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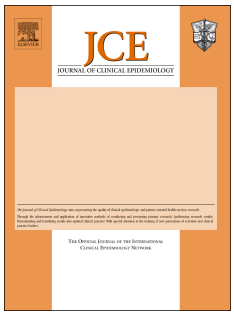

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María del Mar Seguí, Julio Cabrero-García, Ana Crespo, José Verdú, Elena Ronda

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A reliable and valid questionnaire was developed to measure Computer Vision Syndrome at the workplace

María del Mar Seguí[a], Julio Cabrero-García[b], Ana Crespo[c], José Verdú[d], Elena Ronda[e]

[a] *Optic Pharmacology and Anatomy Department, Public Health Research Group, University of Alicante, Alicante, Spain*

[b] *Nursing Department, Faculty of Health Sciences, University of Alicante, Alicante, Spain*

[c] *Public Health Research Group, University of Alicante, Alicante, Spain*

[d] *Balmis Research Group on Community Health and History of Science, Community Nursing Preventive Medicine Public Health and History of Science Department, University of Alicante, Alicante, Spain*

[e] *Public Health Section, Public Health Research Group, Occupational Health Research Centre (CISAL), CIBER Epidemiology and Public Health (CIBERESP), University of Alicante, Alicante, Spain*

Corresponding autor. María del Mar Seguí Crespo. Departamento de Óptica, Farmacología y Anatomía. Universidad de Alicante. Carretera San Vicente del Raspeig s/n. San Vicente del Raspeig. 03690 Alicante. [E-mail: mm.segui@ua.es]

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Abstract

Objectives: To design and validate a questionnaire to measure visual symptoms related to exposure to computers in the workplace.

Methods: Our computer vision syndrome questionnaire (CVS-Q) was based on a literature review and validated through discussion with experts and performance of a pretest, pilot test and retest. Content validity was evaluated by occupational health, optometry and ophthalmology experts. Rasch analysis was used in the psychometric evaluation of the questionnaire. Criterion validity was determined by calculating the sensitivity and specificity, ROC curve and cut-off point. Test-retest repeatability was tested using the intraclass correlation coefficient (ICC), and concordance by Cohen's kappa (κ).

Results: The CVS-Q was developed with wide consensus among experts and was well accepted by the target group. It assesses the frequency and intensity of 16 symptoms using a single rating scale (symptom severity) that fits the Rasch rating scale model well. The questionnaire has sensitivity and specificity over 70%, and achieved good test-retest repeatability both for the scores obtained (ICC=0.802; 95%CI:0.673-0.884) and CVS classification (κ=0.612; 95%CI:0.384-0.839).

Conclusions: The CVS-Q has aceptable psychometric properties, making it a valid and reliable tool to control the visual health of computer workers, and can potentially be used in clinical trials and outcomes research.

Keywords: Asthenopia; Computer terminals; Occupational health; Occupational exposure; Eye diseases; Diagnosis

Running title: DESIGN AND VALIDATION COMPUTER VISION SYNDROME QUESTIONNAIRE

Word count: 5,916

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1. Introduction

The expansion of information technologies in recent decades has resulted in increased use of video display terminals (VDT) in the workplace. The European Working Conditions Survey (EWCS 2010) notes that about 30% of workers use computers *all the time* during their working day and 25% use them *between 1/4 and 3/4 of the time* [1]. Because of this extensive use of computers, many studies have been conducted in an attempt to address questions concerning safety and health for VDT workers [2-6].

Office work involves a range of activities including typing, reading and writing. These tasks require intense visual efforts, focusing at different distances at which objects are placed, mainly from intermediate to near with different accommodation and convergence demands. They also require good coordination of eye movements to observe objects in different locations from paper to screen and keyboard, so that fusion images of both eyes occurs and an adequate binocular vision is obtained [7]. Studies have shown that eye-related symptoms are considered one of the most common health-related complaints in VDT workers [8,9]. It has been estimated that 90% of the 70 million workers in the United States who use a computer more than three hours/day experience such symptoms [10].

It is clear that the economic impact of the visual and musculoskeletal symptoms associated with computer use is high (due to the increased number of errors made during a computer task). Minimizing symptoms that reduce occupational efficiency will result in substantial financial benefit [11]. Hayes et *al.* [12] conclude that environmental variability at work is associated with eye symptoms that have a significant impact on quality of life and physical symptoms.

The American Optometric Association (AOA) defines Computer Vision Syndrome (CVS) as the complex of eye and vision problems related to near work, which are experienced during or related to computer use. CVS is characterised by visual symptoms resulting from interaction with a computer display or its environment. In most cases, symptoms occur because the visual demands of the task exceed the visual abilities of the individual to comfortably perform the task [13]. These symptoms comprise a complex of ocular and visual symptoms (such as itching, burning, dryness, blurred vision or photophobia) that occur during or immediately after the workday. Although the symptoms reported

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by patients are quite consistent across studies, it is notable that the literature offers little guidance about the operational definition of CVS. There are even differences about the criteria used to establish when the worker is considered symptomatic, given the lack of validated measurement instruments. The instruments used for diagnosis are usually unstructured questionnaires focusing on the frequency of occurrence of the symptoms [14-16], their intensity [17] or both [18,19], for example, in the studies of Carta et *al.* [19] and Fenga et *al.* [20]. The first study asks about the frequency (number of episodes per week) and intensity (on a scale of 1 to 5) of 12 symptoms (burning, eye pain, headache, eye redness, photophobia, tearing, repeated blinking, heavy eyelids, itching, blurred vision at distance and near and double vision); workers are then classified as asymptomatic or with insignificant, mild or intense symptomatology according to the score obtained on the questionnaire, yielding a CVS prevalence of around 50%. The second study, however, classifies workers as symptomatic if they present at least one of the nine symptoms included in their questionnaire (burning, eyestrain, eye redness, photophobia, tearing, frequent blinking, eye heaviness, itching and feeling of a foreign body), but does not ask about either the frequency or intensity of symptoms, finding a CVS prevalence of 80%. Thus, the results about the association between work-related risk factors and CVS are questioned.

The availability of a validated questionnaire to measure CVS would allow rigorous evaluation and monitoring of its effects on the visual health of VDT workers, and precise determination of its relation to ergonomic, environmental and psychosocial risk factors in the workplace, or to the individual worker's conditions, thus improving prevention and surveillance in this group.

Accordingly, the objective of this study was to design and validate a questionnaire to measure visual symptoms related to exposure to VDTs in the workplace.

