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GIVING GROUNDS FOR PHYSIOLOGICAL-ERGONOMIC ACTIVITIES AIMED AT REDUCING EYE FATIGUE CAUSED BY WORK WITH VISUAL DISPLAY TERMINALS

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The research was performed on occupational groups which combined visual display terminals (VDT) users. Basic occupational activity of such workers was information input and information read-out from a screen. Constant visual work with a display is a risk factor which can cause health disorders. It makes for visual analyzer strain which becomes apparent through decrease in accommodation as a result of changes in the closest and the farthest point of clear vision. As period of work with a screen becomes longer, fatigue grows, and visual analyzer performance decreases. There are other signs proving eye fatigue; they are changes in temporary characteristics of clear vision stability which are determined by a period of successive contrast perception, and critical fusion frequency which reflects the central nervous system instability.

Long-term visually stressful work with VDT causes strain in the body systems which provide visual process. Non-mobile forced "sitting" position can also cause decrease in physical efficiency. Research which was conducted on workers who had to spend more than 4 hours a shift at VDT in their working environment helped to reveal a dependence between their overall physical efficiency and changes in visual analyzer during a shift. The lower workers' physical efficiency was (both male and female), the greater accommodation decrease was detected in them. It is shown that visually stressful work performed by people with low physical efficiency can make for transfer of strain evolving during a shift into overstrain.

To prevent eye fatigue as well as overall one in VDT users, it is necessary to work out complex preventive activities which include work and rest regimes; preventive measures aimed at vision strain relieving; correction techniques which help to improve physical efficiency; rational workplace organization.

***Key words**: professional user, visual display terminal, visual analyzer, vision strain, accommodation, overall physical efficiency.*

Nowadays computers are widely used in various spheres of economic activities; notably, they are required to perform design and technological works, managerial tasks, to do accounting, and so on. Apart from their industrial use, computers are also a part of our everyday life. 3 billion people are known to not only use a computer for a bigger part of their working activities, but also spend hours looking at a visual display terminal (laptops, smartphones, and TV sets) in their free time. In relation to that, it has become necessary to perform comprehensive research on impacts exerted by visual display units on users' health as it is pointed out in the WHO Decision No. 99 dated 1989 [2].

Work with a visual display terminal

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(VDT) is multi-functional and it involves loads on various systems of an operator's body [5,20,21,23]. Work tasks of VDT users are quite different in terms of intensity and duration of impacts exerted by intellectual, emotional and sensory loads depending on their occupational activity (from information input to operators who control complicated technological processes); these loads determine various labor intensity categories.

We analyzed performed research in the sphere of occupational activities which VDT users tend to have [11,13,15] and revealed that an image on a VDT screen was a leading factor causing visual strain evolvement as such an image differed from an image on paper greatly. Strain which professional VDT users suffer from has certain peculiarities [4,7,14,22]. However, long-term and intensive work with a VDT screen leads to visual analyzer overstrain which is viewed as "computer visual syndrome" with occupational ophthalmopathy evolvement in PC operators [6,16,24]. We can spotlight three similar but not identical states which occur during work with VDT and make for decrease in work efficiency: they are fatigue, monotony, and mental satiety. Fatigue can be described as a natural reaction related to growing strain caused by performing visual-strained work. Here we should particularly highlight that such occupational activity is mostly performed in a non-mobile "sitting" position. Simultaneously low physical activity (hypokinesis) is well-known to result in substantial decrease in overall physical efficiency (OPE) which has a number of negative consequences for central nervous system, cardiovascular system, peripheral nervous system, and for a functional state of a visual analyzer [3,12,17,18]. It is shown that if workers performing visual-strained activities with precise labor (with a hand lens, magnifying glass, or a microscope) increase their overall physical efficiency via training on a cycle ergometer, it improves their subjective estimation of their own health and restores functional capabilities of their bodies including their visual analyzer [8,19]. And here we should note that there haven't been any similar studies on professional VDT users involving estimation of their overall physical efficiency and nature of negative changes in their visual analyzer allowing for gender differences, or in a working shift dynamics; so it made us to choose our research goal.

Research goal. Our goal was to study peculiarities of physiological changes in a visual analyzer occurring during work with VDT in male and female workers allowing for their overall physical efficiency and to give grounds for physiological and ergonomic activities aimed at reducing risks of visual fatigue evolvement.

