• Clinical Research •

Total score of the computer vision syndrome questionnaire predicts refractive errors and binocular vision anomalies

Mosaad Alhassan[1], Tasneem Samman[2], Hatoun Badukhen[3], Muhamad Alrashed[1], Balsam Alabdulkader[1], Essam Almutleb[1], Tahani Alqahtani[1], Ali Almustanyir[1]

[1]Department of Optometry, College of Applied Medical Sciences, King Saud University, Riyadh 11433, Saudi Arabia
[2]Department of Ophthalmology, Specialized Medical Center Hospital, Riyad 12311, Saudi Arabia
[3]Dr Suliman Al-habib Medical Group, Riyadh 12382, Saudi Arabia
Correspondence to: Mosaad Alhassan. Department of Optometry, College of Applied Medical Sciences, King Saud University, P. O. Box: 10219, Riyadh 11433, Saudi Arabia. malhassan@ksu.edu.sa
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Abstract

● **AIM:** To evaluate the efficacy of the total computer vision syndrome questionnaire (CVS-Q) score as a predictive tool for identifying individuals with symptomatic binocular vision anomalies and refractive errors.

● **METHODS:** A total of 141 healthy computer users underwent comprehensive clinical visual function assessments, including evaluations of refractive errors, accommodation (amplitude of accommodation, positive relative accommodation, negative relative accommodation, accommodative accuracy, and accommodative facility), and vergence (phoria, positive and negative fusional vergence, near point of convergence, and vergence facility). Total CVS-Q scores were recorded to explore potential associations between symptom scores and the aforementioned clinical visual function parameters.

● **RESULTS:** The cohort included 54 males (38.3%) with a mean age of 23.9±0.58y and 87 age-matched females (61.7%) with a mean age of 23.9±0.53y. The multiple regression model was statistically significant [R^2=0.60, F=13.28, degrees of freedom (DF=17 122, P<0.001]. This indicates that 60% of the variance in total CVS-Q scores (reflecting reported symptoms) could be explained by four clinical measurements: amplitude of accommodation, positive relative accommodation, exophoria at distance and near, and positive fusional vergence at near.

● **CONCLUSION:** The total CVS-Q score is a valid and reliable tool for predicting the presence of various non-strabismic binocular vision anomalies and refractive errors in symptomatic computer users.

● **KEYWORDS:** computer vision syndrome; refractive errors; accommodation; vergence; binocular vision; symptoms

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INTRODUCTION

Computer vision syndrome (CVS) is a condition characterized by ocular and visual symptoms, such as eye strain, blurred and double vision, burning and itching, and other types of symptoms, such as headaches, resulting from prolonged computer, tablet, or smartphone use. One of the key factors contributing to CVS is the strain placed on the accommodation and vergence systems of the eye when viewing digital screens[1-2].

Previous studies reported that reading from screens including computers, smartphones, and tablets may affect the ability of the eye to focus the image properly (*i.e.,* accommodation), and the ability of the two eyes to converge properly (*i.e.,* vergence) on an object of regard. This differs from reading printed materials at fixed distances. For example, a study found that amplitude of accommodation decreased and accommodative lag (*i.e.,* accommodation accuracy) increased when reading from electronic devices in comparisons to printing materials. The same study found that the ability of the two eyes to properly converge on an object of regard was affected[3]. Another study supporting this finding that responses from both accommodation and vergence systems are significantly worse and unstable when reading from cathode ray tube (CRT)

monitors compared to reading on papers[4]. Constant and repeated reading from computer screens over period of 30min lead to significant lag of accommodation (*i.e.,* accommodation is inaccurate) among healthy individuals[5]. Thus, prolonged computer use can disrupt both accommodation and vergence systems, causing double vision, headaches, and eye strain[6].

The unique characteristics of digital screens, such as glare, contrast, and resolution, can also contribute to CVS. Viewing a computer screen often requires the eyes to move in a different pattern than reading a printed page. This can lead to increased blinking rate, reduced blink amplitude, and altered saccadic eye movements[7].