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2. Methods

The items to be included in the first version of the questionnaire were selected based on a literature review. The questionnaire was then validated by discussion with an expert panel and performance of a pretest, pilot test and retest (Figure 1).

FIGURE 1

2.1. Questionnaire design

2.1.1. Literature review

We reviewed the evidence available in the scientific literature on the associations between VDT exposure and the occurrence of ocular and visual symptoms in order to establish a definition of CVS and determine how to conduct a quantitative assessment of the syndrome. The literature search (for the period January 2001 to December 2010) was carried out using MeSH terms and free text words in the title and abstract. The following search terms were used to indicate this type of occupational symptomatology: *computer vision syndrome, asthenopia, visual fatigue, eyestrain, occupational diseases, ocular* and *visual*; and to indicate the type of exposure and its relation to work: *computer terminals, computer, video display terminal, video display unit* and their acronyms *VDT* and *VDU*, as well as *occupational exposure* and *workplace.* A combination of Boolean operators and truncations were used, and English, Spanish, French and Italian scientific journal articles with abstract were selected. The search strategies formulated in PubMed (Medline) are shown in Appendix A at www.jclinepi.com. These strategies were adapted for use in WebSPIRS for Biological Abstracts, Inspec, PsycINFO, Cinahl and CC Search databases.

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Based on the results of these searches, two reviewers independently selected the relevant articles in accordance with the title and abstract. If abstracts provided insufficient information, the full text of each article was reviewed. Studies were selected if they met all of the following criteria: the study population consisted of workers who routinely used the computer during their workday, the study examined ocular and visual symptoms as a work-related outcome (it was not an ergonomic study aimed only at identifying visual risk factors or assessing preventive interventions or palliative treatment of symptoms), and the study had an epidemiological design (not a review). Disagreements regarding inclusion status were resolved by consensus. The search was expanded by screening the reference lists of the articles included in this first round. A total of 14 studies were selected [14-27].

We also obtained information on the instruments used in studies of symptom assessment. This information was obtained based on completion of a common data collection protocol developed by the authors. The protocol collected information on the characteristics of the instrument used to measure the response variable (CVS): symptoms included, how each symptom was evaluated (frequency, intensity or both), the measurement scale used, if an overall score was calculated, whether CVS severity was classified into different levels based on this score, and if the questionnaire was interviewer-guided or self-administered.

2.1.2. Selection and assessment of symptoms

Based on the review of these studies, we formulated a complete list of symptoms (all symptoms evaluated by the different authors). The symptoms included in the first draft of the questionnaire were selected by grouping symptoms with the same meaning under a single term; the criterion was that they be terms commonly used in clinical practice guidelines and protocols used to monitor the health of VDT workers from different countries [28,29]. Each symptom was considered one item of the questionnaire. Following the same strategy, we planned how to evaluate each item. In designing the response options, the general guidelines were respected [30,31]. We analysed the term used for the

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response variable, understood as "the complex of eye and vision problems related to near work which are experienced during or related to computer use", as indicated by the AOA [13], and how this was defined in each study.

2.2. Validity and repeatability

2.2.1. Content validity

2.2.1.1. Evaluation by expert committee

To evaluate the content validity, we convened a group of six experts in carrying out occupational health surveillance in optometry and ophthalmology. The experts initially conducted an individual assessment of the questionnaire, followed by a joint assessment in a face-to-face meeting in which they discussed the formulation of the questions and responses, as well as the presentation of the questionnaire (structure and format). The results of the literature review were made available to the experts and served as the basis for the discussion. A brainstorming session was conducted, and the final recommendations were taken from the arguments most widely accepted by the participants and always with the aim of improving the questionnaire.

2.2.1.2. Pretest

A pretest was conducted to obtain information on how the questionnaire worked and the feasibility of use under real-life conditions, assessing its ease of understanding, acceptability and whether it could be completed in a reasonable amount of time. The questionnaire was administered to 70 VDT workers of both sexes and different ages. After completing the questionnaire, they were invited to comment in a structured interview on any aspect that involved difficulty. A report was then prepared identifying difficulties in understanding the questions and responses. We revised those items in which at least 15% of respondents experienced difficulty [32,33].

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2.2.2. Pilot Test. Application of the first version of the questionnaire

Between June 2010 and February 2011, we conducted a pilot test by administering the questionnaire to a sample of VDT workers in a public institution; at the time the study began, these workers comprised a population of 2,212 persons.

2.2.2.1. Sample characteristics

The sample size was calculated using Epidat version 3.1. Accepting a 95% confidence level (α=0.05) for an estimated proportion of 0.50, with a required precision of the estimate of 0.05 percent units for an infinite population, the calculated sample size was 385. The sample was obtained by simple random sampling, assuming 25% replacement in accordance with the sample size calculations. The exclusion criteria were established in accordance with the specialised literature [34,35]; an ophthalmologist and an optometrist conducted a preliminary visual examination to allow exclusion of workers whose eye conditions could interfere in the association of ocular and visual symptomatology with VDT exposure (abnormalities, trauma, diseases, surgical interventions and treatments). The sample selection is summarised in Figure 2. Participation in the study was voluntary. Respondents provided informed consent, and data privacy and confidentiality were assured by treating the data aggregately and coding the names of the workers.

FIGURE 2

2.2.2.2. Rasch analysis

We analysed the questionnaire using the Rating Scale Model (RSM), the simplest Rasch model for polytomous items. The RSM is probabilistic, and provides person and item estimates on interval-level scaling based on a logit function [36,37]. RSM allows items to vary in

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their level of difficulty, but assumes that all items share the same rating scale structure. Due to its more restrictive nature, it is robust for small or medium sized samples and is likely to provide more generalizable results [38]. The Joint Maximum Likelihood was implemented as the estimation method [39].