Techniques and scope. We applied techniques which allowed us to obtain comprehensive characteristics of a visual analyzer state in working conditions. Our set of techniques included determination of accommodation volume, period of successive contrast perception (PSCP), and critical fusion frequency (CFF).

We determined overall physical efficiency (OPE) as per PWC170 test with a cycle ergometer. An examined worker was offered to have two training sessions, 5 minutes each, with a 3-minute rest between them (the first session was 23 W (150 kg·m/min), the second one was 75-100 W (450-600 kg·m/min), heart rate was registered during the last 30 sec. PWC170 was calculated as per conventional formula [10].

We examined various occupational groups which comprised VDT users who had to either input information into a PC (accountants, designers, editors, telegraphers, bank clerks etc.) or to read information shown on a screen (production engineers, call centers operators, TV broadcasting centers workers etc.). All the examined workers were practically healthy people aged 25-30 with their working experience being not less than 3 years. Overall, we examined 175 people in a working shift dynamics. To assess overall physical efficiency, we examined 184 professional VDT users (113 males and 71 females aged 25-39).

Primary results. On the basis of the performed research we revealed that the bigger part of a working shift was spent near a VDT screen the more intensive a user's working activities became. We determined that if work on a PC amounted to 67.5% of a working shift than a coefficient of correlation between time spent near a screen and evolving visual analyzer strain was equal to $r = 0.67$ ($P<0.05$), but if that period of work on a PC grew to 87.4% of a working shift, correlation coefficient increased substantially up to $r = 0.92$ ($P< 0.001$).

Constant visual work with a VDT screen makes for visual analyzer strain which becomes apparent through lower accommodation volume caused by changes in the near and far points of accommodation (Table 1).

Table 1

Changes in accommodation parameters in VDT users depending on time spent working with a screen

Period of work with a screen	Time of measuring	Accommodation volume (diopter)	Near point (diopter)	Far point (diopter)
Up to 2 hours	Beginning of a shift	7,05 ± 0,26	7,5 ± 0,30	0,45 ± 0,02
	End of a shift	6,8 ± 0,23	7,1 ± 0,23	0,30 ± 0,05
	% of changes	3,6	5,4	33,4
Up to 4 hours	Beginning of a shift	7,1 ± 0,40	7,8 ± 0,30	0,76 ± 0,06
	End of a shift	6,6 ± 0,35	7,2 ± 0,28	0,56 ± 0,04*
	% of changes	7,1	7,7	25,5
More than 4 hours	Beginning of a shift	7,6 ± 0,35	8,4 ± 0,37	0,80 ± 0,05
	End of a shift	6,3 ± 0,27*	6,7 ± 0,28*	0,50 ± 0,03*
	% of changes	17,2	20,3	37,5

Note: * – validity of discrepancy between a shift beginning and end ($P<0.05$)

As we can see from this table, as a period of time spent working with a VDT screen grows, per cent of decrease in accommodation volume also rises; here contribution made by a period of time spent working with a screen into decrease in accommodation volume amounts to 68.6-69.4%, correlation coefficient being 0.83 ($P<0.01$). There are other signs of visual fatigue, for example, changes in temporary characteristics of clear vision which are determined as per period of successive contrast perception (PSCP) which drops by 11.4-22.9% over a shift in dynamics, and critical fusion frequency (CFF) which reflects central nervous system instability and also goes down by 6.5-15.0%.

Besides, long work with a VDT screen as a rule is combined with subjective sensations, the most typical being "eyes and eye balls reddening" (48.4%), "lacrimation" (36.2%), "visual blurring in the distance" (34.2%) and "unclear vision near" (29.8%), "burning or pain in the eyes" (31.9%), "acute pain in the eyes" (43.8%), "visual fatigue" (70.3%), "overall fatigue" (52.4%). Occurrence of such complaints can on the one hand be caused by peculiarities which screen images have - low contrast, screen flicker, frequent brightness jumps, etc; on the other hand, it can be caused by a period of time spent near a VDT: long-term fixation of a sight on a screen, frequent need to readapt ones' eyes from a screen to a sheet of paper and vice versa. When performing their work functions, VDT users often have to shift their sight from a screen to a keyboard, and then to a paper document. Frequent readaptation of an eye to different brightness levels and distance is one of major negative factors which work with a screen involves. Such work leads to rapid fatigue evolvement, visual blurring, and double imaging. A set of detected disorders is described in literature as "computer visual syndrome". As per data taken from literature, frequency of this syndrome occurrence in professional VDT users amounted to 28.5%; people who had to work on a PC for more than 4 hours a shift mentioned having it in 96.0% of cases as they suffered from decrease in visual acuity, accommodation cramp, and other changes in their visual analyzer [1, 9,].

