Prevalence of Eye Strain Among Radiologists: Influence of Viewing Variables on Symptoms

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OBJECTIVE. To determine the prevalence of and factors contributing to eye strain among radiologists, we examined the influence of the viewing method (PACS vs hard-copy film), age, case volume, technique, work habits, and workstation design on symptoms.

MATERIALS AND METHODS. An Internet-based survey was sent to 2,700 radiologists randomly selected from the membership database of the Radiological Society of North America. Questions included demographic information, viewing method, work habits, and workstation design. Common eye strain symptoms were evaluated on a 5-point Likert scale. Chi-square analysis, analysis of variance, and step-wise and regression analyses were performed to evaluate codependence of the explanatory variables with eye strain.

RESULTS. The adjusted response rate was 14% (380 respondents). The largest age cohort was 36–50 years. The prevalence of eye strain was 36% and was not affected by the viewing method (PACS vs film). Increased symptoms could be independently predicted in radiologists who were women ($p < 0.001$), had longer work days ($p = 0.009$), took fewer breaks ($p = 0.03$), reported screen flicker ($p = 0.0003$), and performed CT screening ($p = 0.04$). Working hours had the strongest influence on eye strain. Eye strain was increased in those who reported studies for longer than 6 hr per day ($p = 0.01$) and decreased in those who took breaks every hour ($p = 0.04$). Symptoms were independent of the length of the break taken and of other workstation and technique factors.

CONCLUSION. Eye strain was common among the radiologists in our study population, with no significant difference between PACS and hard-copy film users. Taking frequent short breaks, eliminating screen flicker, and limiting the number of CT screening studies interpreted may improve symptoms.

Computer technology, which has transformed the workplace, has also introduced an array of related health complaints, most of which involve the visual and musculoskeletal systems. Symptoms of eye strain are the most commonly reported complaints among computer users [1, 2]. Because eye strain has mainly been investigated and described in computer workers, it has also been termed "computer vision syndrome" [1]. Eye strain (asthenopia) is a symptom complex that involves sensations of irritation to the eye itself, changes in vision (such as blurred or double vision), and associated symptoms such as headache [2, 3]. The main cause of eye strain is thought to be fatigue of the ciliary and extraocular muscles due to the prolonged accommodation and vergence required by near-vision work [1–4]. Another causative factor that has been implicated in eye strain is dryness of the eyes resulting from an increased exposed surface area of the cornea when focusing straight ahead (rather than down at written text) and a decreased blink rate due to mental concentration [2]. Computer videotape display factors and workstation design, including screen resolution and contrast, image refresh rates, screen flicker and glare, and working distances and angles are thought to contribute to symptoms [1–3]. Psychologic factors also play a role in determining the degree to which symptoms are experienced and expressed [2, 3]. No permanent damage to the visual system occurs, although work performance can be temporarily compromised [3]. Many studies have been performed to assess eye strain in office workers using computers with current estimates of prevalence of approximately 40% [2]. Improving the ergonomic design of workstations and modifying the work habits of computer users (with sup-

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plementary breaks) have been shown to have positive effects on eye strain in these workers [2, 5–7].

With the introduction of PACS and extensive use of computers for administrative tasks [8], radiologists are likely to be susceptible to such computer-related symptoms. Although the type of lighting and the variety of tasks performed in the office workplace differ considerably from those in the environment in radiology interpreting rooms, eye strain is likely to occur by similar mechanisms. To our knowledge, no scientific study to date has been performed to assess the prevalence of eye and neck symptoms in radiologists. The purpose of our study was to determine the prevalence of eye strain among radiologists, examining the influence of viewing method (PACS vs hard copy), age, case volume, technique, work habits, and workstation design on these symptoms.

Materials and Methods

An Internet-based survey (FormArtist, Quask Software) was sent electronically in January 2003 to 60 radiologists affiliated with our institution (as a pilot study), and twice in February 2003 to 2,700 North American radiologists randomly selected from the membership database of the Radiological Society of North America. A hard-copy version of the survey was also distributed to all attendees (115 radiologists) at an international general radiology conference in February 2003. The identical survey was sent to all three groups (Appendix 1).