The analysis was conducted as follows [37,40]. First, we examined whether the response categories were ordered appropriately and if they had a maximum over a unique interval of the latent variable [36,39]. Second, the fit of the items to the model was examined by infit and outfit mean square error (MNSQ) statistics, with a critical range of 0.7-1.3 [37]. Infit MNSQ gives greater weight to responses to items close to the person's ability level, while outfit MNSQ includes the differences for all items, irrespective of how far away the item difficulty is from the person's ability. Third, we examined the assumptions of unidimensionality and local independence (if the data follow a unidimensional model, there are no local dependencies). For this purpose, in addition to the favourable evidence if the values of the item fit statistics fall within the critical range, we conducted a principal component analyses of Rasch residuals [41]. A first contrast no greater than 2 eigenvalues (equivalent to the standardised residual variance of two items) indicates unidimensionality [39]. Fourth, we analysed the existence of differential item functioning (DIF) by gender and age (two groups were created according to median age). DIF occurs when two or more groups of the same ability levels have different chances of endorsing an item. To classify the presence of DIF, in addition to statistical significance ($p<0.05$), the magnitude of the contrast between the comparison groups must be taken into account: DIF contrasts <0.5 logits are considered negligible, contrasts 0.5 to 1 as moderate and >1 as substantial [42]. Fifth, we examined the targeting of the items to the sample by comparing the mean item difficulty with the mean person score. If the targeting is good, the mean person score will be close to 0 logits (the scale is centred in the value of 0 logits, which corresponds to the mean of the item measures). A map with the joint distribution of items and persons is useful for this purpose and was also used. Finally, to assess the precision of the questionnaire, the information function and its reciprocal, the standard error function, were calculated. Because precision and targeting are related (targeting refers to local precision), we also combined the standard error function with the item-person map in a single figure [43]. The Rasch separation reliability, analogous to Cronbach's alpha coefficient, was also

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calculated. This statistic generally underestimates the reliability while Cronbach's alpha overestimates it [39,44]. Rasch analysis was performed using Winsteps, version 3.61.1 [45].

2.2.2.3. Criterion validity. Sensitivity, specificity and ROC curve

Criterion validity –which measures the validity of a questionnaire compared with a criterion, usually a gold standard– was analysed to determine if the questionnaire correctly or incorrectly classified workers who suffered CVS as symptomatic. In our case, there was no gold standard so the criterion used was obtained from the articles in the literature review [46].

The reference definition used to compare the scores obtained by each worker on the questionnaire was: *occurrence of at least one symptom two or three times a week.* This definition was based on the findings of the literature review, in which the most widely accepted option by the authors to define the response variable was *presence of at least one symptom* with a required frequency of occurrence of *two or three times a week.*

Sensitivity referred to the proportion of persons who had CVS according to the reference definition, who would be classified as "positive" by the questionnaire if the cut-off point was the score considered. Specificity was the proportion of persons who did not have CVS according to the reference definition, who would be classified as "negative" in the questionnaire (because they did not reach the score considered).

We then calculated the sensitivity and specificity of the scores obtained by the 266 workers on the questionnaire. Finally, we chose the cut-off point (score) for classifying a worker with CVS. Given that we considered sensitivity and specificity to be acceptable around 0.80 [47], to find the cut-off point that would optimise both sensitivity and specificity we used the receiver operator characteristic (ROC) curve. The ROC curve was constructed by plotting the sensitivity on the ordinate against 1-specificity on the abscissa. The cut-off point was then selected on this graph from the values in the upper left-hand corner of the curve, seeking a good balance between sensitivity and specificity. The area under the

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curve allowed estimation of the ability of the questionnaire to diagnose CVS; poor questionnaire performance would be indicated by a curve near the diagonal and, thus, a small area, and vice versa.

2.2.3. Test-retest repeatability

A retest was conducted with the participation of 48 volunteers from the previous sample (of n=266). To evaluate whether the time between test administrations influenced the difference in the ratings obtained, the retest was applied at different intervals (7 to 62 days; mean 30.50 ± 14.23). Assignment of the date for the second test was made randomly; during this time, participants could not consult the replies they had given when the questionnaire was first administered.

In regard to the test-retest, the prevalence of each symptom in the two administrations of the questionnaire was compared using the McNemar test, and the differences between the means of the two scores obtained were evaluated with Student´s t test for paired data. We also tested whether there was some factor (mean score, age or time between test administration) that was correlated with larger differences. This was determined using the Pearson correlation coefficient (r), where 0.1-0.3 was considered to be low, 0.3-0.5 was moderate, and >0.5 was high correlation [48]. Test-retest repeatability of the scores was determined using the intraclass correlation coefficient (ICC), and the concordance between the diagnoses was evaluated using Cohen's kappa (κ), with their corresponding 95% confidence intervals (95% CI). The literature recommends an ICC greater than 0.70 for discrimination between groups in research [49]. Concordance, according to the kappa values, was classified as follows: <0.00 poor, 0.00-0.20 slight, 0.21-0.40 fair, 0.41-0.60 moderate, 0.61-0.80 good, and >0.80 almost perfect [50].

The Statistical analyses explained in each section above were conducted using the Statistical Package for the Social Sciences (SPSS) for Windows 17.0.

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3. Results

3.1. Questionnaire design

3.1.1. Literature review

In the 14 studies reviewed, the number of symptoms evaluated varied from 4 in the Woods study [16] to 12 in the studies of Carta et *al.* [19] and Támez-González et *al*. [21]. The most frequent symptoms were *blurred vision, double vision, burning, itching, tearing, heaviness* and *headache.* Some ambiguity was observed in the terminology employed, for example, symptoms like *irritation, itching* or *stinging* can be interpreted differently and may cause confusion when being evaluated.

In all studies the assessment was made by a means of a questionnaire in which individuals indicated if they suffered the symptoms included. Ten studies asked about the frequency of occurrence [14-16,18,19,21-25], and three asked about the perceived intensity of the symptoms [17-19]. Only the study of Speeg-Schatz et *al*. [26] mentioned that the questionnaire was administered by an occupational physician; all the others either indicated that the questionnaires were self-administered or did not specify the mode of administration.

With regard to the name of the response variable, the term *computer vision syndrome* was used only in the study of Sen and Richardson [18], and *asthenopia* was the most commonly used term; other terms were also used, such as *visual fatigue, eyestrain, visual strain* or simply *ocular symptoms*. To establish when the worker would be considered symptomatic, the most frequently accepted definition was *presence of a symptom* [14,16,18,20,21,23,24,26] with a frequency of occurrence of *two or three times a week* [14,23,25]. However, in some studies the definition was imprecise [19,22,27] or was not provided [15].

3.1.2. Selection and assessment of symptoms

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We selected 16 symptoms based on the results of the literature review. In accordance with the evidence found, it was decided to measure the frequency of occurrence as well as the intensity of each symptom. To measure the frequency of occurrence, that is, how often the symptom was presented, we used a rating scale of 0-3 points, with the following categories: *never*=0, *occasionally*=1 *(sporadic episodes or once a week), often*=2 (two or three times a week), and *very often or always*=3 (almost every day). The three levels of intensity, or strength of the symptom, were graded similarly, on a scale of 1 to 3 points, where *moderate*=1, *intense*=2, and *very intense*=3. In the analysis, a symptom rated as *never* occurring was treated as 0 (none) on the intensity scale. Finally, the following expression was proposed to calculate the total score on the questionnaire:

$$\text{Score} = \sum_{i=1}^{16} (\text{frequency of symptom occurrence})_i \text{ x } (\text{intensity of symptom})_i$$

This expression was proposed so that both the frequency and intensity of the symptom would be included in the score obtained, given that both have clinical importance. It is extremely difficult to establish which is more important in establishing the clinical significance of a condition: whether suffering a particular symptom occasionally but very intensely, or frequently but more moderate in intensity.

