Original Article

Visual, ocular surface, and extraocular diagnostic criteria for determining the prevalence of computer vision syndrome: a cross-sectional smart-survey-based study

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ABSTRACT

Background: The American Optometric Association defines computer vision syndrome (CVS), also known as digital eye strain, as "a group of eye- and vision-related problems that result from prolonged computer, tablet, e-reader and cell phone use". We aimed to create a well-structured, valid, and reliable questionnaire to determine the prevalence of CVS, and to analyze the visual, ocular surface, and extraocular sequelae of CVS using a novel and smart self-assessment questionnaire.

Methods: This multicenter, observational, cross-sectional, descriptive, survey-based, online study included 6853 complete online responses of medical students from 15 universities. All participants responded to the updated, online, fourth version of the CVS questionnaire (CVS-F4), which has high validity and reliability. CVS was diagnosed according to five basic diagnostic criteria (5DC) derived from the CVS-F4. Respondents who fulfilled the 5DC were considered CVS cases. The 5DC were then converted into a novel five-question self-assessment questionnaire designated as the CVS-Smart.

Results: Of 10 000 invited medical students, 8006 responded to the CVS-F4 survey (80% response rate), while 6853 of the 8006 respondents provided complete online responses (85.6% completion rate). The overall CVS prevalence was 58.78% (n = 4028) among the study respondents; CVS prevalence was higher among women (65.87%) than among men (48.06%). Within the CVS group, the most common visual, ocular surface, and extraocular complaints were eye strain, dry eye, and neck/shoulder/back pain in 74.50% (n = 3001), 58.27% (n = 2347), and 80.52% (n = 3244) of CVS cases, respectively. Notably, 75.92% (3058/4028) of CVS cases were involved in the Mandated Computer System Use Program. Multivariate logistic regression analysis revealed that the two most statistically significant diagnostic criteria of the 5DC were ≥2 symptoms/attacks per month over the last 12 months (odds ratio [OR] = 204177.2; *P* <0.0001) and symptoms/attacks associated with screen use (OR = 16047.34; *P* <0.0001).

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The CVS-Smart demonstrated a Cronbach's alpha reliability coefficient of 0.860, Guttman split-half coefficient of 0.805, with perfect content and construct validity. A CVS-Smart score of 7–10 points indicated the presence of CVS.
Conclusions: The visual, ocular surface, and extraocular diagnostic criteria for CVS constituted the basic components of CVS-Smart. CVS-Smart is a novel, valid, reliable, subjective instrument for determining CVS diagnosis and prevalence and may provide a tool for rapid periodic assessment and prognostication. Individuals with positive CVS-Smart results should consider modifying their lifestyles and screen styles and seeking the help of ophthalmologists and/or optometrists. Higher institutional authorities should consider revising the Mandated Computer System Use Program to avoid the long-term consequences of CVS among university students. Further research must compare CVS-Smart with other available metrics for CVS, such as the CVS questionnaire, to determine its test-retest reliability and to justify its widespread use.

KEYWORDS
computer, eyestrain, visual fatigue, asthenopia, dry eye, point prevalence, smartphones, CVS-F4, CVS-Smart, CVS-Smart score, machine intelligence, computer vision system

INTRODUCTION

The American Optometric Association (AOA) defines computer vision syndrome (CVS), also known as digital eye strain, as "a group of eye- and vision-related problems that result from prolonged computer, tablet, e-reader and cell phone use" [1]. However, recent updates in the literature have included more specific CVS symptoms such as frequent blinking, increased sensitivity to light, sleep disturbances, and inattention [2-7]. Moreover, the Tear Film & Ocular Surface Society stated that the AOA definition of CVS is insufficient and redefined digital eye strain as "the development or exacerbation of recurrent ocular symptoms and/or signs related specifically to digital device screen viewing" [8].

The main obstacle to determining the actual prevalence of CVS in a certain population is the absence of a global consensus regarding the ideal CVS questionnaire [2, 9]. Certain studies [4-7] used validated and reliable questionnaires, while many others relied on unstructured, non-validated, and unreliable questionnaires, resulting in a wide range of reported prevalences of CVS [2, 9]. Recently, studies [2, 10] concluded that self-assessment questionnaires might be overestimating the true CVS prevalence and that the use of subjective questionnaires alone might not be ideal for this purpose [2, 9, 10].

In our previously published studies [2, 11-13], we used both subjective questionnaires and ophthalmic examinations to accurately determine CVS diagnosis and prevalence. However, the objective ophthalmic examination is a costly, time-consuming, and exhausting method that is unavailable to most researchers and populations [2, 11-13]. Therefore, we aimed to create a well-structured, valid, and reliable questionnaire to serve as a universal, subjective instrument for the definitive diagnosis of CVS. Our method could also be suitable for accurate determination of CVS prevalence in university students.

METHODS

This multicenter, observational, cross-sectional, descriptive, survey-based, online study gained the approval of the Medical Research Ethical Committee, Faculty of Medicine, Sohag University, Sohag, Egypt (ID: Soh-Med-21-12-31). Furthermore, this study obtained its clinical registry number from ClinicalTrials.gov (ID: NCT05187221) [14] and was conducted in 15 Egyptian universities in accordance with the tenets of the Declaration of Helsinki. All respondents provided written informed consent after explanations of the nature and potential consequences of CVS along with the importance of improving our knowledge of it.

According to Cochran's formula [15] for sample size calculation at a 95% confidence level, the minimum sample size required for this study was 385 participants for each questionnaire.

Validity and reliability [16-18] of the CVS questionnaires were assessed through five steps as follows.

1. Joint meeting of authors: The first step in designing this study was a joint meeting of 16 experts in ophthalmology and nine experts in optometry to evaluate the previously published CVS-F1 to -F3 questionnaires [2, 12, 13]; to discuss the limitations, feedback, and colleagues' recommendations; and to analyze any potential biases. In this meeting, the authors created a new modified version designated as the Computer Vision Syndrome–Form 4 (CVS-F4). This fourth version of the series limited the questionnaire responses to a binary Yes/No format [19] to render the questionnaire items more uniform and less subject to statistical bias. The questionnaire included three parts: the first part represented an introduction to improve the respondents' knowledge of CVS and its sequelae before beginning the questionnaire; second part gathered basic information pertaining to age, sex, university address, total daily screen hours, and total screen years based on the respondents' estimations; and third part included the 30 CVS-F4 questionnaire items with a Yes/No answer format.

CVS-F4 included four main groups of questions: ocular complaints, extraocular complaints, risk factors/practices, and other diagnostic criteria. The ocular complaints included eight main symptoms: blurred vision, dry eye, eye strain and fatigue, eye redness and irritation (foreign body sensation, itching, burning, and/or lacrimation), double vision, difficulty in refocusing the eyes, near vision discomfort/difficulty, and unclear objects post-screen use. The extraocular complaints included nine main symptoms: headache, neck/shoulder/back pain, joint pain in the fingers and wrists, inability to hold objects well, difficulty writing with a pen, sleep disturbances/insomnia, hunger and eating late-night/midnight snacks, depression, and suicidal ideation. The risk factors/practices included 11 main items: more than two screen hours daily, refractive errors, poor screen resolution or design, screen glare, screen edge at or above horizontal eye level, close eye-to-screen distance, poor lighting conditions, watching screens in the dark, uncomfortable sitting postures, small font size, and texting with both thumbs. The other diagnostic criteria included two main elements: two or more complaints/attacks monthly for the past 12 months, and a consistent relation of all complaints to the time of screen use. Therefore, CVS-F4 included 30 questionnaire items with a "Yes/No" answer format.