According to previous research, a correlation appears to exist between the visual symptoms of CVS and binocular vision anomalies. Studies have shown a high prevalence of non-strabismic binocular vision anomalies among individuals with CVS symptoms. For instance, one study found that 77% of participants had at least one subnormal accommodative function, whereas 93% had at least one subnormal vergence function[8]. A two-way ANOVA revealed significant differences in various binocular visual functions between the low- and high-risk groups for CVS metrics such as near point of convergence and negative relative accommodation were notably affected, suggesting that these visual functions can predict the severity of CVS symptoms[9-10]. Logistic regression analyses indicated that factors such as negative relative accommodation, positive relative accommodation, near point of convergence, and stereopsis effectively predicted the risk of CVS This highlights the potential use of binocular vision assessments as predictive tools for identifying individuals at risk of developing CVS[9-10].

Previous studies have separated between visual and non-visual symptoms of CVS[11]. For example, a study found significant and strong associations between accommodative infacility and tired eyes as considered the most commonly reported symptoms among computer users[12]. The study reported that the ocular and visual symptoms of CVS were the most significant types of symptoms associated with binocular visual dysfunctions. Whereas, other systemic symptoms, such as headaches and dry eyes of CVS were the least associated ones[12].

Different tools are clinically used to estimate the symptoms associated with computer use. The computer vision syndrome questionnaire (CVS-Q) is a validated and reliable instrument designed to evaluate symptoms related to computer use, including ocular and visual symptoms related directly to everyday life binocular vision skills, other ocular symptoms such as dryness and itching, and finally other systemic symptoms such as headache and foreign body sensations. The questionnaire consists of 16 items that assess the frequency and intensity of these symptoms. Additionally, it identifies the occurrence of individual symptoms, as well as the overall CVS score for users[13]. For the frequency-related questions, participants selected from options such as: “never” (indicating no occurrence), “occasionally” (suggesting sporadic episodes or once a week), or “often” or “always” (meaning two to three times a week or nearly every day). The intensity of each symptom was rated on a scale ranging from 0 (never occurring) to 2 (intense). The overall CVS score is determined by multiplying the total frequency of symptoms by their intensity, with a score of 6 or higher indicating the presence of CVS[13].

Associations between the total scores on the CVS-Q (including all types of symptoms) and multiple visual dysfunctions have not yet been explored. This study aimed to explore the association between total CVS-Q scores and various refractive, accommodative, and vergence anomalies among young adult computer users.

PARTICIPANTS AND METHODS

Ethical Approval Before the study, all participants provided written informed consent. This study was approved by the Research Ethics Committee of King Saud University and the Specialized Medical Center Hospital (IRB Reference Number: 20/0259/IRB), ensuring compliance with the principles of the Declaration of Helsinki.

Participants This descriptive and analytical cross-sectional study was conducted at the Department of Optometry, College of Applied Medical Sciences, King Saud University and the Department of Ophthalmology at the Specialized Medical Center Hospital in Riyadh, Saudi Arabia. In total, 141 participants (54 males and 87 females) aged between 16 and 38y were recruited. All participants used a computer for at least two–three hours daily. The inclusion criteria were a best-corrected visual acuity of 20/20 (6/6) or better for both distance and near vision in each eye, along with self-reported good health. To reduce selection bias, individuals with strabismus, presbyopia, suppression, or amblyopia in one or both eyes as well as individuals with ocular or neurological conditions were excluded.

Measurements and Procedures The study comprised five sequential stages that each participant was required to complete. First, participants began by filling out the CVS-Q. Second, the participants’ ocular and neurological medical histories were reviewed to confirm their eligibility for the study. Third, visual acuity was assessed monocularly and binocularly using a standardized Snellen chart. Any refractive errors were recorded, and tests for strabismus, suppression, and amblyopia were conducted using the cover test and the Worth four-dot test. If the participant did not achieve 6/6 visual acuity, subjective refraction was performed for each eye. Fourth, the

