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Title: Prevalence of computer vision syndrome and its risk factors in a Spanish university population.

Running short title: Computer vision syndrome in a university.

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Abstract

Objectives: To determine the prevalence of digital eye strain or computer vision syndrome (CVS) and its risk factors in a university population (University of Valladolid, Spain).

Methods: An anonymous cross-sectional online survey was conducted in a university population [staff (lecturers and administrative employees) and students (undergraduate, master's and PhD)], including two validated questionnaires (OSDI and CVSS17) and questions about sociodemographic data and VDT use. The prevalence and risk factors for CVS (CVSS17≥29) (multivariate logistic regression model) were calculated.

Results: 1009 participants responded to the survey (35.2±15.2 years; 64.1% women). The mean OSDI and CVSS17 questionnaire scores were 18.9±15.6 and 31.5±6.4, respectively, and 35.4% of the respondents had dry eye symptoms (OSDI>22). The total prevalence of CVS was 65.4% (95%CI 62.1-68.3%). Undergraduate students showed the highest CVS prevalence (72.6%; P<0.01), which was significant. Additionally, women, participants younger than 36 years old, CL wearers and subjects with dry eye symptoms reported a statistically higher CVSS17 score (P≤0.01). In the multivariate model, significant factors associated with the presence of CVS (P≤0.03) were female sex (OR=2.10; 95%CI 1.54-2.88), dry eye symptoms (OSDI >22) (OR=16.98; 95%CI 10.36-27.84), VTD use ≥6 hours daily (OR=1.96; 95%CI 1.09-3.52) and being an undergraduate student (OR=2.23; 95%CI 1.54-3.24).

Conclusion: A high prevalence (65.4%) of CVS was found among the Spanish university population, with the undergraduate student group having the highest prevalence (72.6%). Female gender, more than 6 hours/day of VDT use, being an undergraduate student and dry eye symptoms significantly increased the risk of CVS in the university population.

Key words: Computer vision syndrome; university population; dry eye; prevalence.

In recent decades, new forms of digital displays have been developed and become widespread throughout the world, making them indispensable in every personal, professional, or academic activity. The use of visual display terminals (VDTs), such as computers, laptops, smartphones, tablets, or e-readers, increases the visual demands on the user and can lead to several ocular symptoms related to digital displays that can adversely affect both quality of life[1] and productivity.[2]

This group of eye- and vision-related problems associated with prolonged use of VDTs is described as digital eye strain or computer visual syndrome (CVS) by the American Optometric Association.[3] CVS involves asthenopic symptoms (eye strain, tired eyes or headache), ocular surface symptoms (eye dryness, ocular redness, and itching or tearing, among others), visual disturbances (double vision or blurred vision), and extraocular discomfort (head, neck or back pain).[3–5] It is estimated that CVS could affect 80% of adults who use digital devices for at least 2 hours daily.[3] This condition could have a global prevalence of 60 million people worldwide with an incidence of one million new cases each year.[4] In eye care practice, a diagnosis of CVS mainly depends on subjective patient answers to different validated questionnaires, one of which is the 17-item Computer-Vision Symptom Scale questionnaire (CVSS17).[6,7]

It is well known that VDT users exhibit decreased blinking frequency and amplitude, leading to an increase in ocular surface exposure, tear evaporation and alteration of meibomian gland secretion,[8,9] which contribute to the development of dry eye symptomatology,[9] and close to 50% of VDT users suffer from dry eye disease (DED).[10] It has also been reported that contact lens (CL) wear may increase or exacerbate the presence of CVS symptoms.[11] In addition, a greater effort is required from the

accommodative system because of the greater number of working hours with the VDT placed at a close distance and a higher angle of visualization, which can cause fatigue symptoms, especially in cases of uncorrected refractive error or previous accommodation anomalies.[8]

It is estimated that from 2000 to the present, the number of internet users has increased by 1,392%, which means that 67.9% of the world's population is a user of some digital device.[12] Given the worldwide rise in the use of technology, VDT use has created an unprecedented revolution in learning or teaching strategies in higher educational institutions, especially after the COVID-19 pandemic.[13] For this reason, the detection and prevention of CVS in this population to guarantee the visual health of the academic population is crucial and challenging. Eye care practitioners should be aware of the potential impact of VDT use on CVS and its related factors to respond with the most effective preventive strategies.[6,7]

Therefore, the aim of this study was to determine the prevalence of CVS and its risk factors among students and staff at the University of Valladolid (Spain) to provide evidence-based epidemiology data to help eye care providers improve visual health in university population.