The authors agreed that CVS diagnosis according to the CVS-F4 questionnaire should be based on the five diagnostic criteria (5DC; Table 1) that were originally based on our four pre-tested and published major criteria for accurate CVS diagnosis [2, 11, 12, 20]. All respondents who fulfilled the 5DC were considered CVS cases.

The authors then agreed to further shorten the CVS-F4 into a concise, five-item questionnaire based on the 5DC, thus creating a novel questionnaire designated as the Computer Vision Syndrome–Smart questionnaire (CVS-Smart) for accurate determination of CVS diagnosis and prevalence using a CVS-Smart score. Finally, we formed a scientific committee of five experts to evaluate the validities of the CVS-F4 and -Smart questionnaires.

2. Expert committee meeting: We convened five experts in the fields of ophthalmology, optometry, public health, and community medicine to assess the content validity of the CVS-F4 and -Smart questionnaires. Before the meeting, each expert individually analyzed the content, structure, and Yes/No response format, and specified whether a question is essential for operating an instrument in a set of questionnaire items. This was followed by a face-to-face meeting to discuss the questionnaire items, questions' formulations, and response formats. Previously published articles pertaining to versions CVS-F1 to -F3 [2, 11-13], along with additional articles, reviews, and recent updates [4-8, 20-27], were provided for all experts as the basis of face-to-face discussions. After intensive inquiry and prolonged arguments, the experts reached a consensus that the CVS-F4 questionnaire is valid for university students and young adults; however, they did express some final recommendations to improve the validity and reliability of the CVS-Smart questionnaire. First, the CVS-Smart was the exclusion of risk factors (Table 2). Although risk factors are important in the CVS-F4 questionnaire, a certain risk factor could simply be linked to a specific CVS complaint in the statistical analysis. However, this link is unnecessary in the CVS-Smart, which aims mainly to accurately diagnose CVS and establish its prevalence. Second, separating the ocular complaints into visual and ocular surface categories and adding more symptoms to each division based on the literature updates (Table 2). For instant, the experts recommended adding new complaints to CVS-Smart, such as frequent blinking and increased sensitivity to light (Table 2), and removing other complaints, such as midnight hunger and suicidal ideation (Table 2).

Third, providing three answer choices (Table 2) for each of the five questions in the CVS-Smart questionnaire, rather than the Yes/No responses used in the CVS-F4 questionnaire. Each question is answered as 0, 1, or 2 points in the CVS-Smart; therefore, the total score for a respondent ranges from 0 to 10 points (Table 2). The authors and experts agreed that the diagnosis should be classified as CVS-positive (7–10 points), high probability of CVS (5–6 points), low probability of CVS (3–4 points), no CVS (1–2 points), and healthy individual (0 points) (Table 3). Moreover, they agreed that the final CVS prevalence should be calculated based on a CVS-Smart score of 7–10 points (i.e. the number of CVS-positive cases). The experts further recommended that the respondent should not be considered CVS-positive if the respondent has concurrent eye disease or a history of eye surgery. Such cases require ophthalmic examinations to confirm or exclude a CVS diagnosis, and this issue should be noted in the CVS-Smart score.

Table 1. Five subjective diagnostic criteria for accurate computer vision syndrome diagnosis

Criteria	5DC components
Criterion 1	Presence of one or more ocular complaints
Criterion 2	Presence of one or more extraocular complaints
Criterion 3	Presence of one or more risk factors/practices
Criterion 4	All complaints consistently related to time of screen use
Criterion 5	≥2 symptoms/attacks per month over the last 12 months

Abbreviations: 5DC, five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: A case was considered CVS case if the participant completed the 5DC and responded "Yes" to all 5DC questions.

All expert recommendations and modifications were carefully applied by the authors. The experts agreed that the CVS-Smart questionnaire and final score are ideal for university students and young adults. Tables 2 and 3 summarize the final version of the CVS-Smart questionnaire and scoring according to the experts' recommendations.

Table 2. Computer vision syndrome-Smart questionnaire

Five questions	Content	CVS diagnostic criteria	Score
1. Visual	**Nine visual complaints:** Blurred vision Eye strain/fatigue Double vision Difficulty in refocusing the eyes Near-vision discomfort/difficulty Unclear objects post-screen use Glare/seeing halos Vision diminution Increased sensitivity to light	**Question 1:** **Of these nine visual complaints, how many do you experience?**	
		No visual complaints	**0**
		One visual complaint	**1**
		Two or more visual complaints	**2**
2. Ocular surface	**Nine ocular surface complaints:** Dry eyes Eye redness Eye irritation/discomfort Foreign body sensation Burning/stinging sensation Itching/eye rubbing Watery eye Eyelids feel heavy Frequent blinking	**Question 2:** **Of these nine ocular surface complaints, how many do you experience?**	
		No ocular surface complaints	**0**
		One ocular surface complaint	**1**
		Two or more ocular surface complaints	**2**
3. Extraocular	**Nine extraocular complaints:** Headache Neck pain Shoulder pain Back pain Joint pain in the fingers and wrists Inability to hold objects well Difficulty writing with a pen Sleep disturbances/insomnia Inattention/depression	**Question 3:** **Of these nine extraocular complaints, how many do you experience?**	
		No extraocular complaints	**0**
		One extraocular complaint	**1**
		Two or more extraocular complaints	**2**
4. Frequency	Complaint frequency	**Question 4:** **How do you rate the frequency of your complaints?**	
		Rare	**0**
		Infrequent	**1**
		Frequent	**2**
5. Screen- associated	Complaints occurring during screen use	**Question 5:** **Do your complaints occur during screen use?**	
		Never	**0**
		Sometimes	**1**
		Always	**2**
Total score			**0–10 points**

Abbreviations: CVS, computer vision syndrome. Note: Total score calculated by the respondent; outcomes in the CVS-Smart score.

Table 3. Computer vision syndrome -Smart score*

CVS-Smart total score	CVS probability status	Recommendations
7–10 points	CVS-positive ** (Confirmed case of CVS)	-Consult your ophthalmologist or optometrist for appropriate treatment -Reduce your screen time -Follow instructions (see Table 4) -If you have a chronic eye disease or previous eye surgery, this diagnosis might be inaccurate **
5–6 points	High probability of CVS	-Consult your ophthalmologist or optometrist to confirm or exclude CVS diagnosis -If you are identified as having CVS, please seek the appropriate treatment -If you are identified as not having CVS, please repeat the CVS-Smart every 6 months -Reduce your screen time -Follow instructions (see Table 4)
3–4 points	Low probability of CVS	-Repeat the CVS-Smart every 6 months -Reduce your screen time -Follow instructions (see Table 4)
1–2 points	No CVS	-Repeat the CVS-Smart every 6 months -Follow instructions (see Table 4) to improve your score to 0 points
0 points	Healthy individual	-Follow prophylactic measures (see Table 4)

Abbreviations: CVS, computer vision syndrome. Note: *The experts agreed that the CVS-Smart questionnaire and final score are ideal for university students and young adults, especially those in the Mandated Computer System Use Program; * *The respondent should not be considered CVS-positive if respondent has concurrent eye disease or a history of eye surgery. Such cases require ophthalmic examinations to confirm or exclude a CVS diagnosis.

