

Visual and ocular effects from the use of flat-panel displays

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Abstract

• **AIM:** To evaluate the prevalence of eye symptoms in a non-presbyopic population of video display unit (VDU) users with flat-panel displays.

• **METHODS:** One hundred and sixteen VDU users with flat-panel display from an urban population participated in the study; their ages ranging from 20 to 34y. There were 60 females and 56 males. An eye examination to rule out the presence of significant uncorrected refractive errors, general binocular dysfunctions and eye conditions was carried out. In order to determine and quantify the type and nature of eye symptoms, participants were asked to answer written questionnaire and the results were grouped by gender, age and number of hours a day spent using a VDU.

• **RESULTS:** Seventy-two percent of participants reported eye symptoms related to VDU use. Eye symptoms from moderate-to-severe were found in 23% of participants. The main symptom was moderate-to-severe tired eyes (14%); followed by sensitivity to bright lights (12%), blurred vision at far distances (10%), eyestrain or dry eye or irritated or burning eyes (9%), difficulty in refocusing from one distance to another or headache (8%) and blurred vision at near or intermediate distances (<4%). Eye symptoms were greater among females ($P=0.005$) and increased with VDU use, markedly above 6h spent using a VDU in a typical day ($P=0.01$).

• **CONCLUSION:** Significant eye symptoms relate to VDU use often occur and should not be underestimated. The increasing use of electronic devices with flat-panel display should prompt users to take appropriate measures to prevent or to relieve the eye symptoms arising from their use.

• **KEYWORDS:** asthenopia; eye symptoms; computer terminals; computer vision syndrome

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INTRODUCTION

The use of video display units (VDU) has become an essential element in everyday life for work, study and leisure purposes, with an increasing preference for smaller-screen devices (laptops, tablets and smartphones)^[1-2]. Its use has been boosted by the development and wide availability of Internet (email, text messaging, social networking...).

The increasing use of computers has brought about a much higher incidence of various health problems: visual complaints, ocular and extraocular discomfort (headache and musculoskeletal problems)^[2-4]. Eyestrain or/tired eyes are the most common complaints in VDU users and have a significant relationship with VDU use^[5-17]. It should be noted that a wide range of prevalence rates ranging 19.6%^[16] to 83.7%^[6] were found in office workers. It is difficult to provide an exact value since it depends on several factors, such as the criteria to define the study population or the methods employed to assess it^[18]. For example, surveys are a very common method^[5,17]. However, refractive errors, as well as eye health and general binocular dysfunctions have not been previously evaluated and could have influenced the final results. In addition, dry eye is more common in the population of females increasing with age^[19], therefore a higher proportion of them in studies will also show a higher result for dry eye.

Previous studies^[12-13,15,20] have determined risk factors such as the characteristics of cathode ray tube (CRT) screen (flashes, low resolution, poor image and others), environmental conditions (*e.g.* illumination, relative humidity and others), visual problems (refractive errors and general binocular dysfunctions), ocular problems (dry eye or disease), age, gender, number of hours spent on a VDU and/or the conditions of their use (stressful eye conditions).

The emergence of new technologies, has rapidly introduced the use of flat-panel displays, due to better visual recognition and higher subjective preference in relation to the CRT displays^[15]. However, there is limited published data regarding eye symptoms related to flat-panel displays.

It should be noted that eye symptoms from moderate-to-severe could limit personal activities [5], therefore we thought it would be interesting to determine an accurate prevalence so as to understand the repercussions arising from VDU use, in particular flat-panel displays.

The purpose of this study is to make an assessment of eye symptoms affecting VDU users with flat-panel displays within a well-defined study population: young, non-presbyopic subjects, with no significant uncorrected refractive error, no eye conditions and no general binocular dysfunctions.

SUBJECTS AND METHODS

Subjects They were recruited through advertisements in job and public information boards. VDU users with eye symptoms were not specifically targeted. We looked for subjects aged 20 to 34y using a VDU for at least 2h per day. The upper limit of 34 years old in the inclusion criteria was meant to exclude subjects that could potentially have pre-presbyopia. Candidates who were contact-lens wearers, who had undergone refractive surgery or who had any given systemic or ocular disease were excluded from the study.