accommodation system was assessed using various clinical measurements, including the amplitude of accommodation, positive and negative relative accommodation, accommodative accuracy, and facilities, both monocularly and binocularly. The amplitude of accommodation was measured monocularly while participants wore their best optical correction and focused on a 20/30-line target at 40 cm, with measurements taken when participants reported complete blurring after adding small steps of negative lenses. positive and negative relative accommodation were measured binocularly while participants wore their best optical correction and focused on a 20/30-line target at 40 cm, with measurements taken when participants reported complete blurring after adding small steps of negative and positive lenses respectively. Accommodative accuracy was evaluated through monocular estimated method (MEM) retinoscopy, and the monocular and binocular accommodative facility was assessed using ±2.00 D flipper lenses at 40 cm while participants read 20/30-line targets. Fifth, clinical evaluations of the vergence system measured horizontal heterophoria at distance and near using the Von Graefe technique, near the point of convergence using a printed target, horizontal positive and negative fusional vergence amplitude at distance and near using a prism bar, and a vergence facility test using 12BO/3BI prism flippers while reading a vertical line at 40 cm. The clinical procedures for all the tests have been fully explained in the literature[14-15].

Statistal Analysis Multiple regression analysis was performed to assess the relationship between the total CVS-Q score and several independent variables, including spherical refractive error, cylindrical refractive error, accommodative system measurement, and vergence system measurement. For refractive and accommodative tests, only data from the right eye were considered unless measurements from both eyes were required, as in the case of the binocular accommodative facility test and positive and negative relative accommodation tests. Scatter plots were used to examine the potentially significant associations between the total CVS-Q scores and other variables. A 95% confidence interval was applied, and a *P*-value less than 0.05 was considered statistically significant. All data were analyzed using Statistical Package for the Social Sciences (SPSS) version 28 software.

RESULTS

Demographic of Participants and Descriptive Statistics A total of 141 participants took part in the study, including 54 males (38.3%) with a mean age of 23.9±0.58y, and 87 age-matched females (61.7%) with a mean age of 23.9±0.53y. Table 1 presents the mean values and standard errors of computer usage (in hours per day), total CVS-Q scores, and other clinical variables for both sexes. Comparisons between the two groups (males *vs* females) using an unpaired *t*-test did not reveal any significant differences. Therefore, the data from both groups were combined for further analyses.

Association Between Spent Time and Total Score of CVS-Q This study explored the relationship between the duration of computer use and CVS The Shapiro-Wilk test indicated that the time spent in front of the computer was normally distributed (P=0.016), whereas the total CVS-Q score did not follow a normal distribution (P=0.190). Given the non-normal distribution of the CVS-Q score, Spearman's correlation test was employed. The analysis revealed no significant correlation between the duration of computer use and CVS-Q symptoms (P=-0.102, P=0.228). This lack of correlation suggests that CVS symptoms may not be directly linked to the amount of time spent using a computer but rather to abnormalities in specific visual functions.

Multiple Regression Analysis Between Total Score of CVS-Q and Other Variables The results indicated that accommodation and vergence accounted for 60% of the variance in the occurrence of CVS, as explained by the multiple regression model (R^2=0.60). The impact of these variables on the model was statistically significant, with an F-value of 13.28, degrees of freedom (DF)=17 122, and a P-value of less than 0.001.

Table 2 shows the multiple regression coefficients (B), P-values, and 95% confidence intervals for all variables in the model. Predictors, including the amplitude of accommodation, positive relative accommodation, exophoria at distance and near, and positive fusional vergence at near were significantly correlated with the CVS-Q. A decrease in amplitude of accommodation was significantly associated with higher total CVS-Q scores, indicating more severe symptoms. Similarly, a reduction in positive relative accommodation, which measures an individual’s ability to accommodate both eyes while keeping focused image, correlated with an increased CVS-Q score. Divergent ocular misalignment was also significantly associated with symptoms, as indicated by an increase in exodeviation at both distance and near. As individuals’ convergence abilities decreased, their CVS-Q scores increased. This trend is supported by the positive fusional vergence test at near vision; as this value decreases, indicating a reduced ability to maintain a single binocular vision at near vision, the CVS-Q score increases. Figures 1 and 2 show examples of scatter plots for significant correlations between the amplitude of accommodation and exophoria at distance and the total score of the CVS-Q.