The survey included questions about demographic information (age, sex, and number of years in practice), personal eye care (including use of eye drops and corrective lenses, type of correction and frequency of visits to an ophthalmologist), PACS versus film use, work habits (e.g., frequency and length of breaks taken and length of the work day), and workstation and interpreting environment design (e.g., size and resolution of computer monitors, ergonomics of workstations, and the ability to adjust lighting of the viewing environment). Eye strain was assessed through evaluation of common symptoms frequently described in the computer literature. These symptoms included itching, burning, or irritated eyes; tired or heavy eyes; difficulty seeing clearly (including blurred or double vision); and headache. The occurrence of common eye strain symptoms were evaluated on a 5-point Likert scale ranging from “Never” (1) to “Always” (5). All questions in the survey were presented in a forced-choice format.

The data from the three sets of recipients were pooled. Chi-square analysis, analysis of variance, and step-wise and step regression analyses were then performed to evaluate codependence of the explanatory variables with eye strain symptoms. An eye strain score was derived using principal component analysis based on the variables in the questionnaire that were considered to contribute to eye strain. The resulting score (the first principal component) provided the maximal and most sensitive measure of variation among subjects on the basis of eye strain. Chi-square analysis was used to analyze the subcohorts of the pooled population (the conference attendees, the radiologists affiliated with our institution, and the 2,700 e-mail recipients) for differences in response rate, age, sex, years in practice, and symptoms of eye strain.

Results

The pooled response rate—adjusted for failed e-mail addresses, absentee recipients, and inappropriate recipients (e.g., radiation physicists)—was 14% (380 respondents). The separate subcohorts in our study population had significantly different response rates ($p < 0.0001$) ranging from 46% (the conference subgroup) to 12% (the 2,700-person e-mail subcohort). However, the three groups did not differ significantly in age ($p = 0.16$), sex ($p = 0.71$), years in practice ($p = 0.12$), or total eye strain ($p = 0.20$). For a summary of the survey results from the pooled population, refer to Table 1. The prevalence of eye strain in our study population (defined as eye strain experienced at least some of the time) was 36%. Eye strain was not influenced by viewing method (PACS vs film, $p = 0.36$).

TABLE 1 Demographics, PACS/Film Utilization and Symptoms of Eye Strain

Factor	Category	% of Respondents	Influence of Factor on Eye Strain
Age (yr)	< 35	8	Increased with younger age ($p < 0.01$)
	36–50	55	
	51–65	33	
	> 65	4	
Sex	M	75	Increased with females ($p < 0.001$)
	F	25	
Years in practice	< 1	1	No influence when adjusted for age
	1–6	15	
	6–10	16	
	> 10	68	
Work hours (reviewing cases)	< 4 hr	6	Increased with longer working hours ($p < 0.01$)
	4–6	27	
	7–9	55	
	> 9	12	
% of time using PACS	0–25	40	No influence of viewing method on eye strain
	26–50	15	
	51–75	9	
	76–100	36	
% of time using film	0–25	32	
	26–50	11	
	51–75	17	
	76–100	40	
Eye strain symptoms	Never	35	Not applicable
	Rarely	29	
	Sometimes	24	
	Often	11	
	Always	1	
Frequency of breaks	Once daily	14	Breaks at least every hour reduce eye strain ($p < 0.05$)
	Twice daily	20	
	Every 2 hr	38	
	At least every hour	28	

In our study population, independent predictors of increased eye strain symptoms were female sex ($p < 0.001$), younger age ($p < 0.01$), longer work days ($p = 0.009$), fewer breaks ($p = 0.03$), noticeable screen flicker ($p = 0.0003$), and performance of CT screening ($p = 0.04$). CT screening, when part of the respondent's work week, was almost exclusively performed less than 26% of the time. Age and sex had a significant impact on eye strain symptoms even when adjusting for the length of work day. The number of working hours had the strongest influence on eye strain, followed by age and then by performance of screening CT. Eye strain increased when respondents were reporting studies for more than 6 hr per day ($p = 0.01$) and decreased when respondents were taking breaks at least every hour ($p = 0.04$). Symptoms were independent of the length of the break ($p = 0.22$) and other work station ($p > 0.2$) and technique factors ($p = 0.07$). Corrective lenses were worn by 86% of the respondents. The use of corrective lenses, type of correction, and frequency of eye examinations did not correlate with eye strain symptoms ($p > 0.05$).