Methods

Population and design of the study

An anonymous cross-sectional online survey was emailed to the total population (approximately 25700 people) of the University of Valladolid (Spain), including students (undergraduate, master's, and PhD degrees) and staff (lecturers and administrative

employees), during the 2022/2023 academic year. The online questionnaire was designed using Microsoft Forms and hosted on a secure network server of the University of Valladolid to determine the symptomatology related to CVS. Before answering the questionnaire, all participants gave their consent to be enrolled in the study. The study was approved by the Human Sciences Ethics Committee of Valladolid Area-Este Clinic Hospital (Castilla y Leon Public Health System-SACYL) and followed the tenets of the Declaration of Helsinki and the standards of Good Clinical Practice. The online questionnaire was sent on the mid-November 2022 and was left open for five weeks for completion. Participants cannot modify their answers after sending questionnaire.

Questionnaire design

The online questionnaire was organized into three sections with all compulsory questions. The first section collected sociodemographic data (sex, age, and connection with the university), systemic and ocular health (systemic and/or ocular disorders, pharmacological treatment and ocular surgery), current optical correction and their preference when using VDTs (spectacles and/or CL wear), VDT exposure (daily hours of use of digital devices both inside and outside the classroom or work office), use of artificial tears and information on breaks taken when working with VDTs.

The second section included the validated CVSS17 questionnaire[6,7] that was designed to provide a patient-reported measure of CVS over the preceding month among VDT users.[6,7] This questionnaire is composed of 17 questions, which provide a total score ranging from 17 to 53 points (the higher the score, the greater the patient's CVS symptomatology). The CVSS17 provides information on approximately 15 different symptoms, including a symptom's severity and frequency and the subject's opinion. CVS

can be classified into 5 levels according to the total score, with level 1 corresponding to an absence of symptoms and level 5 to very severe discomfort related to the use of digital screens.[6] Participants with CVSS17 total scores ≥29 points (levels 3, 4 and 5) were considered to have CVS symptoms.

The third section of the questionnaire included the OSDI questionnaire to determine the symptomatology related to DED.[14] It includes 12 items that evaluate the frequency of symptoms over the preceding week. The OSDI questionnaire is structured into three main domains: ocular symptoms (5 questions), vision-related daily function (4 questions) and environmental triggers (3 questions). The OSDI score ranges between 0 and 100, where higher scores represent a greater severity of symptoms, and is classified as follows: no symptoms (score ≤12), mild (score 13-22), moderate (score 23-32), and severe symptoms (score 33-100).[15] Additionally, participants were grouped into two categories, non-DED symptomatology (OSDI ≤22) and DED symptomatology (OSDI >22), following recommendations to provide comparable results with previous epidemiological DED reports.[16]

Statistical Analysis

Statistical analyses were performed using SPSS for Windows software (version 27.0; SPSS, Inc., Chicago, IL, USA) and Microsoft Office Excel (Microsoft Corp. Washington, USA). The normal distribution of the variables was assessed with the Kolmogorov–Smirnov test. Mean, standard deviation, and percentages were used to describe the data when appropriate. Continuous variables were assessed with the Kruskal–Wallis and Mann–Whitney U tests, and categorical variables were assessed with the chi-square test. Descriptive analysis of CVS prevalence (according to CVSS17 levels 1 to 5 and CVSS17

score <29 and ≥29) was performed on the total sample and on groups based on the main study variables of university group [students (undergraduate, master's, and PhD students) and university staff (lectures and administrative employees)], sex (women and men), age (analysed in both two [≤35 and >35 years old] age groups and five [18-25; 26-35; 36-45; 46-55 and >55 years] age groups), CL wear and dryness symptomatology (participants with [OSDI >22] and without [OSDI ≤22] dryness symptomatology). CVSS17 levels and CVS prevalence were reported as percentages with 95% confidence intervals (95% CIs) calculated using bootstrapping through random repetition of 1,000 samples.