The experts reviewed and discussed the previously studied anti-CVS measures [12, 23] and ultimately recommended adding a specific section to improve eye-style and life-style (Table 4) [1, 2, 11-13, 20, 21]. They recommended that eye-style could be improved by wearing spectacles to correct refractive errors, limiting contact lens wearing, and treating concurrent eye conditions such as dry eye disease (Table 4). Life-style could be improved by increasing outdoor activities, losing weight, and allocating more time for sports (Table 4). The experts and authors agreed that the modified Iqbal's instructions (Table 4) are suitable for university students and young adults, especially those in the Mandated Computer System Use Program (MCSUP), and that issues should be noted in the CVS-Smart score recommendations (Table 3). Finally, the experts and authors stated that the instructions should be advised for management and prevention purposes. Table 4 summarizes these modified instructions according to the experts' recommendations.

3. CVS-F4 online survey and CVS-Smart questionnaire: Afterward, we invited 10 000 medical students in 15 Egyptian universities to complete the CVS-F4 online survey via the SurveyMonkey website [28]. Invitations and reminders were sent via emails, telephone calls, and text messages. The study data and Excel sheets were downloaded from SurveyMonkey [29] for statistical and logistic regression analysis. Only complete responses were included in the analysis. Of the 10 000 invited participants, 8006 responded (80% response rate); however, only 6853 of these 8006 respondents provided complete online responses (85.6% completion rate) and were included in the statistical analysis. Based on the 5DC, the final study respondents were allocated to one of two groups (CVS or no-CVS group). A case was considered CVS-positive if the participant completed the 5DC and responded "Yes" to all 5DC questions (Table 1).

Based on the recommendations of the expert committee, we also applied the CVS-Smart questionnaire in a sample of 461 medical students. The sample size was calculated using Cochran's formula [15] (minimum of 385 participants). The CVS prevalence in this student sample was 64.7% (298 CVS-positive cases out of 461 medical students). The CVS-Smart questionnaire and scores have been published online via SurveyMonkey [30].

4. Reliability and validity of CVS-F4 and -Smart questionnaires (Table 5)*:* The Statistical Package for the Social Sciences (IBM SPSS Statistics for Windows, version 28.0; IBM Corp., Armonk, NY, USA) [31] was used by an expert statistician to test the reliability and validity (Table 5) of the online CVS-F4 [28] and -Smart [30] questionnaires. Moreover, analysis of moment structures (AMOS version 7.0 for Windows; SPSS Inc., Chicago, IL, USA) [32] and SmartPLS (SmartPLS 4 for Windows; SmartPLS GmbH, Bonningstedt, Germany) [33] were used for confirmatory factor analysis (CFA) in both questionnaires. The reliability and validity indices and outcomes of the CVS-F4 and -Smart questionnaires are summarized in Table 5.

5. Sample size: Although our calculated sample size using Cochran's formula was 385 participants per questionnaire [15], we actually collected complete responses from 6853 participants for the online CVS-F4 questionnaire [28] and 461 participants for the CVS-Smart questionnaire [30]. We aimed to exceed the calculated sample size to better assess the reliability of both questionnaires; a larger sample size reduces sampling error and yields more accurate outcomes with better population representation [34].

Table 4. Modified Iqbal's instructions [2, 11-13, 20, 21] as anti-computer vision syndrome measures

Anti-CVS measures		
Screen-time instructions	**Screen-style instructions**	**Eye-style and life-style instructions**
-Minimize your screen time -One screen hour daily is ideal -Try not to exceed two screen hours daily -Focus your screen hours to accomplish your necessary assignments -Specify one place only, e.g., home or college, to accomplish your assignments	-Shift from hand-held to non-hand-held screens -Shift from small-sized to large-sized screens -Shift from old to new screen versions -Shift from screens to books for your studies -Print the necessary PDF or word files for your studies -Use speech recognition instead of typing	-Wear your spectacles while watching screens -Avoid/limit contact lens wearing -Treat eye diseases, such as dry eye, with necessary medication
-Desktop computer or laptop is preferred -Avoid using smartphone to complete your assignments -Daytime screen hours are preferred to nighttime screen hours	-Shift from other screens to TV screens to attend/watch necessary online courses, videos, meetings, lectures, and educational programs -Connect TV screens to internet and watch your desired movies, series, and applications -The proper distance for watching TV is 4–6 meters	-Avoid taking your smartphone to bed at night when you are going to sleep
-Avoid or limit video calls -Use regular audio calls -Try to limit smartphone to audio calls and use other screens for video calls -Uninstall the unnecessary applications in your smartphone and other devices -Minimize your social media time	-Avoid the following risk factors that aggravate your symptoms: Poor screen resolution or design Screen glare Screen surface at/above horizontal eye level Close eye-to-screen distance Poor lighting conditions Watching screens in the dark uncomfortable sitting postures Small font size Texting with both thumbs	-Allocate more time for sports -Try to lose weight if you are overweight -Try to improve your social life, family relationships, and gain more friends -Increase interest in non-screen hobbies, e.g., diving -Join community organizations, public services, or social groups, e.g., traveling groups
-Avoid continuous screen watching, take breaks, and apply the 20-20-20 rule	-Adjust screen brightness to the minimum possible -Try not to exceed 50% screen brightness -Use smartphone holder instead of your hands	-Adjust the indoor and outdoor light source to be above or behind your eyes

Abbreviations: CVS, computer vision syndrome.

Table 5. Reliability and validity outcomes of computer vision syndrome-F4 and -Smart questionnaires

Variables	**CVS-F4**	**CVS-Smart**
Number of questionnaire items	30	5
Responses	Binary response (Yes/No format) for each questionnaire item	3 responses/answers/choices for each questionnaire item
Reliability indices		
Kuder–Richardson 20 formula	0.81 (high reliability)	-
Cronbach's alpha coefficient	-	0.860 (high reliability)
Guttman split-half coefficient	-	0.805 (high reliability)
Interrater reliability*:		
-Significance at 0.01	-	Significant for all questionnaire items
-Correlation interpretation	-	Moderate-to-strong correlation for all questionnaire items (range: 0.51–0.69)
Validity indices		
I. Content validity (by five experts)		
-Content validity ratio	1 for each of 24 items and 0.6 for each of remaining 6 items	one per five questionnaire items
-Content validity index	0.92 (acceptable content validity)	1 (perfect content validity)
II. Face validity (by non-experts) Face validity was evaluated by some medical student participants	Good, clear, relevant, appropriate, and comprehensive, but lengthy with some items seeming less important	Strong, clear, relevant, appropriate, concise, simple, easy to understand, comprehensive, and all five items are of identical importance
III. Construct validity		
A. Confirmatory factor analysis		
-Comparative fit index	0.896 (good fit)	0.986 (good fit)
-Tucker–Lewis index	0.860 (good fit)	0.971 (good fit)
-Root mean square error of approximation	0.084 (mediocre fit)	0.078 (mediocre fit)
B. Spearman's rho correlation coefficient		
-Significance at 0.01	-	Significant for all questionnaire items
-Correlation interpretation	-	Strong correlation for all questionnaire items (range: 0.77–0.83)

Abbreviations: CVS-F4, computer vision syndrome form-4 questionnaire [28]; CVS-Smart, computer vision syndrome smart questionnaire [30].Note: *, Spearman's rho correlation coefficient.