To prevent visual and overall fatigue in VDT users, it is necessary to implement complex preventive activities which include periodical medical examinations, work and rest regimes, and rational organization of a working place.

To maintain efficiency at an optimal level during the whole working shift, it is necessary to introduce scheduled breaks; here we should remember that if work involving information input (up to 20,000 characters), or in a dialogue regime is performed for a period of time up to 2 hours per shift, an overall scheduled break should last not less than 30 minutes. Work involving information input in volume up to 40,000 characters or in a dialogue regime up to 4 hours per shift causes such visual fatigue that scheduled breaks with overall duration not less than 50 minutes are required to eliminate it. Even stricter requirements are to be fixed in case of work involving information input in volumes up to 60,000 characters or work in a dialogue regime up to 6 hours per shift. Such work together with visual and overall fatigue causes visual analyzer overstrain; so, scheduled breaks lasting for not less than 70 minutes per shift are to be introduced.

Workers should not perform any functions during their scheduled breaks; they are recommended to leave their working place and, if possible, to go to a rest room or outdoors; or they should try to stop working with a PC for a while and switch to other activities. During breaks it is advisable to do exercises which improve circulation in eye balls; to do relaxing exercises for body and arms muscles, and to do self-massage of a pilary part of a head. We also recommend to take "a live cell" vitamin and mineral complex to prevent computer visual syndrome evolvement [1].

We should note though that workers having to perform visually strained activities do it in a non-mobile sitting position and it can consequently lead to decrease in their physical efficiency. Research performed in industrial environment on people who had to work with VDT for more than 4 hours per a shift allowed to reveal a dependence between their overall physical efficiency (OPE) and changes in their visual analyzer in shift dynamics. Table 2 contains data on three levels of overall physical efficiency in workers (males and females aged 25-39) and character of their distribution (in %).

Assessment of overall physical efficiency which professional users of VDT tended to have revealed that 37% males had low OPE, 46% had average OPE, and only 17% had high OPE. 54% of the examined females had low OPE, 37% had average OPE. And only 9% had high overall physical efficiency.

Table 2

Parameters of 3 levels of OPE in males and females aged 25-39, working with VDT

Parameters	Work with a PC					
	Females			Males		
	Low level	Average level	High level	Low level	Average level	High level
MOC ml/min·kg	< 28,0	29,0–36,0	> 37,0	< 33,0	34,0–40,0	> 40,0
PWC170 kg·m/min·kg	< 14,0	15,0–17,0	> 18,0	< 15,0	16,0–19,0	> 20,0
% of examined	54	37	9	37	46	17

Table 3

Changes in accommodation volume, PSCP and CFF in professional VDT users depending on their OPE in shift dynamics

OPE level	Time of measuring	Accommodation volume (diopter)	PSCP (sec)	CFF (Hz)
Females				
Low	Shift beginning	7,6 ± 0,35	8,3 ± 0,69	42,4 ± 1,14
	Shift end	6,3 ± 0,27*	6,4 ± 0,52*	34,1 ± 0,63*
	% of changes	17,2	22,9	19,4
Average	Shift beginning	7,1 ± 0,40	9,6 ± 0,48	39,9 ± 1,08
	Shift end	6,6 ± 0,35	8,4 ± 0,56	34,9 ± 0,64*
	% of changes	7,1	12,5	12,6
High	Shift beginning	7,05 ± 0,26	8,8 ± 0,69	40,2 ± 1,04
	Shift end	6,8 ± 0,23	7,8 ± 0,71	37,6 ± 0,67
	% of changes	3,6	11,4	6,5
Males				
Low	Shift beginning	6,44 ± 0,31	7,5 ± 0,39	43,4 ± 1,04
	Shift end	5,60 ± 0,29*	6,4 ± 0,42	36,2 ± 0,93*
	% of changes	13,1	16,7	16,3
Average	Shift beginning	6,93 ± 0,24	8,7 ± 0,28	40,9 ± 1,08
	Shift end	6,40 ± 0,28	7,8 ± 0,32	36,6 ± 0,84*
	% of changes	7,7	10,4	10,6
High	Shift beginning	7,02 ± 0,26	8,4 ± 0,42	41,6 ± 0,94
	Shift end	6,81 ± 0,34	7,9 ± 0,51	38,4 ± 0,62
	% of changes	3,0	6,0	7,7

Note: * is validity of discrepancy between a shift beginning and a shift end ($P<0.05$).

