values of accommodation amplitude for all groups.

Tests	Groups	Mean	Std. Error	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Spherical Refractive Errors	Asymptomatic	-.673	.209	-1.09	-.25
	Moderately Symptomatic	-.80	.182	-1.16	-.43
	Severely Symptomatic	-.456	.353	-1.18	.27
Astigmatic Refractive Errors	Asymptomatic	.301	.091	.118	.48
	Moderately Symptomatic	.195	.046	.102	.28
	Severely Symptomatic	.402	.146	.09	.70
Amplitude of Accommodation	Asymptomatic	-6.43	.351	-7.14	-5.73
	Moderately Symptomatic	-5.615	.242	-6.09	-5.13
	Severely Symptomatic	-4.60	.294	-5.21	-3.99
Accommodative Accuracy	Asymptomatic	.357	.077	.202	.51
	Moderately Symptomatic	.23	.059	.115	.35
	Severely Symptomatic	.434	.095	.23	.63
Monocular Accommodative Facility	Asymptomatic	8.95	.625	7.70	10.21
	Moderately Symptomatic	8.59	.541	7.51	9.67
	Severely Symptomatic	8.30	.610	7.03	9.57
Binocular Accommodative facility	Asymptomatic	10.02	.735	8.54	11.49
	Moderately Symptomatic	9.971	.607	8.75	11.18
	Severely Symptomatic	10.26	.996	8.19	12.32
Phoria at Distance	Asymptomatic	-1.224	.339	-1.90	-.54
	Moderately Symptomatic	-.913	.410	-1.73	-.09
	Severely Symptomatic	-2.56	.661	-3.93	-1.19
Phoria at Near	Asymptomatic	-4.612	.649	-5.91	-3.30
	Moderately Symptomatic	-4.11	.578	-5.27	-2.96
	Severely Symptomatic	-5.30	.924	-7.22	-3.38
Positive Fusional Vergence at Distance (Break Point)	Asymptomatic	13.81	1.209	11.38	16.24
	Moderately Symptomatic	19.33	1.115	17.10	21.55
	Severely Symptomatic	18.130	1.923	14.140	22.12
Negative Fusional Vergence at Distance (Break Point)	Asymptomatic	8.00	.60	6.79	9.20
	Moderately Symptomatic	7.79	.367	7.06	8.53
	Severely Symptomatic	8.08	.80	6.40	9.76
Positive Fusional Vergence at Near (Break Point)	Asymptomatic	22.40	1.50	19.38	25.42
	Moderately Symptomatic	26.23	1.14	23.94	28.51
	Severely Symptomatic	23.43	1.50	20.31	26.55
Negative Fusional Vergence at Near (Break Point)	Asymptomatic	13.142	.74	11.64	14.63
	Moderately Symptomatic	13.86	.63	12.60	15.13
	Severely Symptomatic	14.86	1.2	12.20	17.52

Near Point of Convergence (NPC)	Asymptomatic	5.45	.68	4.08	6.82
	Moderately Symptomatic	5.68	.35	4.97	6.38
	Severely Symptomatic	6.60	.76	5.01	8.20
Vergence Facility	Asymptomatic	12	.86	10.25	13.74
	Moderately Symptomatic	10.21	.65	8.91	11.51
	Severely Symptomatic	11	.78	9.376	12.62

Table 3: *Mean values, standard error of the mean (std. error), and 95% codependence intervals for refractive errors, accommodative measurements, and vergence measurements for each group.*

Abbreviations: PFV: Positive Fusional Vergence; NFV: Negative Fusional Vergence; NPC: Near Point of Convergence.