3.2. Validity and repeatability

3.2.1. Content validity

3.2.1.1. Evaluation by expert committee

The expert group agreed that the main symptoms typically reported by workers who use computers were represented in the questionnaire. There was also consensus about the phrasing of the questions and responses, as well as the selected format. Nevertheless, as a result of the expert meeting it was decided to incorporate a paragraph with instructions explaining the procedure to be followed for its self-completion.

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3.2.1.2. Pretest

In the pretest, the flow and order of the items evaluated in the questionnaire were found to be good. The subsequent interviews with respondents showed that they considered it was easy to understand. Minimal modifications were required, related only to the term used to denote some symptoms, and these were corrected before final administration of the questionnaire. Mean time for self-completion of the questionnaire was 2.19 minutes, with a minimum and maximum duration of 0.90 and 5.33 minutes, respectively.

3.2.2. Pilot Test. Application of the first version of the questionnaire

3.2.2.1. Sample characteristics

As can be observed in Table 1, a majority of the 266 workers in the sample were men (58.3%). Respondents ranged in age from 26 to 69 years, with a mean age of 43.18 ± 9.43 years. Of note is that 72.2% (almost three-quarters of the population surveyed) worked with the computer for more than 4 hours a day.

TABLE 1

3.2.2.2. Rasch analysis

Rasch analysis was conducted in two phases. In the first phase, the 16 items were analysed separately with each of the two rating scales (frequency and intensity) to examine their dimensionality, reliability and the effectiveness of their response categories. In the second phase, we conducted a comprehensive Rasch analysis of the 16 items with the rating scale of symptom severity, resulting from combining the two response scales by multiplying their respective scores.

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Frequency and intensity rating scales.

None of the items on either of the two response scales had any missing responses, however, in both scales the most extreme response (*very often or always* and *very intensive*) occurred rarely (less than 3% for all items, and several had zero occurrences). Consequently, we collapsed the two extreme categories into one for all the items on the two scales, giving a rating scale of three categories with the following rescoring: *never/none*=0, *occasionally/moderate*=1, *often/very often or always/intense/very intense*=2. The Rasch analysis results provide favourable evidence of the unidimensionality of each scale, with no misfitting items and good performance of the response options. Furthermore, the wide Bland-Altman limits of agreement (LoA) between the two rating scales (frequency and intensity) of the CVS-Q showed that the two scales are not interchangeable; rather, they provide complementary information, which justifies combining them to obtain the final questionnaire score [51].

CVS questionnaire: severity (frequency x intensity) rating scale.

The questionnaire on symptom severity was the result of combining the responses to the 16 items in the two rating scales by multiplying their respective scores: 0 x 0, 0 x 1 and 1 x 0 = 0; 1 x 1 = 1; 2 x 1 and 1 x 2 = 2; and 2 x 2 = 4, i.e., a rating scale with the following options: 0, 1, 2 and 4 which, for purposes of Rasch analysis, is equivalent to: 0, 1, 2 and 3. There were no disordered categories but in almost all cases one of the two intermediate categories lacked a maximum over a unique interval of the scale. Accordingly, the two intermediate categories were collapsed into one, thus the rating scale for the analysis had three categories: 0, 1 and 2.

The category probability curves for the rating scale are shown in Figure 3.a. The measures for the locations (difficulties) of the 16 items and item fit statistics are shown in Table 2. Because it is a severity scale, the higher the item difficulty, the greater the severity of the symptom. Thus, the most severe symptom was *double vision* and the least severe was *itching*. All the items had infit and outfit MNSQ values within the

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critical range (0.7-1.3), which suggests that the data fit a unidimensional Rasch model. Unidmensionality (and local independence) was also supported by the results of the principal component analysis of Rasch residuals. The first contrast had an eigenvalue = 2, which is within the cut-off to accept that the scale is sufficiently unidimensional. DIF results are also shown in Table 2 (the last two columns). There was no evidence of substantive DIF for any item by either gender or age. One item, however, had moderate DIF by gender (item 6) and two items (12 and 16) had moderate DIF by age – although each in the opposite direction thus cancelling their impact at the scale (total score) level. It should be noted that if we had applied the Bonferroni correction for multiple comparisons, no item would have been identified with DIF.

The targeting of the items to persons was not good, as indicated by the distance (-1.93 logits) between the mean item difficulty and the mean person score. This can be seen in more detail in Figure 3.b, in which the difficulties of the items and scores of subjects are plotted together. Superimposed on the figure is the curve of the standard error of measurement function, which shows that the error is higher at the lower scores of the CVS scale. Finally, the person separation reliability was 0.69, while Cronbach's alpha was 0.78; both of these values can be considered acceptable under the most common standard (≥0.7).

TABLE 2

FIGURE 3

3.2.2.3. Criterion validity. Sensitivity, specificity and ROC curve

The scores obtained on the symptom questionnaire ranged from 0 to 24. A good balance between sensitivity and specificity was found for a cut-off of 6, with values of 75.0% and 70.2%, respectively. A lower cut-off point would increase the sensitivity, but many workers without CVS would be diagnosed as symptomatic. Conversely, a higher score would result in many workers with CVS being diagnosed as asymptomatic. According to these results, VDT workers who obtain a score of 6 or more on the symptom questionnaire are defined as having

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CVS. The area under the ROC curve is 0.826, with a 95% CI of 0.779-0.874 and a p value of <0.001, indicating that the questionnaire has good diagnostic efficacy for detecting CVS. Figure 4 depicts the ROC curve.

FIGURE 4

3.2.3. Test-retest repeatability

The only symptom with a different prevalence between the two administrations of the questionnaire was *tearing* (p=0.035). No differences were observed between the mean scores obtained before and afterwards (p=0.274). No statistically significant correlations were found between the difference between scores and the mean score (r=0.22; p=0.128), age (r=-0.10; p=0.518) or time between administration of the test and retest (r=0.12; p=0.423). Good test-retest repeatability was observed for both the scores (ICC=0.802; 95% CI: 0.673-0.884) and the diagnosis of CVS (κ=0.612; 95% CI: 0.384-0.839).