The study followed the tenets of the Declaration of Helsinki, and informed consent was obtained from all subjects after an explanation of the nature and possible consequences of the study. It also complied with the ethical requirements set by the University of Valencia. This study was conducted at the Lluís Alcanyís Foundation's Optometry Clinic (University of Valencia).

Methods All participants underwent a thorough eye examination, carried out in all cases by the same examiner, who was in charge only of this task. A different examiner analysed the data collected from the participants. Those subjects with significant uncorrected refractive error (those that exceeded a spherical equivalent of -0.5 D or +0.75 D in their correction), general binocular dysfunctions, ocular motility disorders, vertical deviation, strabismus or any other ocular health problem were excluded of the present study. Then, in order to determine and quantify the type and nature of eye symptoms, a questionnaire based on Hayes *et al*'s [5] was used.

Questionnaire A case history included a 10-question questionnaire developed by Hayes *et al* [5] to determine the type and nature of eye symptoms in VDU users. This questionnaire has been already used in previous studies [17,21-23] and it is shown to be reliable. Table 1 shows the classification of the eye symptoms considered, following the one proposed by Hayes *et al* [5].

The symptoms assessed in this questionnaire (blurred vision at far, intermediate and near distances, difficulty in refocusing eyes from one distance to another, irritated or burning eyes, dry eye, eyestrain, headache, tired eyes and sensitivity to bright lights) were graded according to their

Table 1 Classification of eye symptoms related to VDU use

Classification	Symptoms
Visual (blur)	Experience blurred vision at near distances
	Blurred vision at intermediate distances
	Blurred vision at far distances
	Difficulty in refocusing eyes from one distance to another
Ocular surface (dry eye)	Irritated or burning eyes
Asthenopic (eye strain)	Dry eye
	Eyestrain
	Headache
	Tired eyes
	Sensitivity to bright lights

The questionnaire is from Hayes *et al* [5].

Table 2 Demographic data of VDU user participants n=116 (%)

Parameters	No. of subjects
Gender	
F	60 (52)
M	56 (48)
Age (a)	
20-24	47 (41)
25-29	41 (35)
30-34	28 (24)
No. of hours a day using a VDU	
At least 2h	10 (9)
2-4h	35 (30)
4-6h	30 (26)
6-8h	26 (22)
More than 8h	15 (13)

VDU: Video display units.

intensity as: 4 (severe), 3 (moderate), 2 (mild), 1 (slight) or 0 (none). This allowed us to obtain each symptom's mean impact (in a 0-to-4 scale) within the study population. Subjects were fully informed on how to complete the questionnaire and they understood the significance of questions.

Statistical Analysis The data collected from the questionnaire were analysed using SPSS software (version 15.0 for Windows, SPSS Inc., Chicago, IL, USA). The Mann-Whitney *U* test or Kruskal-Wallis tests were used to differences between demographic data (gender, age and number of hours a day using a VDU). A *P*-value <0.05 was regarded as statistically significant.

RESULTS

One hundred and sixteen VDU users, aged 20 to 34y and living in an urban environment participated in this study. All subjects participating in the study were Caucasians and had a corrected monocular visual acuity of 20/20 or better in both eyes. They used flat-panel displays (liquid-crystal displays or light-emitting diodes backlights, that are equivalent in visual results [24]) on devices 49% desktop and 51% laptop. Table 2 shows socio-demographic characteristics of VDU user participants.

Table 3 Percentage of subjects reporting eye symptoms related to VDU use in a typical day n=116

Questions	Eye symptoms (%)				
	None	Slight	Mild	Moderate	Severe
Experience blurred vision at near distances	70	18	9	3	0
Blurred vision at intermediate distances	64	25	9	2	0
Blurred vision at far distances	66	15	9	9	1
Difficulty in refocusing eyes from one distance to another	53	24	15	7	1
Irritated or burning eyes	47	23	21	9	0
Dry eye	49	25	17	9	0
Eyestrain	59	22	10	7	2
Headache	50	25	17	8	0
Tired eyes	28	30	28	12	2
Sensitivity to bright lights	48	21	19	9	3

The questionnaire is derived from Hayes *et al*^[5].

