Amino Acids (2004) 26: 59–63
DOI 10.1007/s00726-003-0032-x

Amino Acids
Printed in Austria

Effects of taurine supplementation on VDT work induced visual stress

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Received June 10, 2001
Accepted April 3, 2003
Published online August 21, 2003;

Summary. In order to evaluate the effects of dietary taurine supplementation on visual fatigue induced by visual display terminals (VDT) work, 25 male college students aged from 20 to 24 years who were not engaged in VDT work were selected to participate in the study. Volunteers were randomly assigned to either the taurine supplementation (n = 13) or the placebo supplementation control group (n = 12). Before and after 12 days of taurine (3 g/day) or placebo supplementation, two identical 2.5-hr VDT work tests were performed while recording the P100, N75 and N145 latencies and P100 amplitude of pattern visual evoked potential (PVEP) and the frequency of critical flicker fusion (CFF). Following 2.5-hr of VDT work, the P100 and N75 latencies of PVEP increased ($P < 0.01$) while the P100 amplitude decreased significantly ($P < 0.01$). The frequency of CFF also reduced significantly ($P < 0.01$). After 12 days of taurine supplementation, the reduction in P100 amplitude after VDT work alleviated significantly ($P < 0.05$). The results suggest that taurine supplementation alleviates visual fatigue induced by VDT work.

Keywords: Taurine – VDT work – Visual fatigue – Pattern visual evoked potential – Critical flicker fusion

Introduction

Work with visual display terminals (VDT) may cause various visual problems such as visual strain, blurring, diplopia, etc., and has adverse effects on the visual nervous system (Aronsson et al., 1995; Murata et al., 1991, 1996). The objective changes in vision physiology include decreased critical flicker fusion (CFF), increased near-point distance, decreased amplitude and prolonged latency of pattern visual evoked potential (PVEP) (Murata et al., 1991; Ossenblok et al., 1988; Iwasaki et al., 1988). The changes in PVEP suggest that VDT work may affect the functioning of the visual nervous system, although no record of VDT work-induced organic disease has been found (Murata et al., 1991; Yamamoto et al., 1991). CFF has been considered to reflect neuron impulse transmission from retinal ganglion cells to the primary visual cortex and is used as an indicator of visual fatigue (Murata et al., 1991).

It has been recognized that taurine plays an important role in maintaining the proper functioning of the central nervous system and retina. The possible functions for taurine include protection of the photoreceptor, regulation of Ca^{2+} transport and regulation of signal transduction (Lombardini, 1991). Depletion of taurine under various circumstances has been found to lead to abnormal electroretinograms (ERG) or degeneration of photoreceptor cells (Wright et al., 1986). Taurine deficiency also affected visual cortex development and visual acuity (Neuringer et al., 1987). In addition, it has been reported that photoreceptor cells release taurine in response to light stress (Salazar et al., 1986). Therefore, we focused our attention on the effect of taurine supplementation on VDT work induced visual fatigue, by evaluating the variation in the physiological indicators of PVEP and CFF.

Subjects and methods

Subjects and study design

Twenty-five male college students aged from 20 to 24 years were selected in this study. None of the volunteers engaged in VDT work and all had normal eyes with appropriate refractive corrections. The protocol was approved by the university's ethics committee and each volunteer gave the informed consent to participate in the study.

Volunteers were randomly assigned to either the taurine supplementation group (n = 13) or the placebo supplementation control group (n = 12) by a

double-blind approach. After the first VDT work, taurine powder (3 g/day, Taisho Co., Tokyo, Japan) or placebo (corn powder) was taken orally for 12 days. Subjects then returned to repeat the identical VDT work at the same time of day after taurine or placebo supplementation.

Subjects performed a 2.5-hr standard English vocabulary test using a personal computer with cathode ray tube (CRT) display under a room illuminance of 500 lx. The black characters were displayed on a white background. Each vocabulary test section was composed of 200 questions in a random sequence and each question had four choices. After finishing one section, the score was calculated by the computer, and then the subjects began a new section with 200 different questions. This process was repeated until the end of the 2.5-hr loading period. During the test, all subjects were encouraged to answer the questions as quickly as possible.

Measurement of PVEP and CFF

The PVEP and CFF were examined both before and within 5 minutes after each VDT work. PVEP was recorded by an Evomatic 400 sensor (Dantec Co., Denmark). Needle-shaped electrodes were inserted subcutaneously in the following position: active electrode in Oz (about 2 cm above the occipital tubercle), reference electrode in Fz (the forehead), ground in left arm. The visual stimulus was a black and white checkerboard pattern displayed on a television monitor and reversed at 1 Hz. At the viewing distance of 120 cm, the check size subtended 36 minutes of arc and the screen of the monitor subtended 12°. The average luminance of the patterns was 51 cd/m^2, resulting in a contrast of 85%. High-pass and low-pass filter settings were 0.5 and 100 Hz (bandpass), respectively. Both eyes were examined at the same time and each recording was the average of 100 responses. On each test, two recordings were made, and the analysis was based on the average of the two recordings. PVEP latencies (one positive and two negative peaks; P100, N75 and N145 components) and the P100 amplitude (the distance in μV between the N75 peak and the P100 peak) were recorded.