Being an online questionnaire, it required no extra budgeting, time, or effort in recruiting the study participants [35]. The link to the online CVS-F4 questionnaire [28] was sent by all authors to their students in 15 universities; hence, many responses were collected. In the online format of the CVS-F4 questionnaire [28], the students responded at their convenience. However, the CVS-Smart questionnaire required manual collection of printed response forms from medical students, as the CVS-Smart was released online [30] but not yet launched for public use.

Statistical analysis: A score of 1 was given to the response "Yes" and 0 to the response "No." SPSS software [31] was used to test the reliability and validity of the CVS-F4 [28] and -Smart [30] questionnaires (Table 5). AMOS [32] and SmartPLS [33] were used for CFA in both questionnaires (Table 5). The online CVS-F4 [28] outcome data were analyzed using STATA statistical software (version 14.2; StataCorp LP, College Station, TX, USA) [36]. Quantitative data are presented as means and standard deviations (SDs). Qualitative data are presented as numbers and percentages. The chi-square and Mann–Whitney U tests were used when indicated. Binary logistic regression analyses, univariate and multivariate, were used to identify factors affecting different studied variables. In the logistic regression analyses, the reference level was a "No" response in the Yes/No format of the CVS-F4, having no *P*-value. Both clinically important variable and those that showed $P < 0.25$ in the univariate analysis, were included in the multivariate analysis. A *P*-value <0.05 was considered statistically significant.

RESULTS

This study included 6853 medical students (for developing and validating the CVS-F4 questionnaire and further application of CVS-F4 for descriptive statistical analysis) (Table 6) with a mean (SD) age of 23.75 (2.71) years, comprising 4125 women (60.2%) and 2728 men (39.8%). The mean (SD) total daily screen hours was 6.91 (3.21) h, whereas the mean (SD) total screen years was 5.66 (3.26) years.

CVS-F4 outcomes among all respondents, with or without CVS (Table 6): Regarding the screen style, the smartphone was the primary screen type in 87.17% (n = 5974) of the study respondents. The two most common ocular complaints were eye strain and dry eye in 60.8 (n = 4166) and 44.6% (n = 3058) of study respondents, respectively. Moreover, the two most common extraocular complaints were neck/shoulder/back pain and headache in 69.6 (n = 4768) and 63.2% (n = 4330) of study respondents, respectively (Table 6).

Sex-based outcomes: Approximately 60.2% of the study respondents were women. We compared the CVS-F4 outcomes of men to those of women. The mean (SD) total daily screen hours were similar in men and women (6.91 [3.13] and 6.91 [3.27] respectively; $P = 0.29$). However, men had significantly more screen years than women (6.08 [3.52] and 5.39 [3.06], respectively; $P < 0.0001$). Generally, women reported significantly more CVS complaints than men, particularly blurred vision, dry eye, eye strain, eye redness, headache, neck/shoulder/back pain, joint pain, inability to hold objects, and depression (all $P < 0.0001$). The overall mean (SD) number of CVS complaints was significantly more in women (7.12 [3.65]) than in men (6.0 [3.75]) ($P = 0.0001$).

CVS diagnosis: Based on the 5DC (Table 1), CVS was diagnosed in 4028 respondents (58.78%, CVS group) and the remaining 2825 respondents (41.22%) were designated the no-CVS group. Table 7 displays the calculation of the CVS prevalence based on the 5DC. CVS prevalence was higher among women (65.87%) than among men (48.06%). Within the CVS group, the most common visual, ocular surface, and extraocular complaints were eye strain, dry eye, and neck/shoulder/back pain in 74.50% (n = 3001), 58.27% (n = 2347), and 80.52% (n = 3244) of CVS cases, respectively. Notably, 75.92% (3058/4028) of CVS cases were involved in the Mandated Computer System Use Program. The comparison in Table 6 reveals that all eight ocular complaints, nine extraocular complaints, and the mean total number of symptoms differed significantly between the CVS and no-CVS groups (all $P < 0.0001$). Table 8 lists the data of the 4808 respondents (70.16%) who were involved in MCSUP. The CVS prevalence was significantly higher in respondents involved in the MCSUP (3058/4808, 63.6%) than in non-involved respondents (970/2045, 47.4%) ($P < 0.001$) (Table 8).

Logistic regression analysis: Table 8 displays results of the univariate logistic regression analysis of the CVS-F4 outcomes for the respondents involved in the MCSUP versus those non-involved. We analyzed the factors affecting CVS occurrence using univariate (Table 9) and multivariate (Table 10) logistic regression analysis of the CVS-F4 outcomes of the respondents, with versus without CVS, based on the 5DC. Both clinically important variables and those that showed $P < 0.25$ in the univariate analysis, were included in the multivariate analysis.

Table 11 summarizes the final regression analysis model for factors affecting CVS occurrence. Multivariate logistic regression analysis revealed that the two most statistically significant diagnostic criteria of the 5DC were ≥2 symptoms/attacks per month over the last 12 months (odds ratio [OR] = 204177.2; $P < 0.0001$) and symptoms/attacks associated with screen use (OR = 16047.34; $P < 0.0001$) (Table 11).

Table 6. Comparison between CVS group and no-CVS group regarding CVS complaints

CVS complaints	No-CVS group, n (%) 2825 (41.22)	CVS group, n (%) 4028 (58.78)	*P*-value
Ocular complaints, n (%)			
Blurred vision			
No	2225 (78.76)	2117 (52.56)	< **0.0001**
Yes	600 (21.24)	1911 (47.44)	
Dry eye			
No	2054 (72.71)	1681 (41.73)	< **0.0001**
Yes	771 (27.29)	2347 (58.27)	
Eye strain and fatigue			
No	1660 (58.76)	1027 (25.50)	< **0.0001**
Yes	1165 (41.24)	3001 (74.50)	
Eye redness and irritation			
No	2180 (77.17)	2069 (51.37)	< **0.0001**
Yes	645 (22.83)	1959 (48.63)	
Double vision			
No	2665 (94.34)	3463 (85.97)	< **0.0001**
Yes	160 (5.66)	565 (14.03)	
Difficulty in refocusing the eyes			
No	2240 (79.29)	2263 (56.18)	< **0.0001**
Yes	585 (20.71)	1765 (43.82)	
Near vision discomfort/difficulty			
No	2381 (84.28)	2675 (66.41)	< **0.0001**
Yes	444 (15.72)	1353 (33.59)	
Unclear objects post-screen use			
No	2238 (79.22)	2279 (56.58)	< **0.0001**
Yes	587 (20.78)	1749 (43.42)	
Extraocular complaints, n (%)			
Headache			
No	1512 (53.52)	1011 (25.10)	< **0.0001**
Yes	1313 (46.48)	3017 (74.90)	
Neck/shoulder/back pain			
No	1301 (46.05)	784 (19.46)	< **0.0001**
Yes	1524 (53.95)	3244 (80.54)	
Joint pain in the fingers and wrists			
No	2090 (73.98)	2197 (54.54)	< **0.0001**
Yes	735 (26.02)	1831 (45.46)	
Inability to hold objects well			
No	2496 (88.35)	2933 (72.82)	< **0.0001**
Yes	329 (11.65)	1095 (27.18)	
Difficulty writing with a pen			
No	2555 (90.44)	3113 (77.28)	< **0.0001**
Yes	270 (9.56)	915 (22.72)	
Sleep disturbances/insomnia			
No	1761 (62.34)	1648 (40.91)	< **0.0001**
Yes	1064 (37.66)	2380 (59.09)	
Hunger and eating late-night/midnight snacks			
No	1259 (44.57)	1232 (30.59)	< **0.0001**
Yes	1566 (55.43)	2796 (69.41)	
Depression			
No	1885 (66.73)	1708 (42.40)	< **0.0001**
Yes	940 (33.27)	2320 (57.60)	
Suicidal ideation			
No	2636 (93.31)	3327 (82.60)	< **0.0001**
Yes	189 (6.69)	701 (17.40)	
Number of symptoms			
Mean ± SD	4.56 ± 3.12	8.18 ± 3.38	**0.0001**
Median (range)	4 (0 to 17)	8 (0 to 17)	