3.3. Final questionnaire

After the improvements and modifications introduced as a consequence of the validation process, the final questionnaire (validated version) was formulated (for the complete CVS-Q, see Appendix B at www.jclinepi.com).

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4. Discussion

The results obtained show that the CVS questionnaire (CVS-Q) has acceptable psychometric properties in VDT workers. The questionnaire includes 16 symptoms that are scored using two rating scales, one for frequency and the other for intensity. The responses to the two rating scales for each symptom are combined multiplicatively into one rating scale for the analysis, resulting in a single symptom severity score. Rasch analysis showed that the 16 items form a unidimensional scale to adequately fit the RSM with no evidence of substantive DIF by gender or age, with person separation reliability = 0.69 and internal consistency (Cronbach's alpha) = 0.78. However, the item targeting was suboptimal since there were more items measuring the upper end of the scale (higher symptom severity) than the lower end (lower symptom severity). Rasch analysis established the hierarchy of difficulty (severity) of symptoms, from the least severe, "itching", to the most severe, "double vision". Because Rasch analysis (if the data fit the model, as was the case in our study) converts the raw scores, which are ordinal, into linear interval scores, the questionnaire can be used with advantage to measure change in clinical trials or in outcomes research. With regard to criterion validity, its sensitivity and specificity were over 70%, furthermore, it achieved good test-retest repeatability both for the scores obtained (ICC=0.802) and for the classification or diagnosis (κ=0.612). The questionnaire was developed with wide consensus among the experts and researchers in the field, and was well accepted by the target group.

The literature review on CVS related to computer use in the workplace revealed many gaps in the knowledge of this condition due to the lack of validated instruments. CVS was measured using questionnaires, which did not follow a standard pattern, and the prevalence results were highly disparate: under 20% in the study of Ye et *al.* [17] and over 80% in that of Támez-González et *al.* [21]. CVS was quantified only in the study of Carta et *al*. [19] who, after evaluating the occurrence of 12 symptoms, calculated a score using a mathematical expression based on the frequency and intensity of the perceived symptoms, and also on the *specificity of the symptoms*; they gave higher scores to those symptoms that (in a prior calculation) had a significant association with computer exposure. The rest of the studies did not address the issue of obtaining a CVS score.

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The influence of the study of Carta et *al*. [19] in designing the CVS-Q is indisputable. However, although it is one of the most rigorous studies identified in the way it evaluated symptoms, we believe their quantification of symptomatology introduced a bias in the diagnosis, for two reasons: first, the score should not depend on the *specificity of symptoms,* given that a cross-sectional study cannot establish a causal relationship between computer exposure and the measured effects; and second, because they did not report the criterion used to select the cut-off point for the diagnosis of symptomatic/asymptomatic.

The questionnaire developed in our study overcomes the deficiencies detected in previous instruments. It is designed based on a compilation of the symptoms studied by other authors, as shown in the literature review. It allows comprehensive evaluation of the presence of symptoms, their frequency and their perceived intensity. We have followed the strategy recommended in the studies by Khadka *et al.* [52,53] of extracting content from the existing items, rewording the items, and including content from additional sources (in our case, from an expert committee evaluation and from a pretest to capture the opinion of VDT workers); all these items were then fit to a simple, uniform, and common rating scale. These authors also note that rating scales in which questions are presented in a complicated format, or have too many response categories, or categories that are not labelled, tend to be dysfunctional [52]. Based on these findings, the CVS-Q is expected to have good functionality and performance given that the items follow a simple and uniform question format, and we use a maximum of three non-overlapping labelled response categories with short descriptors for the rating scales of the questionnaire on frequency, intensity and the combination of both (severity). This provides a systematic way to quantify numerically this symptomatology and to establish a score above which the worker can be considered as symptomatic based on epidemiological criteria; this will allow comparison of the prevalence of symptoms in different types of populations. As compared to other similar studies, ours is the first to present a validated questionnaire to evaluate ocular and visual symptoms related to VDT use.

The main strength of this study is the high degree of compliance with the methodological steps recommended in the international scientific literature for the design and validation of health questionnaires [54]. Failure to carry out this process rigorously and systematically can

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result in errors that may affect the diagnosis, the decisions to be made with respect to individual treatment, the epidemiological registers, and the design and implementation of recommendations [32]. In the case of the CVS-Q, it could lead to errors in evaluating the level of ability to work, affecting the orientation of preventive measures in VDT workers.

Nevertheless, our study presents a series of limitations that must be considered. The diagnosis of CVS, like that of other health problems, is based on patient-reported outcomes, since there is no gold standard for objective measurement of the presence or absence of that condition. In these cases, in an effort to standardise clinical practice, another test must sometimes be chosen as a standard of validity, recognising that it is not perfect, but is considered the best available standard (silver standard). It is true that some aspects related to CVS can be measured objectively, for example, tear osmolarity, blink rate and conjunctival hyperemia. All of these are probably altered more frequently in patients with CVS, but none is so closely linked to the syndrome as to be used as a reference based on which the disease can be considered as present or absent. These reasons led us to choose the definition of CVS most commonly accepted in recent studies as the silver standard to assess the criterion validity of the questionnaire.

Another limitation to keep in mind, however, is the failure to control for work-related and ocular conditions in the test-retest, since it was assumed that these would remain the same between the first and second administration of the questionnaire. However, the lack of correlation between the difference between scores and the time between administrations suggests that under standard conditions with the time between test administrations of 2 days to 2 weeks, as recommended in the literature [55], the difference in the ratings obtained would have been even smaller. Thus, we would in any case be underestimating the repeatability due to this limitation.

The last limitation is related to the fact that the item-person targeting was suboptimal, primarily because the questionnaire lacks sufficient items for more precise measurement at the lower end of the scale where persons without symptoms or with few or milder symptoms would be located. However, given the extensive list of symptoms included in the questionnaire and the need to reduce the response options to produce a technically better instrument, it is difficult to conceive of new items with new symptoms, and seems unreasonable to persist in creating rating

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scales with more response options, which in the end the respondents do not adequately discriminate in answering the questionnaire. On the other hand, symptom questionnaires commonly have mistargeting problems if the study sample is taken from a general population rather than a clinical population [56]. In future investigations, the questionnaire could be applied to VDT workers who are especially vulnerable to the effects of this exposure (e.g., those with dry eye problems, or accommodation and/or convergence disorders, among others) to determine if targeting is improved in a more “symptomatic sample” [57].