Discussion

In recent years, technologic advances (including the introduction of MDCT) coupled with an increasing number of unfilled radiology positions have led to an increasing workload for radiologists [9]. Radiology services can be quantified in terms of relative value units (RVUs), which account for both the number and complexity of procedures performed by a radiologist. An 18.5% increase in RVUs per radiologist was measured between 1993 and 1997 [9] and a 13% increase was measured between 1995–1996 and 1998–1999 [10]. To effectively manage these increasing demands, radiologists need to focus on strategies to maximize productivity. Eye strain, which has a high prevalence in our study population, can hinder productivity and diagnostic interpretation by causing "perceptual errors, performance errors, decrease in reaction time, fatigue, and even burn out…" [11]. These symptoms are therefore highly relevant to the radiologist in today's work environment.

Given the high prevalence of eye strain in computer users, our finding that eye strain did not differ between PACS and film users was unexpected. It is reasonable, however, to believe that the practice of radiology, which requires prolonged focusing and concentration, produces strain on the visual system that may markedly outweigh the influence of using computers rather than viewboxes. There may also have been some contamination between PACS and film groups, with film-based radiologists using computers frequently for administrative tasks (e.g., receiving e-mail and approving reports).

The influence of age and sex on eye strain symptoms is difficult to explain. A similar sex effect has been described in two other studies on eye strain [12, 13]. However, the most likely explanation for both is a self-reporting bias, whereby a person's background and beliefs affect the recall and reporting of symptoms. In addition, the low response rate in our study population may have created a nonresponse bias, whereby younger radiologists were more likely to respond if experiencing worse symptoms and older radiologists were likely to respond with the same frequency regardless of the degree of symptoms experienced. Other factors may also contribute to this finding. For example, the "one-size-fits-all" ergonomic design of most radiology departments, possibly being less favorable for female radiologists, may play a role. Our survey also did not specifically investigate certain aspects of radiology practice that may be influenced by age or sex that could affect eye strain symptoms. Such factors would include the location of the practice (tertiary center vs community hospital), amount of call time, number of days worked per week, and involvement in research activities.

Most of the radiologists in our study population wore corrective lenses. We did not find an association between eye strain and the use of corrective lenses or the type of correction required. Those with small refractive errors and oculomotor problems may only become symptomatic during the demanding conditions of sustained work on VDTs. Formal eye assessment and use of appropriate corrections may therefore be beneficial for radiologists [2, 4, 13, 14].

The performance of screening CT (e.g., pulmonary nodule screening, CT colonography, and full-body CT studies) was a predictor of increased eye strain symptoms in our study population. Because almost all of those who performed CT screening spent less than 26% of the work week on this task, we could not assess the variations in eye strain with differing amounts of screening CT. Increased eye strain when performing CT screening likely results from the high volume of images that must be assessed in such studies. Using standard prevalence figures for colonic polyps [15] and the average number of images per CT colonographic examination, we estimated that a radiologist must review 13,000 2D images to detect one colonic polyp. It is likely that other forms of cross-sectional imaging (e.g., CT angiography) will increase eye strain in radiologists as technology allows faster acquisition of thin slices and larger data sets.

Other than screening CT, the technique used did not influence eye strain symptoms. In testing the hypothesis of differences between PACS and film interpretation, we did not assess mammography and interventional radiology because use of PACS is less consistent in these two areas than other techniques. However, these two areas do provide unique ergonomic challenges to the radiologist and are an area for future research.

The influence of workstation design on eye strain is of great interest because workstations are highly modifiable especially at the stage of initial PACS implementation. Noticeable screen flicker is a factor that we have shown correlates strongly with eye strain. Apparent or noticeable flicker may be avoided by optimizing the refresh rate for CRT monitors and pixel response time for LCD monitors [16–18]. Appropriate and timely computer screen maintenance is also likely to be helpful.

Other workstation factors were not shown to have an influence on eye strain in our study population. However, many radiologists did not have sufficient knowledge regarding factors such as screen size, resolution, and type for us to accurately assess their impact on eye strain.