The odds ratios (ORs) along with Wald X^2 tests and 95% CIs were calculated with multivariate logistic regression analysis to assess the relationships of university group (undergraduate, master's, or PhD students; lecturers; and administrative employees), sex, age (≤35 and >35 years old), CL wear, VDT use, and dryness symptomatology as independent variables with CVS (CVSS17 ≥29 points). All statistical analyses were considered significant at $P<0.05$.

Results

Descriptive data of the overall sample

One thousand nine participants responded to the survey (response rate of 3.9%) and were included in the study. Table 1 summarizes the sociodemographic characteristics of the overall sample. The mean age was 35.2 ± 15.2 years (range 18 to 69 years). Of the total participants, 64.1% (n=647) were women ($P<0.001$). The average hours of daily VDT use to study or work in an office were 5.8 ± 2.2 (ranging from 0 to 14). On the other hand, the average number of hours of personal VDT use was 3.5 ± 2.0 (ranging from 0 to 12).

The mean OSDI score was 18.9 ± 15.6 (0 to 90.9), and the percentage of respondents with dry eye symptoms (OSDI >22) was 35.4% (95% CI 32.5%-38.2%). Participants were classified according to their role at the university as lecturers (n=271, 26.9%), administrative employees (n=208, 20.6%), undergraduate students (n=405, 40.1%), master's degree students (n=53, 5.3%) and PhD students (n=72, 7.1%).

CVSS17 scores

The mean CVSS17 score in the overall sample was 31.5 ± 6.4 (95% CI 31.1-31.9). Lecturers had the lowest CVSS17 score, with statistically significant differences from administrative staff and undergraduate students (P<0.01; Figure 1). Additionally, women, participants younger than 36 years old, CL wearers and subjects with dry eye symptoms had statistically higher CVSS17 scores (P<0.03; Figure 1).

Overall CVS prevalence

According to the CVSS17 score, 7.8% (95% CI 6.1%-9.5%) of the participants were classified at level 1, 26.8% (95% CI 23.9%-29.5%) at level 2, 38.1% (95% CI 34.9%-41.1%) at level 3, 22.5% (95% CI 19.9%-25.0%) at level 4 and 4.9% (95% CI 3.5%-6.3%) at level 5 (P<0.001). The total prevalence of CVS (CVSS17 score ≥29) was 65.4% (95% CI 62.1%-68.3%), and 34.6% (95% CI 31.7%-37.9%) of the sample did not have CVS (CVSS17 score <29) (P<0.001).

CVS prevalence in university groups

Statistically significant differences in the percentages of CVS level and symptomatic CVS in each university group were found (Figure 2). A higher percentage of students were classified as levels 3, 4 and 5 (P=0.01) and had CVS (70.2%, 95% CI 66.0%-74.0%; P<0.01) compared with university staff. A detailed analysis among the different

university groups found a similar trend, with a significantly different proportion of CVS levels (P<0.01) and symptomatic CVS (P<0.01) (Figure 3). Undergraduate students showed the highest CVS prevalence (72.6%), followed by master's students (67.9%), with lecturers having the lowest prevalence of CVS (54.6%). Table 2 summarizes the results of the university groups.

CVS prevalence by sex

Women showed a higher proportion of CVS levels 3, 4 and 5 (P<0.01; Figure 2) and a higher CVS prevalence (P<0.01; 73.7%, 95% CI 70.2%-77.0%) compared with men (50.6%, 95% CI 45.3%-55.5%).

CVS prevalence by age

A similar trend was found according to age groups, where participants younger than 35 years old showed a higher proportion of CVS levels 3, 4 and 5 (P<0.01; Figure 2) and a higher percentage of CVS (69.7%, 95% CI 65.8%-73.4%; P<0.01). A detailed analysis of the age groups found that all groups showed a greater than 50% prevalence of symptomatic CVS (P<0.01, Table 3). The percentage of CVS decreased with increasing age (P<0.01), from a prevalence of 72.2% in the youngest group (18-25 years) to 59.9% in the group older than 55 years (Table 3).