In conclusion, this study provides an instrument validated with the Rasch model to measure ocular and visual symptoms related to computer use in the working population. The questionnaire is simple and is designed to be easily completed by the worker. The response options allow evaluation of the severity (frequency and intensity) of each particular symptom and the overall symptoms severity (CVS score), so that results can be compared between different individuals or in the same individual at different times and circumstances. The questionnaire has acceptable psychometric properties, making it a valid and reliable tool to be included in the eye examinations conducted in regular patient care and in clinical trials for the control and monitoring of the visual health of workers exposed to computer screens.

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Appendix

Supplementary data

Supplementary data related to this article can be found at http://...

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Appendix A. SEARCH STRATEGIES FORMULATED IN PUBMED (MEDLINE)

Appendix B. COMPUTER VISION SYNDROME QUESTIONNAIRE (CVS-Q)

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FIGURE CAPTIONS

Fig. 1. Steps in the design and subsequent validation of the Computer Vision Syndrome Questionnaire (CVS-Q).

Fig. 2. Selection of the sample of workers (n=266) who participated in the pilot test.

Fig. 3. (a) Category response curves for the rating scale. Probability of response for the three response categories (Y axis) along the latent variable (severity of symptons) minus the item difficulty (X axis). (b) Person-item map for the 16-item CVS Questionnaire. Difficulties of the items and scores of the subjects are plotted together: on the left of the dashed line, the items; on the right, the subjects (each # in the person column represents three persons and each dot represents one to two persons). From top to bottom: from highest to lowest severity of symptoms. The figure also includes (superimposed) the curve of the standard error function of the questionnaire scores.

Fig. 4. ROC curve of the questionnaire on ocular and visual symptoms to measure the presence of CVS in VDT workers.

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Table 1. Sociodemographic characteristics of questionnaire respondents: pilot test

	n	%
Total	266	100
Sex		
Women	111	41.7
Men	155	58.3
Age groups (years)		
≤35	67	25.2
36-45	106	39.8
≥46	93	35.0
Years working with computers		
≤10	103	38.7
11-20	106	39.8
≥21	57	21.4
Occupational use of computer		
≤4 hours/day	74	27.8
>4 hours/day	192	72.2

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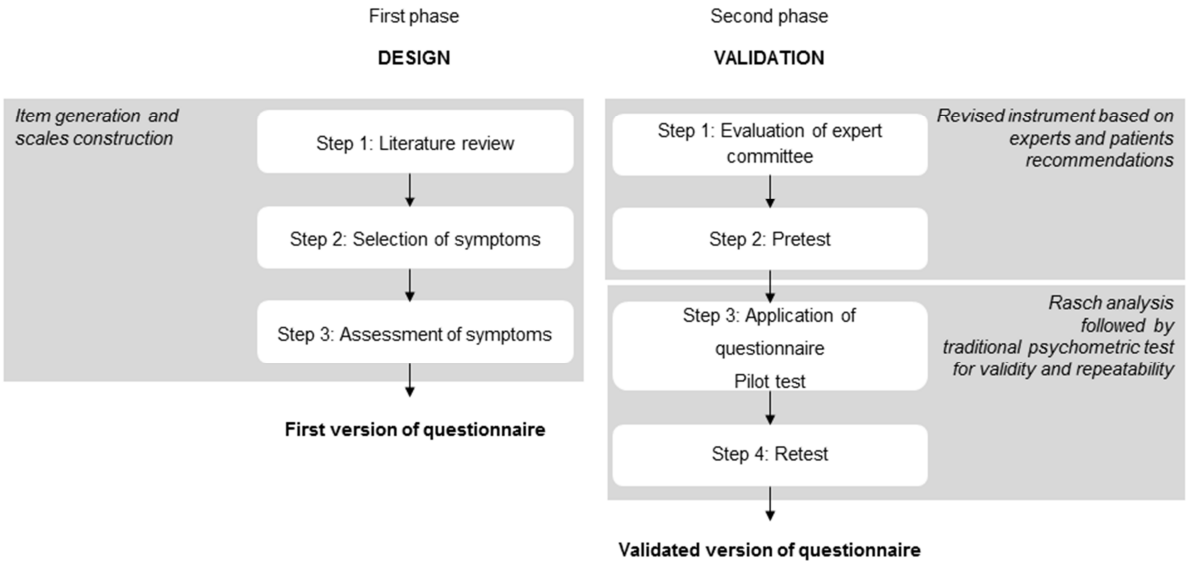
Table 2. Item Rasch analysis results of the symptom severity scale

Item number	Item description	Difficulty	SE	Infit MNSQ	Outfit MNSQ	Gender DIF contrast	Age DIF contrast
1	Burning	0.7	0.15	1.03	0.89	0.19	-0.25
2	Itching	-1.3	0.11	0.76	0.84	-0.24	0.09
3	Feeling of a foreign body	-0.02	0.13	0.96	0.94	-0.15	0.30
4	Tearing	-0.32	0.12	1.08	1.04	0.03	0.13
5	Excessive blinking	0.31	0.14	1.07	1.00	-0.11	0.05
6	Eye redness	-0.76	0.11	1.12	1.15	-0.68*	-0.40
7	Eye pain	0.63	0.15	0.96	0.97	-0.33	-0.15
8	Heavy eyelids	0.39	0.14	1.13	1.23	0.34	-0.50
9	Dryness	-0.17	0.12	1.24	1.20	0.19	0.24
10	Blurred vision	-0.50	0.12	0.77	0.80	-0.19	0.01
11	Double vision	1.95	0.22	1.17	1.14	-0.86	0.20
12	Difficulty focusing for near vision	-0.53	0.12	1.09	1.03	0.15	0.62*
13	Increased sensitivity to light	-0.45	0.12	1.05	1.03	0.08	-0.11
14	Coloured halos around objects	1.42	0.18	1.07	0.90	-0.71	-0.18
15	Feeling that sight is worsening	-1.02	0.11	0.8	0.75	0.19	0.37
16	Headache	-0.36	0.12	1.06	1.07	0.59	-0.65*