Table 3 summarizes the results of the questionnaire derived from Hayes *et al*^[5]; which is, the frequency of occurrence of each eye symptom, grouped by its intensity level. The questionnaire's internal consistency was verified by means of the Cronbach's alpha test (0.82).

Seventy-two percent of subjects ($n=83$) showed some eye symptom (confidence level at $95\% \pm 8.17$; range 63.83% to 80.17%). Slight or mild eye symptoms were commonly found, however 23% (27 subjects) showed moderate-to-severe eye symptoms (confidence level at $95\% \pm 7.66$; range 15.34% to 30.66%).

The median total score of eye symptoms was 7 [interquartile range (IQR) =7; overall range 0-27]. Figure 1 shows the data grouped by the 116 participants' socio-demographic characteristics. Data have been grouped by gender, age and hours per day of VDU use. The differences in eye symptoms by gender, age and by number of hours a day of VDU use are analysed below.

Gender Statistically significant differences were observed between two genders ($U=1168.5$; $P=0.005$). When it came to individual symptoms between the two genders, tired eyes ($U=1130$; $P=0.002$), headache ($U=1349.5$; $P=0.048$) and blurred vision at near distances ($U=1190$; $P=0.001$) were the ones showing statistically significant differences.

Age The median age of participants was 25y (IQR=8; age range 20-34y). For the purposes of this analysis, three age subgroups at five-year intervals were established. Statistically significant differences were not observed across the three age subgroups ($H=2.87$; $P=0.24$). In regard to individual symptoms, statistically significant differences was observed in blurred vision at near distances ($H=8.99$; $P=0.011$).

Number of Hours a Day of Video Display Units Use Subjects were classified into five different subgroups, according to the number of hours spent each day using a VDU. Statistically significant differences were observed between the five different subgroups ($H=13.27$; $P=0.01$). Regarding individual symptoms, tired eyes ($H=12.39$; $P=0.015$)

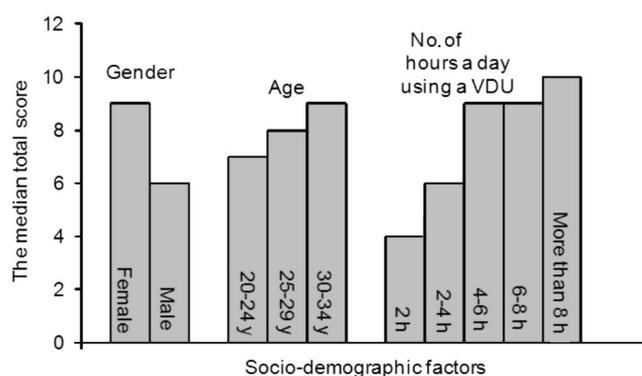


Figure 1 The median total score of eye symptoms obtained by the participants ($n=116$) in relation to socio-demographic factors.

and blurred vision at far distances ($H=16.65$; $P=0.002$) were the ones for which statistically significant differences across subgroups were found.

Repeatability of Questionnaire A study about the repeatability of the questionnaire according to the ranking method established (in a 0-to-4 scale) was carried out. Two sessions at a time separated by at least 48 to 72h were performed on 38 VDU users. The repeatability was analysed using the Bland-Altman method. In concordance with the current guidelines from the British and International Standards, that recommend the expression of repeatability in term of standard deviation (Sw), the repeatability was $Sw=1.53$ and the limits of agreement at the 95% level were -0.24 ± 2.99 (Figure 2).