The study found that other refractive, accommodative, and vergence visual functions were not significantly correlated with the CVS-Q scores. However, the vergence facility test was nearly significant, with a P-value of 0.07, indicating that it was close to showing a meaningful relationship, but ultimately did not reach statistical significance (Table 2).

Table 1 Participants' demographics, mean values, and standard error of the means (SEM)

Variables	Gender	Mean±SEM
Computer use (hours per day)	Male	8.92±0.37
	Female	8.55±0.31
Total score of Computer Vision Syndrome Questionnaire (CVS-Q)	Male	7.60±0.74
	Female	9.24±0.64
Spherical refractive error (diopter)	Male	-0.21±0.15
	Female	-0.35±0.102
Cylindrical refractive error (diopter)	Male	0.16±0.066
	Female	0.13±0.034
Amplitude of accommodation (diopter)	Male	5.90±0.363
	Female	4.93±0.240
Negative relative accommodation (diopter)	Male	2.33±0.096
	Female	2.11±0.09
Positive relative accommodation (diopter)	Male	3.14±0.301
	Female	3.53±0.20
Accommodative accuracy (diopter)	Male	0.33±0.06
	Female	0.28±0.056
Monocular accommodative facility (cycle per minute)	Male	9.92±0.60
	Female	10.95±0.49
Binocular accommodative facility (cycle per minute)	Male	9.24±0.75
	Female	10.49±0.51
Phoria at distance (prism diopter)[a]	Male	-0.98±0.35
	Female	-0.02±0.39
Phoria at near (prism diopter)[a]	Male	-4.18±0.52
	Female	-3.60±0.41
Positive fusional vergence at distance (break point; prism diopter)	Male	16.52±1.194
	Female	17.74±1.03
Negative fusional vergence at distance (break point; prism diopter)	Male	7.0±0.44
	Female	8.36±0.40
Positive fusional vergence at near (break point; prism diopter)	Male	21.62±1.66
	Female	21.62±1.29
Negative fusional vergence at near (break point; prism diopter)	Male	13.45±0.68
	Female	13.97±0.60
Near point of convergence (centimeter)	Male	6.92±0.49
	Female	6.05±0.34
Vergence facility (cycle per minute)	Male	10.71±0.82
	Female	11.06±0.54

[a]For phoria measurement, the negative sign denotes exophoria, and the positive sign denotes esophoria. SEM: Standard error of mean.

DISCUSSION

The precise cause of CVS remains unclear; however, it typically arises when the eye muscles become fatigued or the corneal surface becomes dry. Prolonged computer use is believed to impair the flexibility and functionality of the oculomotor system owing to constant fluctuations in accommodative and vergence demands, leading to eye strain and fatigue. Limited information is available on how refractive errors, accommodation, and vergence are affected by computer use or near work. Thus, this study aimed to explore whether individuals with severe CVS, based on the total CVS-Q score, exhibit abnormal clinical values of refractive, accommodative, and vergence anomalies. Previous studies have focused on the associations between specific types of symptoms (*e.g.*, double vision, headache, and blurry vision) and different clinical visual functions[9,16]. There is a lack of literature on this association, or comparisons of different refractive, accommodative, and vergence tests related to the total CVS-Q score. To our knowledge, this is the first study to examine these associations. Substantial evidence suggests that CVS is caused by repetitive strain on the visual system, leading to symptoms of asthenopia. Although screen time has been correlated with symptom

Table 2 Regression coefficients (B), *P*-values and 95%CI different predictors of multiple regression analysis