The performed research allowed to detect discrepancies in visual fatigue evolvement in professional VDT users in shift dynamics; such discrepancies depended on OPE level (table 3).

As we can see from the data presented in Table 2, accommodation volume decreased in female VDT users in shift dynamics; this decrease amounted to 0.25 - 1.3 diopter or 3.6-17.2% in various occupational groups. We should note that decrease in accommodation volume was caused by the near point moving farther by 0.4-1.7 diopter or 5.4-20.3%. The far point moved closer to eyes by 11.6-37.5% during a shift. As we analyzed the obtained data, we revealed that changes in accommodation volume were closely related to overall physical efficiency of VDT users. The lower OPE female workers had the greater decrease in accommodation volume occurred in them; thus, if OPE was low, accommodation volume went down by 17.2% while in case of people with high OPE the reduction was only by 3.6%. Similar parameters of decrease in accommodation volumes were detected among male VDT users; however, allowing for usually better physical abilities of men, changes in shift dynamics were less apparent in them in comparison with females even if their overall physical efficiency was low.

The multiple regression analysis which we performed revealed that contribution made by OPE level into changes in accommodation volumes among males and females was quite similar and amounted to 68.6-69.4% with correlation coefficient being equal to 0.82-0.83; i.e. the lower overall physical efficiency was, the more apparent changes in accommodation volumes occurred, and, consequently, the greater decrease in visual analyzer efficiency was detected.

We can also judge on decrease in visual analyzer efficiency both in males and females as per changes in temporary properties of a visual organ, PSCP and CFF, which are the evidence of visual fatigue evolvement. Here most apparent and hazardous decrease in all parameters was detected in people with low overall physical efficiency regardless of their sex.

Decrease in overall physical efficiency makes for growing number of people who tend to have various complaints. Thus, a share of female professional VDT users with low OPE who had complaints ranged from 9.2% to 12.8% when a shift started; when a shift ended, the share grew to 34.9-70.5%. Only 2.5-6.3% of females with high OPE had complaints at the beginning of a shift and 3.7-28.6% of them had complaints when a shift ended. A share of male users complaining on visual discomfort was a bit lower. Thus, 7.2-10.8% of males with low OPE had complaints when starting work; 23.8-60.9% of them had complaints when their shift ended. 1.2-5.1% of males with high OPE complained at the beginning of a shift and the share grew to 7.0-25% by the end of a shift.

Consequently, to maintain efficiency at an optimal level during visually strained work with a VDT screen, it is necessary, on the one hand, to apply correction techniques which make for increase in OPE level, and, on the other hand, to perform prevention activities aimed at visual fatigue elimination. To achieve this, we developed specific training exercises on a cycle ergometer; these exercises became a part of a working day and were done during scheduled breaks.

Exercises were done on an electric cycle ergometer during 3 months 5 times a week. A load was chosen individually and amounted to 75-100 Wt. Each load stage was performed during 3 minutes. Frequency of pedaling was set by a metronome and amounted to 60 rpm. One training session lasted for 10-15 minutes. Heart rate was registered at the end of each load stage.

As a result of performed training period, decrease in heart rate under the same load was detected. Thus, we revealed that heart rate of people with low OPE amounted to 159±2.3 beats/min at the end of cycle ergometer load, while the same load led to 125±2.0 beats/min in people with high OPE; i.e., when the same load was offered to different people, physiological costs of training were authentically higher for people with low OPE than for those with high one. The same data were obtained as per results of assessing a visual analyzer functional state. Thus, as we analyzed the obtained data, we revealed that accommodation volume in people with low OPE decreased by 12% by a shift end, but when their OPE grew due to training, this decrease amounted to only 4%. If OPE was low, PSCP decreased by 22.9%, and CFF, by 19.4%, among females, and by 16.7% and 16.3% correspondingly among males. A percent of decrease in temporary properties in shift dynamics both among males and females proves that visual fatigue evolves in them by a shift end. PSCP dropped by 11.4% and CFF, by 6.5% in females with high OPE, and by 6.0% and 7.7% correspondingly in males with high OPE, i.e., by a shift end visual fatigue was quite insignificant as the obtained parameters of decrease in temporary properties were lower than those which could prove that visual fatigue really evolved (15%). Also a number of people complaining on subjective sensations of fatigue and visual discomfort fell after training exercises.