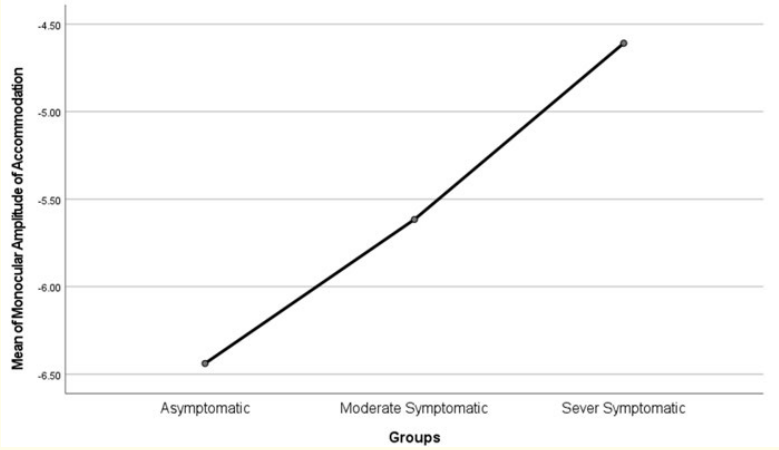

Figure 1: *Mean values of monocular amplitude of accommodation for each group.*

Regarding the vergence tests, the non-parametric Kruskal-Wallis test revealed a significant difference only in the positive fusional vergence test at distance (H = 10.158, P = .006). However, this result was unexpected, as it showed that the moderately and severely symptomatic groups had larger (i.e. better) amplitudes than those of the asymptomatic group (Figure 2). The mean values for the near point of convergence receded more in the severely symptomatic group than that in the other groups. Specifically, the severely symptomatic group had a receding near point of convergence of more than 1 cm than that in the asymptomatic group (Figure 3). Although this result was considered clinically significant, it was not statistically significant (F = .140, P = .097).

Prevalence of normal vs. abnormal measurements among groups

Table 4 summarizes the percentages of the number of participants considered to have normal or abnormal measurements among all groups. Although there were no statistically significant differences, there was a higher frequency of individuals with abnormal

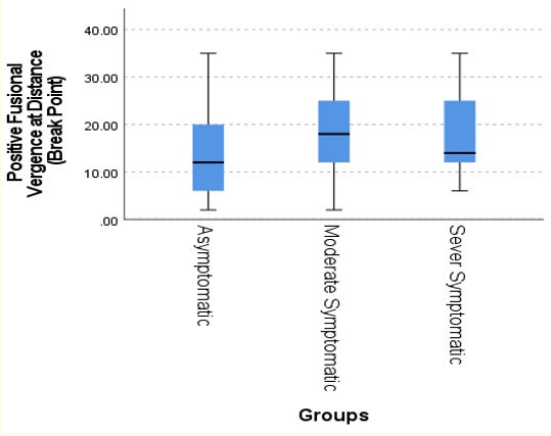

Figure 2: *Box-plot graph of positive fusional vergence at distance for all groups.*

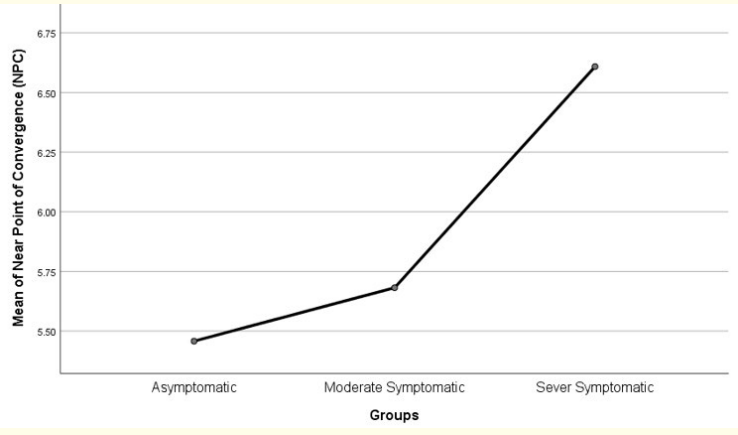

Figure 3: *Mean values of near point of convergence for each group.*

measurements among the severely and moderately symptomatic groups than in the asymptomatic group for various clinical tests, including anisometropia, amplitude of accommodation, monocular accommodative facility, amount of phoria at distance, near point of convergence, and vergence facility tests. However, the only test that reached a marginally significant level was the near point of convergence (P = .069).

Tests		Groups	Normal (%)	Abnormal (%)	Chi-Square	df	P-value
Refractive Errors	Sphere	Asymptomatic	8	92	37.87	2	<.001*
		Moderately Symptomatic	57	43			
		Severely Symptomatic	48	52			
	Astigmatism	Asymptomatic	86	14	.789	2	.783
		Moderately Symptomatic	90	10			
		Severely Symptomatic	87	13			
	Anisometropia	Asymptomatic	92	8	.522	2	.77
		Moderately Symptomatic	89	11			
		Severely Symptomatic	87	13			