Variable	Regression coefficients (*B*)	*P*	95%CI	
			Lower bound	Upper bound
Spherical refractive error	0.132	0.101	-0.110	1.215
Cylindrical refractive error	-0.123	0.253	-2.686	0.712
Amplitude of accommodation[a]	-0.074	<0.001	-1.266	-0.682
Negative relative accommodation	-0.054	0.554	-1.081	0.583
Positive relative accommodation[a]	0.308	0.027	0.047	0.765
Accommodative accuracy	-0.05	0.291	-2.007	0.606
Monocular accommodative facility	-0.068	0.683	-0.160	0.244
Binocular accommodative facility	0.043	0.298	-0.288	0.089
Phoria at distance[a]	-0.395	0.001	-0.593	-0.146
Phoria at near[a]	-0.20	0.03	-0.186	-0.268
Positive fusional vergence at distance (break point)	0.028	0.168	-0.126	0.022
Negative fusional vergence at distance (break point)	-0.158	0.099	-0.356	0.031
Positive fusional vergence at near (break point)[a]	0.106	<0.001	0.300	0.134
Negative fusional vergence at near (break point)	0.094	0.231	-0.051	0.209
Near point of convergence	0.065	0.888	-0.269	0.310
Vergence facility	0.046	0.07	-0.013	0.240

[a]*P* value is statically significant at the 0.05 level. CI: Confidence interval.

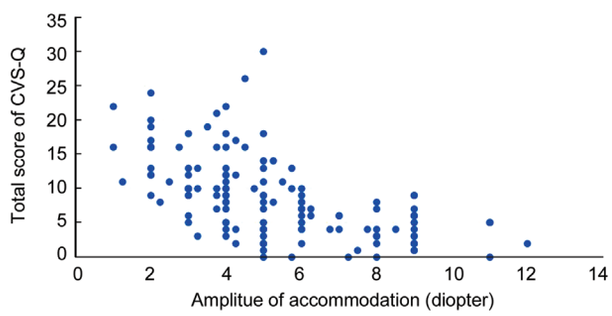

Figure 1 Scatter plot of indirect and significant correlation between total score of CVS-Q and amplitude of accommodation in diopter
CVS-Q: Computer vision syndrome questionnaire.

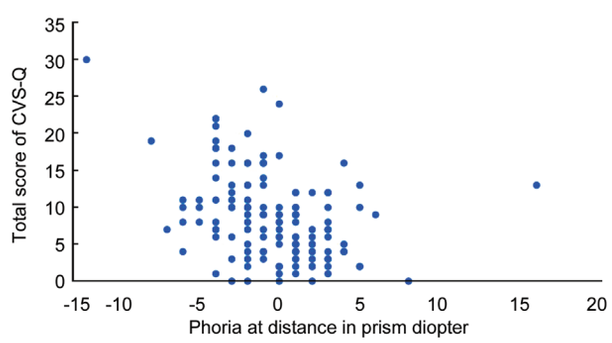

Figure 2 Scatter plot of direct and significant correlation between total score of CVS-Q and amount of exophoria in prism diopter at distance Minus signs in horizontal axis denotes exophoria, plus signs in horizontal axis denotes esophoria. CVS-Q: Computer vision syndrome questionnaire.

manifestations, our study found no link between overall CVS scores and the time spent on digital devices. This aligns with previous studies that also reported no correlation between the severity of CVS and duration of computer use. A study using a CVS-Q indicated that the severity was unrelated to years of computer work or continuous usage[17]. Another study found no significant differences in visual symptoms between participants working on computers for three or six hours[18]. In contrast, a larger population study found a significant positive correlation between CVS symptoms and time spent on digital devices[7,19]. Patil *et al*[19] reported a weak but significant correlation between hours spent on computers and symptom scores. Variations in symptom frequency across studies may stem from different methodologies; some studies used validated questionnaires, whereas others did not.