Abbreviations: CVS, computer vision syndrome. Note: P-values < 0.05 are shown in bold; The chi-square test or Mann–Whitney U test was used for statistical analysis.

Table 7. Calculating CVS prevalence based on the 5DC (Table 1)

Criteria	5DC components	Online responses by 6853 medical students, n (%)	
		Yes	No (Zero count)
Criterion 1	Presence of one or more ocular complaints	5946 (86.76)	907 (13.24)
Criterion 2	Presence of one or more extraocular complaints	6538 (95.40)	315 (4.60)
Criterion 3	Presence of one or more risk factors/practices	6327 (92.32)	526 (7.68)
Criterion 4	All complaints consistently related to time of screen use	5155 (75.22)	1698 (24.78)
Criterion 5	≥2 symptoms/attacks per month over the last 12 months	4533 (66.15)	2320 (33.85)
Prevalence	**CVS case**	**4028 (58.78)**	2825 (41.22)

Abbreviations: CVS, Computer vision syndrome; 5DC (Table 1), five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: CVS case; A case was considered CVS case if the participant completed the 5DC and responded "Yes" to all 5DC questions.

DISCUSSION

The primary aim of this study was to create a new subjective CVS questionnaire that can replace the four major diagnostic criteria proposed in our previous studies [2, 11-13, 20, 21, 37], aid respondents and researchers to subjectively diagnose CVS, and decrease the need for objective ophthalmic examinations in CVS diagnosis. We created CVS-Smart [30] and its scoring based on experts recommendations and 5DC, derived from CVS-F4 [28]. CVS-Smart [30] includes only five questionnaire items, the score varies from 0–10 points, and the respondent is considered CVS-positive if the total score is 7–10 points. CVS-Smart [30] subjectively differentiates between positive, high probability, low probability, and no-CVS cases. This indicates that CVS-Smart [30] is an excellent subjective, free, online, 1-min self-assessment questionnaire that accurately diagnoses CVS and determines CVS prevalence.

The focus of our modified instructions was to provide simple, alternative options for users of electronic devices and cell phones to reduce their screen time and modify their screen- and life-styles. These instructions were based on the scientific, clinical, and personal experiences of the authors, their expertise in this field [2, 11-13, 20, 21], recommendations of the expert committee, along with additional articles, reviews, and recent updates [1, 4-8, 20-27]. Reduction of screen time improves screen-induced foveal dysfunction, the associated visual outcomes, and subsequently, the subjective CVS complaints [11, 13, 20, 21].

Few questionnaires in the literature are as reliable and valid as Computer-Vision Symptom Scale (CVSS17) reported by Gonzalez-Perez et al. [5] and computer vision syndrome questionnaire (CVS-Q) reported by Segui Mdel et al. [6] in the years 2014 and 2015, respectively. The CVSS17 questionnaire includes 17 items pertaining to 15 CVS symptoms [5], whereas the CVS-Q includes 16 items regarding the frequency and intensity of 16 CVS symptoms [6]. CVS-Q [6] and CVSS17 [5] were both originally Spanish questionnaires developed using Rasch analysis [5, 6, 16] and expert recommendations [5, 6]; however, we believe that CVS-Q [6] is more easily interpreted than CVSS17 [5]. Although no previous studies have compared CVS-Smart, CVS-Q, and CVSS17, we believe that CVS-Smart [30] is more focused and less time consuming than CVSS17 [5] and CVS-Q [6], with much simpler interpretation, as no equations or calculations are required in CVS-Smart [30].

CVSS17 includes 15 questionnaire items comprising seven visual and eight ocular surface symptoms [5]; however, it omits extraocular symptoms. CVS-Q includes 16 questionnaire items comprising seven visual symptoms, eight ocular surface symptoms, and only one extraocular symptom [6]. In contrast, CVS-Smart [30] includes 27 questionnaire items in three distinct symptom categories: nine visual symptoms, nine ocular surface symptoms, and nine extraocular symptoms [30]. CVS-Smart includes a higher number of questionnaire symptoms [30] than both CVS-Q [6] and CVSS17 [5], with equal focus on the three symptom categories, allowing better interpretation and reducing the probability of missing a CVS case. CVS-Q [6] focuses on symptom frequency as part of CVS diagnosis, unlike CVSS17 [5], which has minimal focus on symptom frequency. However, CVSS17 [5] has good focus on the timing of symptom occurrence and its relation to screen use period, unlike CVS-Q [6], which has no focus on symptoms timing. CVS-Smart [30] has a unique focus on the frequency and timing of symptoms that occur during screen use [30]. Further comparative large-scale studies could provide evidence-based guidance on the advantages and disadvantages of these three CVS questionnaires.

Tesfaye et al. [23] reported a 78.8% CVS prevalence among 500 academic staff members, which is far higher than our observed prevalence of 58.78% among 6853 medical students. Wangsan et al. [24] also reported a higher 80% CVS prevalence among 527 students participating in online courses. Shah and Saboor [25] reported that 101 of 127 (79.5%) adult bank workers complained of CVS symptoms, whereas Boadi-Kusi et al. [26] reported a 71.2% CVS prevalence among 139 bank workers. Alhasan and Aalam [27] used CVS-Q to investigate CVS prevalence among 416 radiologists, revealing a 65.4% prevalence, which is similar to our observed 58.78% prevalence.