CVS prevalence by CL wear

CL wearers showed a higher percentage of CVS levels 3 and 5 (P=0.04; Figure 2) and a significantly higher CVS prevalence (73.2%, 95% CI 66.8%-79.0%; P=0.01) than non-CL wearers (63.4%, 95% CI 60.1%-66.8%).

CVS prevalence by dry eye symptomatology

Participants with dryness symptomatology (OSDI score >22) showed a statistically higher percentage of CVS levels 3, 4 and 5 (P<0.01; Figure 2). Additionally, participants with dryness symptomatology showed a statistically significant difference in CVS prevalence (P<0.01). In this analysis, a substantial percentage of participants without CVS symptoms did not have dryness symptomatology (94.5%, 95% CI 92.0%-96.6%), but a slightly higher percentage of participants with CVS (51.2%, 95% CI 47.2%-55.3%) showed dryness symptomatology (Figure 2).

CVS prevalence by other study variables

Finally, no statistically significant differences (P≥0.35; Table 4) between the CVS and non-CVS groups were found for systemic diseases, systemic medication, medication affecting the ocular surface, ocular surgeries or the time breaks taken by participants when using VDTs. In turn, the proportion of respondents using VDTs for ≥6 hours daily and the use of artificial tears were significantly higher in the group with significant CVS symptoms (P≤0.03).

Risk factors for CVS

According to the multivariate adjusted model, significant factors associated with the presence of CVS (P≤0.03) were female sex (OR=2.10), dry eye symptoms (OSDI >22) (OR=16.98), VTD use ≥6 hours daily (OR=1.96) and being an undergraduate student (OR=2.23) (Figure 4). Although there was a trend of a higher prevalence of CVS in CL users and subjects ≤35 years of age, there was a nonsignificant association between CL wear (OR=1.18, 95% CI 0.80-1.77; P=0.42) and age group (OR=0.93, 95% CI 0.56-1.54; P=0.78) and the risk of CVS in the multivariate model.

Discussion

This is the first study conducted considering different university population groups (lecturers, administrative employees, and undergraduate, master's, and PhD students) to determine the prevalence and associated factors of CVS in a large sample of 1009 subjects of a highly educated population.

A high prevalence of CVS of 65.4% was found in the university population assessed, with undergraduate students having the highest prevalence (72.6%) and lecturers having the lowest prevalence (54.6%; P<0.01). These results are consistent with other reports that found a similar CVS prevalence in Spanish university students [between 73.8%[17] (undergraduate and postgraduate students) and 76.6%[18] (undergraduate and master's degrees) with the CVS-Q questionnaire] and in other countries and degrees. For example, a CVS prevalence between 69.1%[19] (in medical students; CVS-Q questionnaire) and 77.1%[19] (in undergraduate students; CVS-Q questionnaire) was described in the USA, 80%[20] (in medicine and engineering students; nonvalidated questionnaire) in India, and 82.5%[21] (in medical students who wear spectacles; CVS-Q questionnaire) in Paraguay, and the highest prevalence reported was 90%[22] (undergraduate students from 5 universities; nonvalidated questionnaire) in Malaysian students.

The prevalence of CVS in the university student population was significantly higher than the prevalence in lecturers (54.6%) and administrative employees (67.3%). However, the CVS prevalence in lecturers and administrative staff is similar to the previously reported prevalence in other professional populations, such as Italian office workers (67.2%; CVS-Q questionnaire)[23] and Spanish health care workers (56.8%; CVS-Q questionnaire).[24] Therefore, these results suggest that undergraduate students have a greater risk of

developing CVS, as the multivariate logistic model confirmed that students have more than double the probability of suffering from CVS (OR=2.19; 95% CI 1.51-3.17; p<0.01) than the rest of the university population assessed (Figure 4). However, although the prevalence of CVS varies depending on the population assessed and the questionnaire used, all previous reports described an elevated prevalence of CVS in undergraduate university students, which could develop into a major public health problem in developing countries, contributing to reduced academic performance and work productivity with a negative impact on the quality of life of VDT users.[1,25]