MNSQ: mean square error; DIF: differential item functioning; *p<0.05



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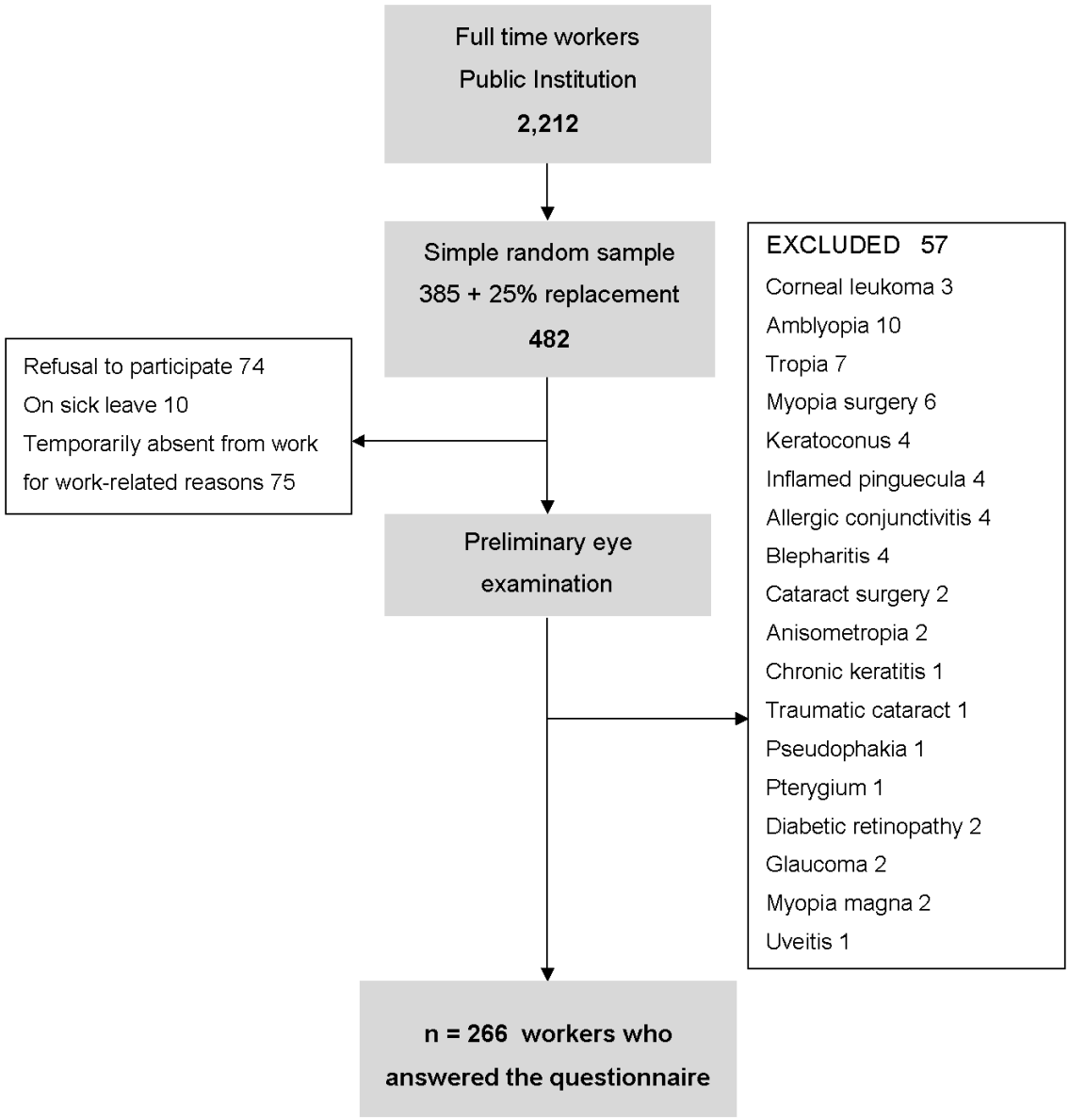

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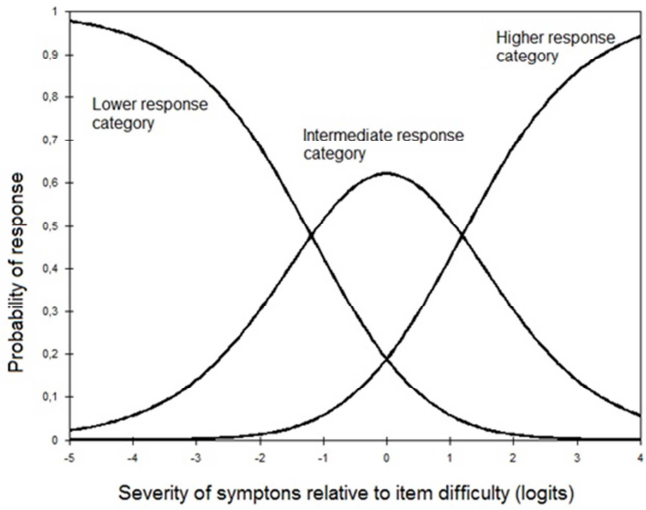

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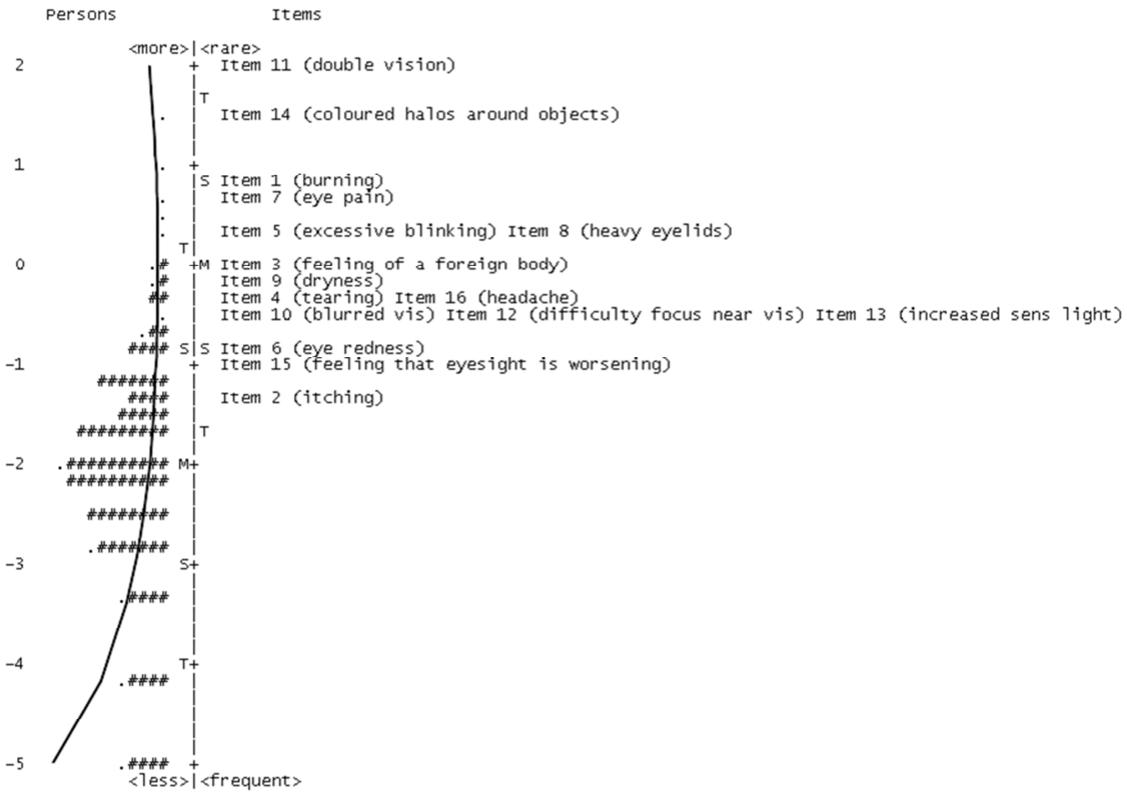