Table 8. Comparing between participants involved and non-involved in the Mandated Computer System Use Program

Variable	Non-involved, n (%) 2045 (29.84)	Involved, n (%) 4808 (70.16)	OR (95% CI)	*P*-Value
Sex, n (%)				
Men	1022 (49.98)	1706 (35.48)		
Women	1023 (50.02)	3102 (64.52)	1.82 (1.63–2.02)	< **0.0001**
Screen time, Mean ± SD				
Total daily screen hours	6.56 ± 3.25	7.06 ± 3.18		< **0.0001**
Screen years	5.94 ± 3.51	5.55 ± 3.16		< **0.0001**
Screen style, n (%)				
>2 screen hours/day	1811 (88.56)	4454 (92.64)	1.62 (1.37–1.93)	< **0.0001**
≥3 screen years	1623 (79.36)	4010 (83.40)	1.30 (1.15–1.49)	< **0.0001**
Night screen hours	1249 (61.08)	3089 (64.25)	1.15 (1.03–1.27)	**0.01**
Continuous screen hours	949 (46.41)	2433 (50.60)	1.18 (1.07–1.31)	**0.001**
Multiple screens	1133 (55.40)	3216 (66.89)	1.63 (1.46–1.81)	< **0.0001**
Small-sized screens	1323 (64.69)	3197 (66.49)	1.08 (0.97–1.21)	0.15
>50% screen brightness	853 (41.71)	1965 (40.87)	0.96 (0.87–1.07)	0.52
Screen type, n (%)				
Smartphone	1775 (86.80)	4199 (87.33)	1.05 (0.90–1.22)	0.54
Laptop	133 (6.50)	401 (8.34)	1.31 (1.07–1.60)	**0.01**
Pad/tablet	58 (2.84)	99 (2.06)	0.72 (0.52–1.00)	0.05
Desktop computer	92 (4.50)	165 (3.43)	0.75 (0.58–0.98)	**0.03**
Ocular complaints, n (%)				
Blurred vision	707 (34.57)	1804 (37.52)	1.13 (1.01–1.27)	**0.02**
Dry eye	783 (38.29)	2335 (48.56)	1.52 (1.37–1.69)	< **0.0001**
Eye strain and fatigue	1142 (55.84)	3024 (62.90)	1.34 (1.21–1.49)	< **0.0001**
Eye redness and irritation	676 (33.06)	1928 (40.10)	1.36 (1.22–1.51)	< **0.0001**
Double vision	210 (10.27)	515 (10.71)	1.05 (0.88–1.24)	0.59
Difficulty in refocusing the eyes	639 (31.25)	1711 (35.59)	1.22 (1.09–1.36)	**0.001**
Near vision discomfort/difficulty	517 (25.28)	1280 (26.62)	1.07 (0.95–1.21)	0.25
Unclear objects post-screen use	657 (32.13)	1679 (34.92)	1.13 (1.02–1.27)	**0.03**
Extraocular complaints, n (%)				
Headache	1146 (56.04)	3184 (66.22)	1.53 (1.38–1.71)	< **0.0001**
Neck/shoulder/back pain	1292 (63.18)	3476 (72.30)	1.52 (1.36–1.70)	< **0.0001**
Joint pain in the fingers and wrists	713 (34.87)	1853 (38.54)	1.17 (1.05–1.30)	**0.004**
Inability to hold objects well	412 (20.15)	1012 (21.05)	1.05 (0.93–1.20)	0.40
Difficulty writing with a pen	299 (14.62)	886 (18.43)	1.32 (1.14–1.52)	< **0.0001**
Sleep disturbances/ insomnia	989 (48.36)	2455 (51.06)	1.11 (1.00–1.24)	**0.04**
Hunger and eating late-night/midnight snacks	1235 (60.39)	3127 (65.04)	1.22 (1.10–1.36)	< **0.0001**
Depression	902 (44.11)	2358 (49.04)	1.22 (1.10–1.35)	< **0.0001**
Suicidal ideation	212 (10.37)	678 (14.10)	1.42 (1.21–1.67)	< **0.0001**
Symptoms/attacks, n (%)				
≥2 symptoms/attacks per month over the last 12	1162 (56.82)	3371 (70.11)	1.78 (1.60–1.98)	< **0.0001**
months Symptoms/attacks occurring for at least 2	1076 (52.62)	3097 (64.41)	1.63 (1.47–1.81)	< **0.0001**
years	1359 (66.45)	3796 (78.95)	1.89 (1.69–2.12)	< **0.0001**
Symptoms/attacks associated with screen use				
Medical studies, n (%)				
Screens as a main study source	1183 (57.85)	3690 (76.75)	2.40 (2.15–2.69)	< **0.0001**
Medicine/science consuming most of screen time	1034 (50.56)	3395 (70.61)	2.35 (2.11–2.61)	< **0.0001**
Previous dry eye disease, n (%)	623 (30.46)	1797 (37.38)	1.36 (1.21–1.52)	< **0.0001**
Refractive error, n (%)	964 (47.14)	2609 (54.26)	1.33 (1.20–1.48)	< **0.0001**
Contact lens wearing, n (%)	183 (8.95)	563 (11.71)	1.34 (1.13–1.61)	**0.001**
Poor screen resolution or design, n (%)	406 (19.85)	1106 (23.00)	1.21 (1.06–1.37)	**0.004**
Screen glare, n (%)	369 (18.04)	989 (20.57)	1.18 (1.03–1.34)	**0.02**
Screen edge at/above horizontal eye level, n (%)	493 (24.11)	1572 (32.70)	1.52 (1.36–1.72)	< **0.0001**
Close eye-to-screen distance, n (%)	807 (39.46)	2328 (48.42)	1.44 (1.30–1.60)	< **0.0001**
Poor lighting conditions, n (%)	806 (39.41)	2084 (43.34)	1.18 (1.06–1.31)	**0.003**
Watching screen in the dark, n (%)	1253 (61.27)	3022 (62.85)	1.07 (0.96–1.19)	0.22
Uncomfortable sitting postures, n (%)	1122 (54.87)	2895 (60.21)	1.24 (1.12–1.38)	< **0.0001**
Small font size, n (%)	694 (33.94)	1866 (38.81)	1.23 (1.11–1.38)	< **0.0001**
Texting with both thumbs, n (%)	952 (46.55)	2559 (53.22)	1.31 (1.18–1.45)	< **0.0001**
Number of symptoms				
Mean ± SD	6.13 ± 3.69	6.93 ± 3.71		**0.0001**
Median (range)	6 (0 to 17)	6 (0 to 17)		
CVS diagnosis based on 5DC, n (%)	970 (47.43)	3058 (63.60)	1.62 (1.47–1.78)	< **0.0001**

Abbreviations: OR, odds ratio; CI, confidence interval; CVS, computer vision syndrome; 5DC (Table 1), five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: *P*-values < 0.05 are shown in bold; Non-involved, participants not involved in the Mandated Computer System Use Program; Involved: participants involved in the Mandated Computer System Use Program.