Accommodative Measurements	Amplitude of Accommodation	Asymptomatic	35	65	2.509	2	.285
		Moderately Symptomatic	26	74			
		Severely Symptomatic	17	83			
	Accommodative Accuracy	Asymptomatic	80	20	1.30	2	.937
		Moderately Symptomatic	77	23			
		Severely Symptomatic	78	22			
	Monocular Accommodative Facility	Asymptomatic	41	59	4.35	2	.113
		Moderately Symptomatic	60	40			
		Severely Symptomatic	22	78			
	Binocular Accommodative Facility	Asymptomatic	41	59	12.265	2	.002*
		Moderately Symptomatic	73	27			
		Severely Symptomatic	65	35			
Vergence Measurements	Phoria at Distance	Asymptomatic	67	33	4.40	2	.11
		Moderately Symptomatic	50	50			
		Severely Symptomatic	48	52			
	Phoria at Near	Asymptomatic	45	55	2.508	2	.285
		Moderately Symptomatic	42	58			
		Severely Symptomatic	61	39			
	PFV at Distance (Break Point)	Asymptomatic	27	73	4.416	2	.110
		Moderately Symptomatic	45	55			
		Severely Symptomatic	43	57			
	NFV at Distance (Break Point)	Asymptomatic	51	49	.249	2	.883
		Moderately Symptomatic	51	49			
		Severely Symptomatic	57	43			
	PFV at Near (Break Point)	Asymptomatic	40	60	6.918	2	.031*
		Moderately Symptomatic	65	35			
		Severely Symptomatic	57	43			
	NFV at Near (Break Point)	Asymptomatic	16	84	0.555	2	.758
		Moderately Symptomatic	12	88			
		Severely Symptomatic	13	87			
	NPC	Asymptomatic	84	16	5.338	2	.069
		Moderately Symptomatic	81	19			
		Severely Symptomatic	60	40			
	Vergence Facility	Asymptomatic	55	45	2.089	2	.352
		Moderately Symptomatic	42	58			
		Severely Symptomatic	44	56			

Table 4: *Percentages of the number of participants considered as having normal or abnormal measurements among all groups and chi-square test (X^2) values.*

Abbreviations: PFV: Positive Fusional Vergence; NFV: Negative Fusional Vergence; NPC: Near Point of Convergence. (*) P-value is significant at 0.05 level.

In contrast, the results based on the chi-square test (X^2) showed that the number of participants with spherical refractive errors was higher in the asymptomatic group than in the severely symptomatic group. However, this result may have had minimal impact because the refractive errors were fully corrected for all participants. The results of the binocular accommodative facility test showed that the asymptomatic group had more cases with abnormal measurements than the moderately and severely symptomatic groups. For the vergence tests, only the positive near-fusional vergence showed significant differences. The asymptomatic group had more cases of abnormal measurements than the other groups. Almost all the participants in all groups had normal stereoacuity test results.

Associations between the total score of CVS and different clinical measurements

The results revealed a significant negative correlation between the total computer vision syndrome score and amplitude of accommodation (P = .274, P = .001). This suggests that as the total computer vision syndrome score increased, there was a higher likelihood of accommodative insufficiency. However, the other correlations were not statistically significant (P >.05).

Results of this study aimed to investigate whether individuals with severe computer vision syndrome have more refractive, accommodative, and vergence anomalies. To the best of our knowledge, this is the first study to investigate such associations and to determine which accommodative and/or vergence tests can be used clinically to diagnose and predict the occurrence of computer vision syndrome. There is insufficient literature investigating this association or comparing different accommodative and vergence tests for computer vision syndrome occurrence.

Substantial evidence suggests that computer vision syndrome results from repetitive strain on the visual system, leading to asthenopic symptoms. Although screen time has been associated with the manifestation of symptoms, this study found no correlation between the total computer vision syndrome score and time spent on digital devices. This result is consistent with those of previous studies that also found no association between the severity of computer vision syndrome and the duration of computer use. A study that measured computer vision syndrome using the Computer Vision Syndrome Questionnaire reported that computer vision syndrome severity was not associated with the number of years of computer work or continuous computer use [17]. In addition, another study found no significant differences in visual symptoms between participants working on a computer for 3 or 6 hours [18]. In contrast to our results, a study based on a larger population found a significant positive correlation between computer vision syndrome symptoms and time spent using digital devices [19]. Patil., *et al*. [20] showed a weak but significant correlation between hours spent in front of computers and symptom questionnaire scores. The differences in the frequency of symptoms across studies may be related to the methods used to quantify symptoms; some studies used validated, standard questionnaires while others did not.