Our research gave grounds for "standard" levels of overall physical efficiency which was required for work with VDT for males and females as per PWC170 parameters (females ≥ 15.0, males ≥ 16.0 kg·m/min·kg) and maximum oxygen consumption (females ≥ 29.0, males ≥ 34.0 ml/min·kg).

When working with VDT, it is also very important for a working place to conform to ergonomic requirements. Working furniture design (desks and arm-chairs) is to provide possibility of individual adjustment according to a user height so that a comfortable working posture could be maintained. When a working place for a PC user is organized, a VDT is to be placed on a desk in such a way that its back panel is against a wall; a screen is not to be placed opposite a window or any other light sources which could produce patches of light on it. A desk is to have such a size that a distance between a user and a screen is not less than 60-70 cm, and between a user and a keyboard, 30-40 cm. Luminance at a working place matters greatly in work with a VDT as it is required for visual comfort maintenance. Overall luminance in a room where VDTs are placed should be within 300-500 meter-candela. And here, apart from lamps lighting a whole room, there should be an individual one (not less than 60 Wt) with a solid lampshade which lights up only a text a user works with.

Conclusions. We detected that if there were no specific preventive activities, level of functional overstrain in a visual analyzer grew and it caused decrease in its efficiency. Preventive activities in case of work with VDT should above all be aimed at visual overstrain prevention and a working day regime should include visual gymnastics which is aimed at accommodation recovery and eye muscles training as well as better circulation in the eyes.

Workers should take "a live cell" vitamin and mineral complex during their scheduled breaks as it helps to prevent computer visual syndrome evolvement.

And allowing for VDT users work being performed in a non-mobile working posture, i.e. under working hypokinesis, we should provide for greater and more intense motor activity, both during a working day, and leisure hours.

To increase overall physical efficiency to "standard" levels and to achieve resistance to working process factors, we developed specific programs based on integrated approach to application of physical training and education techniques.

References

1. Bakutkin I.V., Spirin V.F., Bakutkin V.V. Rannyaya diagnostika zritel'nogo utomleniya i blizorukosti v usloviyakh vysokoi zritel'noi nagruzki v techenie rabochei smeny [Early diagnostics of eye fatigue and myopia under high visual load during a working shift]. *Professiya i zdorov'e: Materialy XI Vserossiiskogo congress* [*Occupation and health: materials of the XI All-Russian congress*]. In: N.F. Izmerov, ed. Moscow, REINFOR Publ., 2012, pp. 75–76 (in Russian).

2. Videodispleinye terminaly i zdorov'e pol'zovatelei: materialy Vsemirnoi organizatsii zdravookhraneniya № 99 [Visual display terminals and users' health: World Health Organization materials No. 99]. From Eng. V.M. Bondarovskaya, A.S. Kovalenko. Zheneva, WHO Publ., 1989, 150 p. (in Russian).

3. Agadzhanyan N.A., Dvoenosov V.G., Ermakova N.V., Morozova G.V., Yusupov R.A. Dvigatel'naya aktivnost' i zdorov'e [Physical activity and health]. Kazan', Izd-vo KGU, Publ., 2005, 216 p. (in Russian).

4. Ignat'ev S.A., Kornyushina T.A., Shapovalov S.L., Milyavskaya T.I. Zritel'noe utomlenie pri rabote s videodispleinymi terminalami i sovremennye metody ego profilaktiki [Eye fatigue caused by work with visual display terminals and contemporary techniques used to prevent it]. Moscow, MIK, Publ., 2013, 240 p. (in Russian).

5. Fatkhutdinova L.M., Izmailov M.F., Amirov N.Kh., Gallyamov A.B. Izuchenie vegetativnykh narushenii u pol'zovatelei videodispleinykh terminalov [Studies on vegetative disorders in visual display terminals users]. *Kazanskii meditsinskii zhurnal*, 1999, no. 6, pp. 443–445 (in Russian).