Table 9. Univariate logistic regression analysis of factors affecting CVS occurrence (based on 5DC) (Table 1)

Variable	No-CVS group, n (%) 2825 (41.22)	CVS group, n (%) 4028 (58.78)	OR (95% CI)	*P*-value
Sex, n (%)				
Men	1417 (50.16)	1311 (32.55)	1	
Women	1408 (49.84)	2717 (67.45)	2.09 (1.89–2.30)	< **0.0001**
Screen time, Mean ± SD				
Total daily screen hours	6.61 ± 3.16	7.12 ± 3.23	1.05 (1.03–1.07)	< **0.0001**
Screen years	5.72 ± 3.42	5.63 ± 3.16	0.99 (0.98–1.01)	0.24
Screen style, n (%)				
>2 screen hours/day	2487 (88.04)	3778 (93.79)	2.05 (1.73–2.44)	< **0.0001**
≥3 screen years	2163 (76.57)	3470 (86.15)	1.90 (1.98–2.16)	< **0.0001**
Night screen hours	1638 (57.98)	2700 (67.03)	1.47 (1.33–1.63)	< **0.0001**
Continuous screen hours	1205 (42.65)	2177 (54.05)	1.58 (1.44–1.74)	< **0.0001**
Multiple screens	1656 (58.62)	2693 (66.86)	1.42 (1.29–1.57)	< **0.0001**
Small-sized screens	1786 (63.22)	2734 (67.87)	1.23 (1.11–1.36)	< **0.0001**
>50% screen brightness	1090 (38.58)	1728 (42.90)	1.20 (1.08–1.32)	< **0.0001**
Screen type, n (%)				
Smartphone	2474 (87.58)	3500 (86.89)	0.94 (0.81–1.09)	0.41
Laptop	180 (6.37)	354 (8.79)	1.42 (1.18–1.71)	< **0.0001**
Pad/tablet	62 (2.19)	95 (2.36)	1.08 (0.78–1.49)	0.66
Desktop computer	131 (4.64)	126 (3.13)	0.66 (0.52–0.85)	**0.001**
Ocular complaints, n (%)				
Blurred vision	600 (21.24)	1911 (47.44)	3.45 (3.00–3.73)	< **0.0001**
Dry eye	711 (25.17)	2347 (58.27)	3.72 (3.35–4.12)	< **0.0001**
Eye strain and fatigue	1165 (41.24)	3001 (74.50)	4.16 (3.76–4.62)	< **0.0001**
Eye redness and irritation	645 (22.83)	1959 (48.63)	3.20 (2.87–3.56)	< **0.0001**
Double vision	160 (5.66)	565 (14.03)	2.72 (2.26–3.26)	< **0.0001**
Difficulty in refocusing the eyes	585 (20.71)	1765 (43.82)	2.99 (2.67–3.33)	< **0.0001**
Near vision discomfort/difficulty	444 (15.72)	1353 (33.59)	2.71 (2.40–3.06)	< **0.0001**
Unclear objects post-screen use	587 (20.78)	1749 (43.42)	2.93 (2.62–3.27)	< **0.0001**
Extraocular complaints, n (%)				
Headache	1313 (46.48)	3017 (74.90)	3.44 (3.10–3.81)	< **0.0001**
Neck/shoulder/back pain	1524 (53.95)	3244 (80.54)	3.53 (3.17–3.93)	< **0.0001**
Joint pain in the fingers and wrists	735 (26.02)	1831 (45.46)	2.37 (2.13–2.63)	< **0.0001**
Inability to hold objects well	329 (11.65)	1095 (27.18)	2.83 (2.48–3.24)	< **0.0001**
Difficulty writing with a pen	270 (9.56)	915 (22.72)	2.78 (2.40–3.21)	< **0.0001**
Sleep disturbances/ insomnia	1064 (37.66)	2380 (59.09)	2.39 (2.17–2.64)	< **0.0001**
Hunger and eating late-night/midnight snacks	1566 (55.43)	2796 (69.41)	1.82 (1.65–2.02)	< **0.0001**
Depression	940 (33.27)	2320 (57.60)	2.72 (2.46–3.01)	< **0.0001**
Suicidal ideation	189 (6.69)	701 (17.40)	2.93 (2.48–3.47)	< **0.0001**
Symptoms-attacks, n (%)				
≥2 symptoms/attacks per month over the last 12	510 (18.05)	4023 (99.88)	3652 (1511–8825)	< **0.0001**
months	1027 (36.35)	3176 (78.85)	6.24 (5.61–6.95)	< **0.0001**
Symptoms/attacks occurring for at least 2 years	1130 (40.00)	4025 (99.93)	2012 (647.18–6257)	< **0.0001**
Symptoms/attacks associated with screen use				
Medical studies, n (%)				
Mandated Computer System Use Program	1750 (61.95)	3058 (75.92)	1.94 (1.74–2.15)	< **0.0001**
Screens as a main study source	1873 (66.30)	3000 (74.48)	1.48 (1.33–1.65)	< **0.0001**
Medicine/science consuming most of screen time	1719 (60.85)	2710 (67.28)	1.32 (1.20–1.46)	< **0.0001**
Previous dry eye disease, n (%)	661 (23.40)	1759 (43.67)	2.53 (2.28–2.82)	< **0.0001**
Refractive error, n (%)	1208 (42.76)	2365 (58.71)	1.90 (1.72–2.10)	< **0.0001**
Contact lens wearing, n (%)	223 (7.89)	523 (12.98)	1.74 (1.48–2.05)	< **0.0001**
Poor screen resolution or design, n (%)	462 (16.35)	1050 (26.07)	1.80 (1.60–2.04)	< **0.0001**
Screen glare, n (%)	385 (13.63)	973 (24.16)	2.02 (1.77–2.30)	< **0.0001**
Screen edge at/above horizontal eye level, n (%)	603 (21.35)	1462 (36.30)	2.10 (1.88–2.34)	< **0.0001**
Close eye-to-screen distance, n (%)	882 (31.22)	2253 (55.93)	2.80 (2.53–3.09)	< **0.0001**
Poor lighting conditions, n (%)	909 (32.18)	1981 (49.18)	2.04 (1.85–2.25)	< **0.0001**
Watching screen in the dark, n (%)	1579 (55.89)	2696 (66.93)	1.60 (1.45–1.76)	< **0.0001**
Uncomfortable sitting postures, n (%)	1305 (46.19)	2712 (67.33)	2.40 (2.17–2.65)	< **0.0001**
Small font size, n (%)	821 (29.06)	1739 (43.17)	1.85 (1.67–2.05)	< **0.0001**
Texting with both thumbs, n (%)	1249 (44.21)	2262 (56.16)	1.62 (1.46–1.78)	< **0.0001**

Abbreviations: OR, odds ratio; CI, confidence interval; CVS, computer vision syndrome; 5DC (Table 1), five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: *P*-values < 0.05 are shown in bold.

Table 10. Multivariate logistic regression analysis of factors affecting CVS occurrence (based on 5DC) (Table 1)