The results showed that spherical and astigmatic refractive errors are not suitable parameters for predicting the occurrence of computer vision syndrome. This may be explained by the role of optical correction in alleviating associated symptoms. This finding is consistent with a study by Shrestha., *et al*. where they concluded that refractive error did not show any significant correlation with ocular symptoms [21]. A study found that wearing habitual correction reduced the mean asthenopia score [22]. Notably, various studies have associated the incidence of computer vision syndrome with non-corrected refractive errors, especially irregular astigmatism and hyperopia [23]. A population study conducted in Australia found that the prevalence of refractive errors was similar in participants with or without eyestrain [24]. Tawil., *et al*. reported that astigmatic refractive errors were associated with computer vision syndrome; however, myopic and hyperopic spherical refractive errors were not [25]. In a 10-year follow-up study, refractive errors were not associated with visual fatigue in computer operators [26]. However, this study found that the number of individuals with anisometropia with a 0.75D difference between the two eyes was higher among the severely symptomatic group. Although the frequency was not significantly different from that of the other groups, this factor might be important to consider when investigating computer vision syndrome. These insignificant differences might be due to the unequal sample sizes between the groups.

Regarding the accommodative tests in this study, the main finding was that the amplitude of accommodation was lower in the severely symptomatic group than in the asymptomatic group. This result supports previous evidence that working with video display terminals can reduce accommodation amplitude [27]. A reduction in the ability to excrete sufficient accommodation, a clinical sign of accommodation insufficiency, is usually associated with asthenopic eye symptoms. A population study among school students reported that accommodation insufficiency is the most likely cause of symptoms among all accommodative anomalies [28]. Interestingly, our results did not show any significant differences with respect to other accommodative tests between the groups, although the number of individuals with the abnormal monocular accommodative facility was higher in the severely symptomatic group. This could be due to the smaller number of participants in this group than in the other groups. Our results are consistent with the study by Rosenfield, which found no significant association between the computer vision syndrome and accommodation facility tests, which could also be explained by the limited sample size [29]. Monocular and binocular accommodative facility tests are useful tools to predict the occurrence of visual symptoms and asthenopia. Reductions in monocular and binocular accommodative facilities are typical diagnostic signs of accommodative infacility, which has been found to be the most common ocular abnormality in symptomatic patients [21,30]. Increased near work has also been significantly correlated with decreased accommodation facilities and increased asthenopic symptoms [31]. Tosha., *et al*. suggested that visual discomfort is associated with accommodative fatigue rather than insufficiency [32].

Regarding vergence measurements, a comparison of the means of the three different groups found that the severely symptomatic group had better positive fusional vergence values at distance than the asymptomatic group. This finding was unexpected because it suggests that symptomatic participants have larger fusional vergence amplitudes than asymptomatic participants. This could be attributed to the inequality in the sample size. Nonetheless, a study that measured fixation disparity after 30 minutes of reading text on a computer screen found that computer vision syndrome was worse in participants exhibiting zero fixation disparity than in those with exo-fixation disparity [33]. Regarding the near point of convergence, the results of this study found that the mean values receded by more than 1 cm as the computer vision syndrome score increased, although it was not statistically significant. A more recent study reported a receding near point of convergence after 20 min of both smartphone and computer use. However, there are no reports correlating asthenopic symptoms with altered vergence findings on computer screens or handheld devices [7]. Remote near point of convergence is a useful clinical tool for diagnosing patients with convergence insufficiency [34].

Limitation of the Study

This study had some limitations, such as the subjectivity of the severity score, as it has been proven that participants with a high pain threshold may not manifest symptoms [35]. The sample size was also not sufficient to generalize the results of some tests, and there was an inequality in sample size between the groups. Furthermore, cycloplegic refraction could not be performed because the participants could not return to the clinic more than once. Further studies may be beneficial, particularly when considering workplace environments.

Conclusion

Although the exact mechanisms underlying computer vision syndrome are not yet fully understood, the findings of this study suggest that both accommodative and vergence measurements might be useful for diagnosing and managing the condition. Specifically, the amplitude of accommodation appeared to be the most reliable predictor of computer vision syndrome occurrence, whereas the near point of convergence might be a more useful tool for predicting symptom severity. These findings suggest that individuals with computer vision syndrome are more likely to be clinically diagnosed with accommodative and/or "convergence insufficiency."

Prevention is the primary strategy in managing computer vision syndrome. Since computer vision syndrome can have various underlying causes, it requires a multidirectional approach, and the treatment plan must be tailored to individual patients to relieve symptoms. Further research in this area is warranted to better understand the underlying causes of computer vision syndrome and develop more effective prevention and treatment strategies.

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Conflict of Interest

The author declares that there is no conflict of interest.

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