6. Kuz'menko M.A., Poteryaeva E.L., Gusarevich O.G., Romeiko V.L. Komp'yuternyi zritel'nyi sindrom i razvitie professional'noi oftal'mopatii u operatorov PEVM [Computer visual syndrome and occupational ophthalmopathy in PC operators]. *Meditsina truda i promyshlennaya ekologiya*, 2010, no. 1, pp. 31–35 (in Russian).

7. Kornyushina T.A. Fiziologicheskie mekhanizmy razvitiya zritel'nogo utomleniya pri vypolnenii zritel'no-napryazhennykh rabot [Physiological mechanisms of eye fatigue evolvement caused by visually stressful work]. *Vestnik oftal'mologii*, 2000, no. 4, pp. 33–36 (in Russian).

8. Kudryashova Zh.M. O nekotorykh osobennostyakh zritel'nogo sensornogo vospriyatiya pri dlitel'nom ogranichenii myshechnoi aktivnosti [On certain peculiarities of visual sensory perception under long-term restricted muscular activity]. *Funktsionirovanie analizatorov pri deistvii na organizm ekstremal'nykh razdrazhitelei: Sbornik materialov simpoziuma*. Leningrad, 1974, pp. 21–24 (in Russian).

9. Kuz'menko M.A., Nesina I.A., Poteryaeva E.L. Ispol'zovanie vitaminno-mineral'nogo kompleksa «zhivaya kletka» dlya profilaktiki komp'yuternogo zritel'nogo sindroma u ofisnykh rabotnikov [Use of "living cell" vitamin and minerals complex to prevent computer visual syndrome in office workers]. *Professiya i zdorov'e: Materialy IX Vserossiiskogo kongressa i IV Vserossiiskogo s"ezda vrachei-profpatologov [Occupation and health: materials of the XI All-*

Russian congress and IV All-Russian congress of occupational pathologists]. In N.F. Izmerov, ed. Moscow, Del'ta Publ., 2010, pp. 296–298 (in Russian).

10. Metody issledovaniya i farmakologicheskoi korrektsii fizicheskoi rabotosposobnosti cheloveka [Techniques for examination and pharmaceutical correction of human physical performance]. In: I.B. Ushakov, ed. Moscow, Meditsina Publ., 2007, 104 p. (in Russian).

11. Mironov A.I., Gadakchan K.A., Zhilova N.A. Fiziologo-gigienicheskaya otsenka truda i zdorov'ya lits zritel'no-napryazhennogo truda [Physiological-hygienic assessment of labor and health for people employed at workplaces with visually stressful labor]. *Materialy X Vserossiiskogo s"ezda gigienistov i sanitarnykh vrachei [Materials of X All-Russian congress of hygienists and sanitary inspectors]*. In: G.G. Onishchenko, A.I. Potapov, eds. Moscow, 2007, vol. 2, pp. 1180–1182 (in Russian).

12. Feigin A.A., Mikhaleva S.P., Korzh T.V., Kornyushina T.A. Professional'naya oftal'mopatiya i gipokineziya: diagnostika, lechenie, profilaktika [Occupational ophthalmopathy and hypokinesis: diagnostics, treatment, and prevention]. *Professiya i zdorov'e: Materialy III Vserossiiskogo kongressa* [*Occupation and health: Materials of III All-Russian congress*]. In: N.F. Izmerov, ed. Moscow, Del'ta, Publ., 2004, pp. 415–417 (in Russian).

13. Sarkisyan G.T. Otsenka uslovii truda, funktsional'nye narusheniya nervnoi sistemy, zritel'nogo analizatora u rabochikh komp'yuternykh firm g. Erevana i ikh profilaktika [Working conditions assessment, functional disorders of nervous system and visual analyzer in workers employed by computer firms in city of Erevan and their prevention]. *Professiya i zdorov'e: Materialy IX Vserossiiskogo kongressa i IV Vserossiiskogo s"ezda vrachei-profpatologov [Occupation and health: materials of the XI All-Russian congress and IV All-Russian congress of occupational pathologists]*. In: N.F. Izmerov, eds. Moscow, Del'ta, Publ., 2010, pp. 448–450 (in Russian).