Lighting in the viewing environment is a key factor in workstation design that is often not adequately addressed in PACS implementation [19]. Although we inquired whether the lighting of the viewing environment was adjustable, we did not ask more detailed questions about ambient lighting. For example, factors such as the type of lighting (overhead vs indirect), the presence of windows or viewboxes, and the number and position of monitors in the image interpreting room are likely to be important, as indicated by Siegel et al. in a survey of radiologists using PACS [20].

In our study, we found that reviewing cases for less than 7 hr per day and taking short breaks at least once per hour positively affected eye strain symptoms. This information provides practical suggestions for radiologists to minimize symptoms. Studies in computer workers indicate that work rate may increase with the introduction of short supplemental breaks compensating for time "lost" during the breaks [2, 5].

Many radiologists may not be aware of other simple strategies to reduce eye strain that have been described in the computer literature. For example, one recommendation is the 20-20-20 rule: focus 20 ft (6.1 m) away from the monitor for 20 sec every 20 min. This allows users to change their posture and temporarily rest the muscles of accommodation. The ideal position for viewing a monitor is 25 inches (60 cm) away, with the gaze directed slightly below the horizontal plane [21]. Monitors placed on top of a PC housing on a conventional table (height, 28 inches or 72 cm) are likely to be at eye level for the average viewer and therefore too high [22]. White coats should be removed when working at a computer to avoid the reflection of light or glare onto the monitor. Monitor brightness should be matched to that of the viewing environment [21]. Artificial tears and increased blinking may help; the eyes frequently become dry from a reduced rate of blinking while one is using computers [3, 23].

The main drawback of our study was a low survey response rate despite attempts to maximize response rate by keeping the survey as brief as possible and using a forced-answer format. The use of e-mail to distribute a survey, although convenient and rapid, has been shown to result in a lower response rate than that achieved with conventional postal mail surveys [24, 25]. The survey response may have been further hindered by the requirement of a specific type of computer software (FLASH) to access the survey. Physicians in general have also been shown to have a lower mean response rate to surveys compared with the general population [26].

A low response rate can generate a nonresponse bias, whereby those who do respond may be more likely to experience symptoms or may belong to a selected demographic group. This bias could have a significant effect on our estimate of prevalence, causing erroneous elevation. Associations between eye strain and other variables are likely to be more robust to this nonresponse bias. The lack of a significant difference between our subcohort with a higher response rate of 46% and that with a lower response rate of 12% with respect to demographics and eye strain symptoms argues against a strong nonresponse bias in our study population.

A second difficulty in our study arises from the lack of a standardized form of assessment for eye strain. Without a standardized system for scoring eye strain, the eye strain in radiologists cannot be compared accurately with that of other groups. Eye strain has been extensively studied in the computer literature. Self-reporting is the most commonly used assessment method because it is fast and cheap and can be applied to general populations [27]. However, the use of self-reporting introduces the issue of self-reporting bias, whereby the personal experiences of the respondent may affect the recall, interpretation, and reporting of symptoms.

Finally, we encountered problems in quantifying the exact amount of time spent reviewing cases. In an attempt to make the survey as brief as possible, we did not investigate several factors determining workload. First, we did not differentiate between radiologists in private versus academic practice. Those in academic groups have been shown to average substantially fewer procedures or studies per year than those in community practice [9, 10]. Although this difference may relate partly to the complexity of the studies, academic radiologists typically spend a significant portion of their time in research and teaching activities. Our study did not take into account these work activities. In addition, we did not query respondents regarding the number of days worked per week, number of weeks worked per year, or on-call activities.

In conclusion, eye strain was common in radiologists in our study population and did not vary significantly between those using PACS and film. Given ongoing technologic advances, the rate-limiting factor to productivity will be radiologist fatigue, including eye strain. Taking breaks of any length at least every hour, limiting work day length, eliminating computer screen flicker, and adopting other simple strategies discussed previously may improve symptoms. Increased high image volume studies (e.g., screening CT) in radiology practices may increase symptom prevalence, and time spent reviewing such studies should be limited. According to existing literature studying computer users, improving the ergonomic design of workstations is likely to help symptoms, but education of radiologists on proper viewing habits is equally important.