According to the multivariate logistic model, being an undergraduate student is not the only risk factor for developing CVS in the assessed Spanish university population. Women (OR=2.10; 95% CI 1.54-2.88; p<0.01) also had more than double the probability of suffering from CVS than men (Figure 4). This higher risk for women has been previously described,[17,23,26–28] and other authors have found similar (OR=1.78; 95% CI 1.35-2.34 in female professionally active computer users[28]) or higher (OR=2.95; 95% CI 2.14-4.08[17] in female university students and OR=3.42; 95% CI 1.94-6.04[23] in female office workers) female-associated risks of CVS. Some authors suggest that this higher risk is related to the higher prevalence of DED in women,[16] and the relationship between female sex and DED is well known.[16] Therefore, special attention should be given to female VDT users by eye care practitioners. Nevertheless, because most of the participants (64.1%) in this survey were women [with a higher percentage in all studied groups (Table 2) and age groups (Table 3)], further research to assess the reasons for the higher risk of CVS in females should be conducted.

Moderate or severe dry eye symptoms (OSDI >22) represent the highest risk of CVS (OR=16.98; 95% CI 10.36-27.84; p<0.01; Figure 4). The percentage of participants with dryness symptomatology (OSDI score >22) was significantly higher (p<0.01) in the CVS group (51.2%) than in the non-CVS group (5.4%). These results are consistent with recent literature reports that have found a significant relationship between dry eye symptoms and VDT use.[10,29] Additionally, undergraduate students with CVS had higher OSDI scores, and the higher the OSDI value is, the greater the risk of CVS (OR=1.20; 95% CI 1.17-1.24; p<0.01).[17] According to the OSDI score, 35.4% of the university population assessed presented moderate or severe dry eye symptoms. It is also well known that the prevalence of DED increases in people over 50 years of age,[16] and therefore, older participants could be expected to exhibit CVS. However, the results showed a slightly higher CVS prevalence in younger VDT users (Table 3), with no statistically significant risk factor (OR=0.93, 95% CI 0.56-1.54; P=0.78), consistent with a previous report[18] that found lower CVS among older undergraduate students (22-29 years) than among younger undergraduate students (18-19 years).

A higher prevalence of DED symptomatology was found compared with that of a recent epidemiology report in a large population (n=1,077) in Spain that found dryness symptoms (OSDI >22) in 15.5% (95% CI 13.2%-17.6%) of the population, suggesting a higher risk of DED symptomatology in the university population.[30] Other reports (in office workers in New York) also found a higher prevalence (29.9%) of dryness symptomatology.[12] However, in a 2016 meta-analysis, the global prevalence of DED in office workers was estimated to be 49.5% (ranging from 9.5% to 87.5%), although the authors highlighted the necessity of implementing common DED diagnostic criteria in research to allow for a more relevant estimation of DED prevalence.[10]

This high prevalence of dry eye symptoms may be largely because the use of VDTs increases the vicious cycle of dry eyes.[16,31] The use of VDTs decreases blink rates and increases incomplete blinks, resulting in tear film instability, increased tear evaporation and hyperosmolarity.[31] Given that VDT use is a consistent risk factor for DED[10,29], eye care practitioners should pay special attention to VDT users with preexisting symptoms of dryness, as they are at an increased risk of suffering from CVS. According to the current literature, management strategies for digital display-induced dry eye to improve tear film stability and decrease tear evaporation, such as blink animation programmes, oral intake of omega-3 fatty acids, the 20-20-20 rule, instillation of high-viscosity artificial tears or adjustable chairs with ergonomic training, are usually recommended.[31,32]

Moreover, study findings that spending more than 6 hours/day with digital devices doubles the probability of suffering from CVS are common.[5,23] The results of this study are consistent with those of other studies; a CVS OR of 1.96 (95% CI 1.09-3.52; P=0.03) was found in participants who used VDTs more than 6 hours daily. Additionally, the CVS group spent significantly more time in front of digital screens for study/work-related tasks and personal use than the non-CVS group (P<0.01; Table 4), and although in both groups most of the participants (over 90%) spent more than 6 hours/day in front of VDTs, this percentage was significantly higher in the CVS group (P=0.03; Table 4).