14. Sautkin V.S., Potapov N.N. Sostoyanie zritel'nogo analizatora i profilaktika utomleniya pri rabote s videodispleinymi terminalami [Visual analyzer state and prevention of fatigue during work with visual display terminals]. *Oftal'mologicheskii zhurnal*, 2000, no. 1, pp. 74–76 (in Russian).

15. Tebenova K.S. K voprosu o professional'noi deyatel'nosti rabotnikov VDT s ergonomicheskikh pozitsii i spetsifiki okazyvaemykh imi uslug svyazi [On issues of occupational activities which VDT workers are involved in from the ergonomic point of view and peculiarities of communication services they provide]. *Gigiena truda i meditsinskaya ekologiya*, 2011, no. 1, pp. 42–51 (in Russian).

16. Feigin A.A. Komp'yuternyi zritel'nyi sindrom (KZS) u rabotayushchikh na PEVM [Computer vision syndrome (CVS) in people working on PCs]. *Problemy snizheniya professional'nykh riskov pri rabote na PEVM i VDT: sbornik vystuplenii uchastnikov nauchno-prakticheskikh seminarov [Issues of lowering occupational risks during work on a PC or with a VDT: a collection of reports by participants of theory and practical workshops*]. Moscow, VNII okhrany i ekonomiki truda Roszdrava, Publ., 2008, pp. 85–90 (in Russian).

17. Fudin N.A., Klassina S.Ya., Pigareva S.N. Vzaimosvyaz' pokazatelei myshechnoi i serdechno-sosudistoi sistem pri vozrastayushchei fizicheskoi nagruzke u lits, zanimayushchikhsya fizicheskoi kul'turoi i sportom [Relationship between the parameters of muscular and cardiovascular systems in graded exercise testing in subjects doing regular exercises and sports]. *Fiziologiya cheloveka*, 2015, vol. 41, no. 4, pp. 82–90 (in Russian).

18. Shumilin V.K., Elin A.M. Osnovnye faktory riska pri rabote na PEVM i ikh vliyanie na zdorov'e pol'zovatelei [Basic risk factors of work on PCs and their influence on users' health]. *Problemy snizheniya professional'nykh riskov pri rabote na PEVM i VDT: sbornik vystuplenii uchastnikov nauchno-prakticheskikh seminarov [Issues of lowering occupational risks during work on a*

PC or with a VDT: a collection of reports by participants of theory and practical workshops]. Moscow, VNII okhrany i ekonomiki truda Roszdrava, Publ., 2008, pp. 31–43 (in Russian).

19. Yampol'skaya E.G., Shardakova E.F., Elizarova V.V. Osobennosti funktsional'nykh izmenenii organizma rabotnikov, vypolnyayushchikh pretsizionnye raboty [The peculiarities of functional changes of organisms of workers, who carried out precession works]. *Vestnik Tverskogo gosudarstvennogo universiteta. Seriya: Biologiya i ekologiya*, 2007, no. 6, pp. 75–79 (in Russian).

20. Nakazawa T., Okubo Y., Suwazono Y., Kobayashi E., Komine S., Kato N., Nogawa K. Association between duration of daily VDT use and subjective symptoms. *American Journal of Industrial Medicine*, 2002, vol. 42, no. 5, pp. 421–426.

21. Parihar J.K., Jain V.K., Chaturvedi P., Kaushik J., Jain G., Parihar A.K. Computer and visual display terminals (VDT) vision syndrome (CVDTS*). Medical Journal Armed Forces India*, 2016, vol. 72, no. 3, pp. 270–276.

22. Irbarren R., Irbarren G. Visual function study in work with computer. *Medicina (B. Aires)*, 2002, vol. 62, no. 2, pp. 141–144.

23. Mocci F., Serra A., Corrias G.A. Psychogical factors and visual fatigue in working with video display terminals. *Occupational and Environmental Medicine*, 2001, vol. 58, no. 4, pp. 267–271.

24. Sheedy I.E. What is in a name: computer vision syndrome. *Optometry*, 2002, vol. 73, no. 7, pp. 399–402.

Matyukhin V.V., Shardakova E.F., Yampolskaya E.G., Elizarova V.V. Giving grounds for physiological-ergonomic activities aimed at reducing eye fatigue caused by work with visual display terminals. Health Risk Analysis, 2017, no. 3, pp. 66–75. DOI: 10.21668/health.risk/2017.3.08.eng

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