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APPENDIX 1. Eye Strain Survey

Demographics

1. Age
   a. < 35 years
   b. 36–50 years
   c. 51–65 years
   d. > 65 years

2. Sex
   a. Male
   b. Female

3. How many years in practice?
   a. < 1 year
   b. 1–5 years
   c. 6–10 years
   d. > 10 years

4. Do you wear corrective lenses (either glasses or contact lenses)?
   a. Yes
   b. No
   If yes, when do you wear them?
   a. For reading
   b. For distance
   c. For both

5. Do you use eye drops on a regular basis?
   a. Yes
   b. No
   If yes, which kind of drops do you use?
   a. Artificial tears
   b. Glaucoma drops
   c. Antibiotic drops
   d. Other

6. When was your last eye examination?
   a. Never
   b. Within the last year
   c. > 1 year ago

Working Conditions

7. During the past year, estimate the percentage of studies you reviewed on:
   i. Film
   ii. PACS
Choices: a. 0%, b. 1–25%, c. 26–50%, d. 51–75%, e. 76–99%, f. 100%

8. How many hours a day (on average) do you spend reviewing cases?
   a. <4 hours
   b. 4–6 hours
   c. 7–9 hours
   d. >9 hours

9. On average, what percentage of time in a week do you spend working on the following techniques?
   i. Screening CT (e.g., total-body scans, pulmonary nodule scans)
   ii. Diagnostic CT
   iii. MRI
   iv. Sonography
   v. Conventional radiography (films)
   vi. Nuclear medicine studies
   vi. Angiography
Choices: a. 0%, b. 1–25%, c. 26–50%, d. 51–75%, e. 76–100%

10. How many studies do you review on average per day:
   i. when reviewing cross-sectional imaging (including nuclear medicine scans)?
   ii. when reviewing conventional radiographs?
Choices: a. 0–25, b. 26–50, c. 51–75, d. 76–100, e. > 100

11. How often do you take a break from looking at films?
   a. Once a day
   b. Twice a day
   c. Every 2 hours
   d. At least every hour

12. What is the average duration of your breaks (excluding lunch break)?
   a. < 5 min
   b. 5–10 min
   c. 11–15 min
   d. > 15 min

(continues on next page)

APPENDIX 1. Eye Strain Survey (continued)

Eye–Neck Strain Symptoms

13. How often, from 1 (never) to 5 (always), do you experience the following symptoms during work:
   i. Itching, burning, or irritated eyes?
   ii. Tired or heavy eyes?
   iii. Difficulty seeing clearly (e.g., blurred or double vision)?
   iv. Headache?
   v. Neck soreness or stiffness?

Choices: 1. never, 2. rarely, 3. sometimes, 4. often, 5. always

14. When do you experience these symptoms most intensely?
   a. Only at the beginning of the day
   b. Only at the end of the day
   c. Starting part way through the day and persisting for the rest of the day
   d. All day

15. If you predominantly use PACS now, have you ever used predominantly hard-copy films in the past?
   a. Yes
   b. No

If yes, then how do the symptoms with PACS compare to those with film?
   a. Much worse now that you use PACS
   b. Slightly worse now that you use PACS
   c. About the same with PACS and film
   d. Better now that you use PACS

Workstation Design (only for those working with PACS)

16. How many monitors do you work with at your workstation?
   a. One
   b. Two
   c. More than two
   d. Number varies

17. Which kind of monitor do you use?
   a. LCD (flat screen)
   b. CRT
   c. Both
   d. Don't know

18. What is the screen size of the monitor you use most of the time?
   a. 17 inches
   b. 19 inches
   c. 21 inches
   d. Don't know
   e. Screen size varies

19. What is the resolution of your monitor?
   a. High resolution (2,000 × 2,500 pixels)
   b. Medium resolution (1,000 × 1,600 pixels)
   c. Low resolution (512 × 512 pixels)
   d. Don't know
   e. Screen resolution varies

20. Does your screen have noticeable flicker?
   a. Yes
   b. No

21. Can you optimize the lighting of your viewing environment?
   a. Yes
   b. No

22. Is the height of your workstation adjustable?
   a. Yes
   b. No

   If yes, do you ever adjust it?
   a. Yes
   b. No

23. Are you able to easily adjust your viewing distance?
   a. Yes
   b. No