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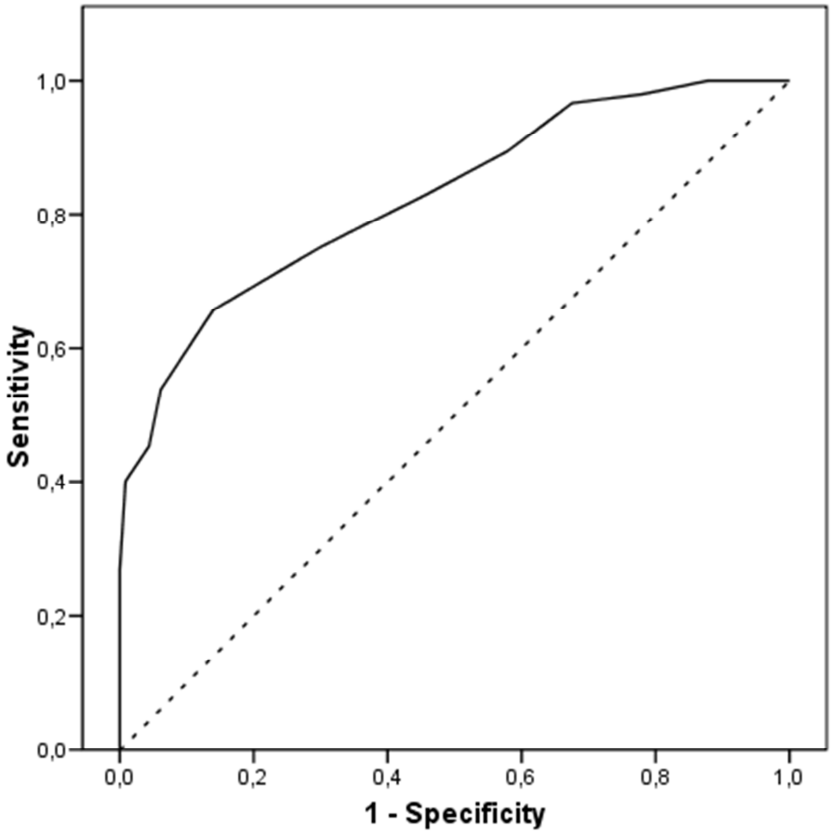

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Appendix A. SEARCH STRATEGIES FORMULATED IN PUBMED (MEDLINE)

i. (asthenopia[MeSH Terms]) AND (computer terminals[MeSH Terms] OR occupational exposure[MeSH Terms] OR workplace[MeSH Terms])

ii. ("computer vision syndrome"[Title/Abstract] OR asthenopia[Title/Abstract] OR "visual fatigue"[Title/Abstract] OR eyestrain[Title/Abstract]) AND ("computer*"[Title/Abstract] OR "video display terminal*"[Title/Abstract] OR "video display unit*"[Title/Abstract] OR "VDT"[Title/Abstract] OR "VDU"[Title/Abstract])

iii. (occupational diseases[MeSH Terms] AND (ocular[Title/Abstract] OR visual[Title/Abstract])) AND (computer terminals[MeSH Terms] OR "computer*"[Title/Abstract] OR " video display terminal*"[Title/Abstract] OR "video display unit*"[Title/Abstract] OR "VDT"[Title/Abstract] OR "VDU"[Title/Abstract])

iv. (i) OR (ii) OR (iii)

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Appendix B. COMPUTER VISION SYNDROME QUESTIONNAIRE (CVS-Q)

To be completed by worker

Indicate whether you experience any of the following symptoms during the time you use the computer at work. For each symptom, mark with an **X**:

a. First, the frequency, that is, how often the symptom occurs, considering that:

NEVER = the symptom does not occur at all

OCCASIONALLY = sporadic episodes or once a week

OFTEN OR ALWAYS = 2 or 3 times a week or almost every day

b. Second, the intensity of the symptom:

Remember: if you indicated NEVER for frequency, you should not mark anything for intensity.

	a. Frecuency			**b.** Intensity	
	NEVER	OCCASIONALLY	OFTEN OR ALWAYS	MODERATE	INTENSE
1 Burning					
2 Itching					
3 Feeling of a foreign body					
4 Tearing					
5 Excessive blinking					
6 Eye redness					
7 Eye pain					
8 Heavy eyelids					
9 Dryness					
10 Blurred vision					

11 Double vision					
12 Difficulty focusing for near vision					
13 Increased sensitivity to light					
14 Coloured halos around objects					
15 Feeling that sight is worsening					
16 Headache					

To be completed by investigator

Calculation of **TOTAL SCORE** Apply the following expression:

$$\text{Score} = \sum_{i=1}^{16} (\text{frequency of symptom occurrence})_i \text{ x } (\text{intensity of symptom})_i$$

Considering that:

- Frequency:
  - Never=0
  - Occasionally=1
  - Often or always=2
- Intensity
  - Moderate=1
  - Intense=2

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	a. Frequency	b. Intensity	Frequency x Intensity
1 Burning			
2 Itching			
3 Feeling of a foreign body			
4 Tearing			
5 Excessive blinking			
6 Eye redness			
7 Eye pain			
8 Heavy eyelids			
9 Dryness			
10 Blurred vision			
11 Double vision			
12 Difficulty focusing for near vision			
13 Increased sensitivity to light			
14 Coloured halos around objects			
15 Feeling that eyesight is worsening			
16 Headache			
$\text{Score} = \sum_{i=1}^{16} (\text{frequency of symptom occurrence})_i \text{ x } (\text{intensity of symptom})_i$ *=			

If the total score is ≥6 points, the worker is considered to suffer Computer Vision Syndrome

* The result of Frequency X Intensity should be recoded as: 0 = 0; 1 or 2 = 1; 4 = 2