Variable	OR (95% CI)	*P*-value
Women	1.15 (0.82–1.60)	0.42
Screen time		
Total daily screen hours	0.94 (0.89–0.99)	**0.01**
Screen style		
>2 screen hours/day	1.18 (0.66–2.09)	0.57
≥3 screen years	0.84 (0.54–1.32)	0.44
Night screen hours	0.89 (0.61–1.29)	0.54
Continuous screen hours	1.14 (0.82–1.60)	0.43
Multiple screens	0.92 (0.66–1.28)	0.63
Small-sized screens	1.00 (0.72–1.40)	0.99
>50% screen brightness	1.22 (0.88–1.69)	0.22
Screen type		
Laptop	1.31 (0.72–2.38)	0.37
Desktop computer	0.77 (0.35–1.70)	0.53
Ocular complaints		
Blurred vision	4.07 (2.59–6.38)	< **0.0001**
Dry eye	6.01 (3.97–9.11)	< **0.0001**
Eye strain and fatigue	8.75 (6.07–12.61)	< **0.0001**
Eye redness and irritation	3.39 (2.29–5.01)	< **0.0001**
Double vision	0.55 (0.28–1.09)	0.09
Difficulty in refocusing the eyes	2.89 (1.77–4.31)	< **0.0001**
Near vision discomfort/difficulty	2.06 (1.21–3.52)	< **0.0001**
Unclear objects post-screen use	4.03 (2.44–6.64)	< **0.0001**
Extraocular complaints		
Headache	1.35 (0.97–1.87)	**0.04**
Neck/shoulder/back pain	1.64 (1.16–2.32)	**0.005**
Joint pain in the fingers and wrists	0.78 (0.55–1.10)	0.16
Inability to hold objects well	0.67 (0.43–1.06)	0.09
Difficulty writing with a pen	1.49 (0.90–2.46)	0.12
Sleep disturbances/ insomnia	1.04 (0.74–1.47)	0.82
Hunger and eating late-night/midnight snacks	1.12 (0.77–1.63)	0.54
Depression	0.91 (0.63–1.30)	0.60
Suicidal ideation	0.49 (0.30–0.82)	**0.006**
Symptoms/attacks		
≥2 symptoms/attacks per month over the last 12 months	357756.7 (90928.08–1407358)	< **0.0001**
Symptoms/attacks occurring for at least 2 years	1.25 (0.89–1.76)	0.20
Symptoms/attacks associated with screen use	24798 (5333.29–115309)	< **0.0001**
Medical studies		
Mandated Computer System Use Program	1.64 (1.16–2.32)	**0.005**
Screens as a main study source	1.46 (1.02–2.08)	**0.04**
Medicine/science consuming most of screen time	1.03 (0.72–1.47)	0.89
Previous dry eye disease	0.76 (0.52–1.12)	0.17
Refractive error	1.93 (1.39–2.68)	< **0.0001**
Contact lens wearing	0.97 (0.52–1.81)	0.93
Poor screen resolution or design	1.58 (0.99–2.52)	**0.04**
Screen glare	0.85 (0.52–1.40)	0.53
Screen edge at/above horizontal eye level	1.19 (0.80–1.78)	0.39
Close eye-to-screen distance	1.79 (1.26–2.52)	**0.001**
Poor lighting conditions	1.62 (1.13–2.34)	**0.009**
Watching screen in the dark	1.72 (1.21–2.45)	**0.003**
Uncomfortable sitting postures	1.79 (1.28–2.50)	**0.001**
Small font size	1.33 (0.91–1.93)	0.14
Texting with both thumbs	1.64 (1.19–2.25)	**0.002**

Abbreviations: OR, odds ratio; CI, confidence interval; CVS, computer vision syndrome; 5DC (Table 1), five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: *P*-values < 0.05 are shown in bold.

Table 11. Final logistic regression analysis model for factors affecting CVS occurrence (based on the 5DC) (Table 1)

Variable	OR (95% CI)	*P*-value
Screen time		
Total daily screen hours	0.94 (0.90–0.99)	**0.01**
Ocular complaints		
Blurred vision	3.85 (2.52–5.86)	**< 0.0001**
Dry eye	5.47 (3.85–7.77)	**< 0.0001**
Eye strain and fatigue	8.64 (6.17–12.09)	**< 0.0001**
Eye redness and irritation	3.20 (2.22–4.60)	**< 0.0001**
Difficulty in refocusing the eyes	2.63 (1.66–4.18)	**< 0.0001**
Near vision discomfort/difficulty	1.99 (1.21–3.28)	**0.007**
Unclear objects post-screen use	3.67 (2.31–5.82)	**< 0.0001**
Extraocular complaints		
Headache	1.44 (0.99–1.95)	**0.04**
Neck/shoulder/back pain	1.63 (1.20–2.24)	**0.002**
Suicidal ideation	0.53 (0.34–0.82)	**0.004**
Symptoms/attacks		
≥2 symptoms/attacks per month over the last 12 months	204177.2 (56190.44–741911.1)	**< 0.0001**
Symptoms/attacks associated with screen use	16047.34 (3595.44–71623.26)	**< 0.0001**
Medical studies		
Mandated Computer System Use Program	1.55 (1.14–2.14)	**0.006**
Screens as a main study source	1.45 (1.06–2.00)	**0.02**
Refractive error	1.83 (1.36–2.47)	**< 0.0001**
Poor screen resolution or design	1.61 (1.02–2.63)	**0.04**
Close eye-to-screen distance	1.80 (1.32–2.6)	**< 0.0001**
Poor lighting conditions	1.58 (1.13–2.22)	**0.007**
Watching screen in the dark	1.58 (1.15–2.19)	**0.005**
Uncomfortable sitting postures	1.64 (1.20–2.24)	**0.002**
Texting with both thumbs	1.60 (1.19–2.15)	**0.002**

Abbreviations: OR, odds ratio; CI, confidence interval; CVS, computer vision syndrome; 5DC (Table 1), five subjective diagnostic criteria for accurate computer vision syndrome diagnosis. Note: Both clinically important variable and those that showed *P* <0.25 in the univariate analysis, were included in the multivariate analysis; *P*-values < 0.05 are shown in bold.

We developed a new, subjective, reliable, and valid CVS questionnaire designated as CVS-Smart, using the elements of the novel, structured, reliable, and valid CVS-F4 questionnaire, after a consensus among experts. A study limitation would be the lack of clinical examinations, which might further reveal the value of these questionnaires in accurate CVS diagnosis. Further high-quality studies could confirm the diagnostic accuracy of these questionnaires in comparison with other common diagnostic approaches for CVS. Regarding training in preventive measures for CVS, a convolutional neural network was used to detect eye blinks and monitor blink rates using a long short-term memory network [38]. Using the significant variables collected in our validated questionnaire, further studies could use artificial intelligence capabilities to develop appropriate, reliable, intelligent, mobile applications [39] for screening, diagnosing, and promptly managing CVS, an increasingly common problem.

CONCLUSIONS

CVS-Smart is a novel, reliable, and valid questionnaire derived from the components of the novel, structured, reliable, and valid CVS-F4 questionnaire and a consensus among a committee of experts. The main advantages of CVS-Smart are its simple and precise calculation of CVS prevalence and its ability to differentiate between CVS-positive, high probability, low probability, and no-CVS cases. Our findings must be verified by future studies using this questionnaire in different populations, age groups, and occupations working with electronic devices. We recommend CVS-Smart for CVS screening and diagnosis as well as determination of CVS prevalence among certain populations, whereas CVS-F4 is better used for analysis of relationships and correlations between CVS complaints, risk factors/practices, and routine screen styles. In a future study, we aim to compare the CVS-Smart and -Q questionnaires.

ETHICAL DECLARATIONS

Ethical approval: This study gained the approval of the Medical Research Ethical Committee, Faculty of Medicine, Sohag University, Sohag, Egypt (ID: Soh-Med-21-12-31). Furthermore, this study obtained its clinical registry number from ClinicalTrials.gov (ID: NCT05187221) [14] and was conducted in accordance with the tenets of the Declaration of Helsinki. All respondents provided written informed consent after explanations of the nature and potential consequences of CVS along with the importance of improving our knowledge of it.

Conflict of interest: None.

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