Additionally, it is extensively recognized that CL wear is one of the leading risk factors for DED,[16] with reports suggesting a DED prevalence up to four times higher in CL wearers.[17] Considering that dryness symptomatology is one of the main causes of CVS, CL wear may also be related to CVS. However, although a significantly higher number

of CL wearers (22.7%) was found in the CVS group than in the non-CVS group (15.8%), CL wear was not a significant risk factor for CVS (OR=1.18; 95% CI 0.80-1.77; P=0.42). Our results are in line with those published by Meyer et al.[33] who found that CL wearers do not experience symptoms of digital eye strain at higher frequency or severity than non-CL wearers. These authors emphasize that the digital strain symptoms may not be directly linked to the surface sensation of the CL itself but may result from several simultaneous factors, such us, blink pattern, non-ergonomic environment, taking breaks or binocular vision factors.[33] In contrast, other studies have reported that CL wear is a risk factor for CVS (OR=1.97; 95% CI 1.16-2.20; P=0.01)[17] in a sample of 851 university students and that regular CL wear (OR=4.85; 95% CI 1.25-18.8; P=0.02) could also increase CVS after 6 h of computer work.[11]

The main limitation of this study is the cross-sectional study design, which limits the inference of causality of the results but allow to demonstrate the association between CVS and the identified risk factors due to the large number of participants. Moreover, in the current study, no eye care clinical examinations were conducted, and all the variables analysed were self-reported, so future studies including an eye exam could be necessary to improve the description of the relationship between CVS and refractive or ocular surface patient characteristics. Additionally, the survey did not include questions about stress, hours of sleep, neck, and shoulder pain, ergonomic or environmental conditions (indoor air quality, lighting conditions, etc.) during VDT use, which could lead to measurement bias. In future studies, it would be interesting to compare the prevalence of CVS in university students and staff between different countries using the same methodological procedure and validated questionnaires to improve knowledge about CVS. These findings could inform preventive strategies and provide information on the

implications of CVS in university populations, especially among younger subjects. Finally, eye care practitioners should be aware of the relevance of triaging questionnaires and CVS risk factors when exploring university populations and/or patients who use VDTs for long periods for study, work, or personal tasks.

Conclusions

This study investigated the prevalence of CVS and its associated factors in a large Spanish university population. CVS was found to have a prevalence of 65.4%, with undergraduate students having the highest prevalence (7 out 10 students). Female gender, more than 6 hours/day of VDT use, being an undergraduate student and presenting dry eye symptoms significantly increased the risk of CVS. These results highlight the importance of preventing CVS in university populations and the paramount role of eye care practitioners in reducing eye complications related to CVS in patients who use VDTs for long periods and present CVS risk factors.

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Figure Legends

Figure 1. Summary of differences in CVSS17 scores between university role, sex, age, CL wear and DED symptoms groups. Mean, maximum, minimum and Mann–Whitney U test p values are presented for each variable. Und-St=undergraduate students; MSc-St=master students; PhD-St=Doctorate students; CL=contact lens; y=years.

Figure 2. Summary of CVSS17 levels and computer vision syndrome (CVS) prevalence by each group analysed. The 95% confidence interval (CI) bars are represented. The X^2 P values for each CVS level (1 to 5) and for groups with or without CVS are shown.

Figure 3. Summary of CVSS17 levels and computer vision syndrome (CVS) prevalence by university population groups. The 95% confidence interval (CI) bars are represented. The X^2 P values for each CVS level (1 to 5) and for groups with or without CVS are shown.

Figure 4. Association of computer vision syndrome (CVS) with main risk factors. The results of the multivariate logistic regression model for CVS versus non-CVS are shown for the independent variables of sex, dry eye symptoms, VTD use ≥6 hours daily and university groups. CI =confidence interval; OR =odds ratio.