The results of this study showed that spherical and astigmatic refractive errors are not suitable parameters for predicting the occurrence of CVS This may be explained by the role of optical correction in alleviating associated symptoms. All participants wore their habitual or modified optical correction during the study, and they already had at least 20/20 vision in either eye. Our methodology for studying the possible role of refractive errors in CVS while participants wore their optical corrections is problematic. Optical correction of refractive errors is considered a strong factor in reducing CVS[20-22]. Another study should be conducted to investigate the effect of prescribing optical correction on CVS in participants who habitually do not wear glasses. Our findings are consistent with those of Shrestha *et al*[12], who concluded that refractive error does not show any significant correlation with ocular symptoms. One study found that habitual correction reduced the mean asthenopia score[23]. Notably, various studies have

associated the incidence of CVS with uncorrected refractive errors, especially irregular astigmatism and hyperopia[24]. A population study conducted in Australia found that the prevalence of refractive errors was similar in participants with and without eyestrain[25-26]. Al Tawil *et al*[26] reported that astigmatic refractive errors are associated with CVS; however, myopic and hyperopic spherical refractive errors are not. In a 10-year follow-up study, refractive errors were not associated with visual fatigue in computer operators[16].

In terms of accommodative tests, our main finding was that the amplitude of accommodation and positive relative accommodation (PRA) (*i.e.*, the maximum ability to stimulate accommodation with both eyes while maintaining clear and single binocular vision) were significantly associated with total symptoms of CVS-Q scores. There was an indirect relationship between these two tests and the total CVS-Q score. Thus, individuals with severe CVS-Q scores have less ability to maintain a focused image at all times, and they get tired easily. A reduction in the amplitude of accommodation and positive relative accommodation is a clinical sign of accommodative insufficiency, which is often linked to asthenopic symptoms[27]. Several previous studies have considered a reduction in the amplitude of accommodation to be the strongest predictor of CVS. For example, a population study of school students indicated that accommodative insufficiency (AI) was likely to be the primary cause of symptoms among various accommodative anomalies[28]. The amplitude of accommodation decreased significantly after four days of computer work[29].

Regarding vergence measurements, the results showed significant associations between the amount of exophoria at distance and near (*i.e.*, eyes tended to diverge) and total CVS-Q scores. As the CVS-Q score worsened (higher), the amount of exophoria increased, with the amount of exophoria near being greater than the distance. In addition, there was an indirect and significant association between positive fusional vergence at near and total CVS-Q score. This means that as CVS worsens, computer workers will have less ability to fuse two images, each from one eye, into a single image. A greater amount of exophoria near than distance combined with a reduction in positive fusional vergence at near is considered a typical clinical sign of convergence insufficiency (CI)[27]. These findings suggest that computer workers suffering from asthenopic symptoms are at a high risk of developing exophoria in distance vision and/or convergence insufficiency in near vision. This result is consistent with those of other studies[12,29]. Another study found a significant correlation between horizontal heterophoria and asthenopia symptoms in computer users[30]. Symptoms such as eyestrain, eye fatigue, and headache are commonly reported in patients with convergence insufficiency[31]. Another vergence system parameter that showed a possible association with the total CVS-Q score was the vergence facility test. The association between the two parameters approached significance but not.

Results of this and other studies cannot be used to generalize the concept that there is an association between CVS and clinical signs for different reasons for every single computer user. Factors other than the clinical signs may contribute to the development of CVS Factors such as screen size, screen position, room illumination, text-background contrast, text size, and viewing distance may contribute to CVS episodes[32]. The characteristics of the participants are important factors to be carefully considered. In the current study, most participants did not exhibit severe CVS, as indicated by their total CVS-Q scores. Among the 141 participants, only 23 reported severe symptoms (>15). Future research should concentrate on recruiting only patients with significant symptoms to explore the potential associations between various clinical signs and symptoms.

In conclusion, although the exact causes of CVS are not completely understood, our research indicates that computer users with severe symptoms may experience either accommodative insufficiency or convergence insufficiency. Accommodative insufficiency and convergence insufficiency are among the most prevalent binocular vision disorders that necessitate targeted care and management, such as the prescription of glasses and vision therapy. Additionally, our study proposes that the overall score of the CVS-Q is a dependable method for identifying individuals with normal and abnormal binocular vision issues, eliminating the need to examine each specific symptom outlined in the questionnaire. This finding could assist clinicians and researchers in saving time when interpreting the questionnaire results.

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