DISCUSSION

The findings of present study have shown that a large number of VDU users experienced eye symptoms related to VDU use (72%). A high percentage of these symptoms were insignificant or mild in nature (49%) in concordance with previous studies^[5-6]. However, it should be noted that despite the fact that subjects with significant uncorrected refractive errors, eye health problems or general binocular dysfunctions were excluded, significant eye complaints from moderate-to-

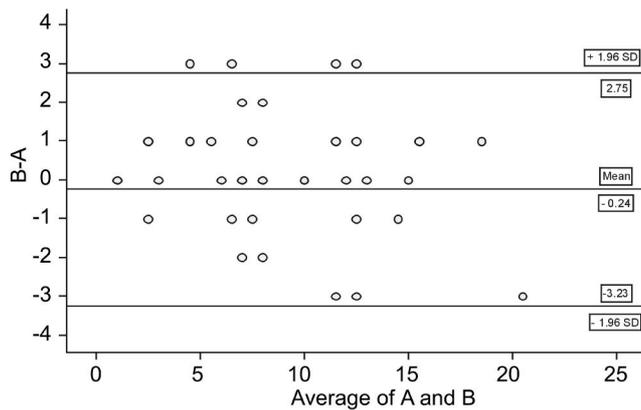


Figure 2 Bland –Altman plot of repeatability between two sessions (A and B) in 38 participants.

severe in 23% of subjects ($n=27$) were found. These subjects could have less productivity due decreased visual efficiency. Therefore, these findings show that appropriate ergonomic measures should be taken to minimize eye symptoms in VDU users.

The median total score of eye symptoms in our study, was similar to a previous study^[17]. Portello *et al*^[17] used the same ranking method (in a 0-to-4 scale), but evaluated the frequency of eye symptoms, therefore our results, which are based on the intensity of eye symptoms, cannot be compared directly with their findings. On the other hand, the determination of the repeatability of the questionnaire derived of Hayes *et al*^[5] according to the ranking method established (in a 0-to-4 scale) is another contribution from the present study. The repeatability of this test can be considered appropriate, since the findings have shown little variability between the two measures so it is reliable in the evaluation of eye symptoms in VDU users.

Socio-demographic findings (Figure 1) have reported more eye symptoms among females than males, which is in good agreement with previous studies^[6,12]. However, the findings of this study have determined that in particular females had more complaints of tired eyes, headache and problems of blurred vision at near distances than males. In addition, increasing age also had impact on eye symptoms, although no statistically significant differences were found. The oldest-age subgroup (30 to 34y) had more eye symptoms than the other two subgroups. In particular, blurred vision at near distances increased with age. Finally, previous studies^[6,10,20] have also shown that the intensity of eye symptoms increased with the amount of time spent daily using a VDU. The findings of this present study showed that there was a significant increase of eye symptoms above 6h spent using a VDU in concordance with previous studies^[10,20]. This factor seems to be one of the main triggers of eye symptoms, particularly tired eyes and blurred vision at far distances were the main symptoms that showed a statistically significant correlation with the number of hours a day of VDU use.

Dry eye is another very common symptom in VDU users^[9], however values of prevalence should be taken with caution due to the influence of multiple factors, the different methodologies applied and the study population^[17]. It may result from many factors such as: environmental factors, reduced blink rate, incomplete blinking, increased corneal exposure, age and gender, systemic diseases and medications, contact lens wear, ocular conditions and cosmetics^[3]. In our study, 34% of participants showed insignificant or mild dry eye and only moderate in 9%. These results are difficult to compare with other studies, it should be noted that our population study were young and non-presbyopic subjects, in addition, contact lens wearers were excluded.

In conclusion, the participants of this study used flat-panel displays, therefore our findings have determined their current influence upon the eye symptoms of these VDU users. Twenty-three percent of subjects showed both moderate-to-severe visual and ocular symptoms. Symptoms were higher in females and markedly more than 6h spent using a VDU. These conditions are likely to have a significant detrimental impact on both productivity and quality of life. In addition, despite the better quality and characteristics of flat-panel displays against CRTs, the findings of this study should prompt users to take appropriate measures to prevent or to relieve eye symptoms arising from their use.

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