CFF was recorded by the same equipment and the television monitor as PVEP measurement. The reverse frequency increased at 4 cycles/sec each time. CFF was determined by increasing the reverse frequency of the checkerboard pattern on the screen until the amplitude of the response curve was less than 3.0 μV.

Measurement of urine taurine and creatinine

Overnight urine specimens have been demonstrated to be suitable for assessing dietary taurine intake (Ogawa, 1986). Therefore, the subjects' overnight urine specimens were collected in the morning of each experiment day and stored at -20°C for assay. Urine taurine concentration was determined by capillary electrophoresis with a Waters capillary ion analyzer (Millipore Co. Milford, MA, USA) using Waters AccQ-Fluor Reagent Kit (Millipore). First, 10 μl of urine was delivered to a 0.5 ml micro reaction tube. Then 70 μl of AccQ-Fluor borate buffer was added and the mixture was vortexed. Finally, 20 μl of AccQ-Fluor reagent was added and vortexted at once for 10 sec. After that, the sample was heated for 10 min at 55°C. A fused silica capillary of length 75 μm I.D. $\times$ 70 cm was used to separate the derivatized samples. The UV absorbance signal was measured at 254 nm. The applied voltage was 20 kV and hydrostatic injection time was 60 sec. The eluent was borate buffer (120 mM sodium tetraborate and 0.5 M SDS). Electrophoretic data were collected and analyzed by 805 Data Station software (Millipore). The final concentration of taurine was corrected by reference to urine creatinine level. Urine creatinine concentration was determined by Taussky's procedure.

Statistics

Data were expressed as mean $\pm$ SD. Statistical analyses were performed by paired *t*-test or Wilcoxon signed rank test for paired data. The probability level of 0.05 was selected as the criterion for statistical significance.

Results

Following 2.5-hr of VDT work, the P100 and N75 latencies of PVEP increased significantly (93.98 ± 4.71 ms vs. 95.45 ± 4.96 ms; 71.80 ± 5.26 ms vs. 73.85 ± 6.48 ms; $P < 0.01$, respectively). The amplitude of PVEP decreased significantly from $8.33 \pm 3.19\,\mu$V to $5.81 \pm 2.66\,\mu$V ($P < 0.01$). The frequency of CFF also reduced significantly from 32.48 ± 5.46 Hz to 28.64 ± 5.74 Hz ($P < 0.01$) after VDT work (Table 1).

As shown in Fig. 1, the taurine supplementation group had a significant increase in urine taurine concentration from 339.8 ± 217.7 mmol/g cr. to 2737.3 ± 1086.6 mmol/g cr. ($P < 0.01$) after 12 days of taurine supplementation, while the control group showed no significant change of taurine level in urine (318.7 ± 169.2 mmol/g cr. vs. 304.1 ± 141.4 mmol/g cr.).

Between the two identical VDT work tests before and after taurine supplementation, there were no significant differences both in taurine and control groups in either the number of questions answered (taurine group: 843 ± 78

Table 1. Latencies and amplitude of PVEP and CFF before and after VDT work without supplementation (n = 25)

	Before VDT work	After VDT work
PVEP latency (ms)		
N75	71.80 ± 5.26	73.85 ± 6.48*
P100	93.98 ± 4.71	95.45 ± 4.96*
N145	116.36 ± 5.38	116.96 ± 5.18
PVEP amplitude (μV)		
P100	8.33 ± 3.19	5.81 ± 2.66*
CFF(Hz)	32.48 ± 5.46	28.64 ± 5.74*

* $P < 0.01$ compared with before VDT work by paired *t* test

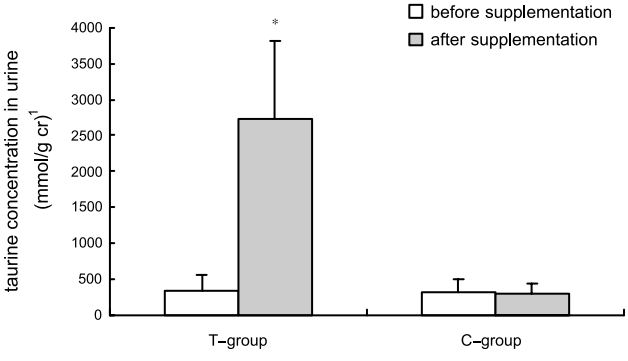

Fig. 1. Taurine concentration in urine before and after supplementation in two groups. *$P < 0.01$ compared with concentration before supplementation. [1]corrected by urine creatinine level. T-group: taurine supplementation group, C-group: placebo supplementation control group

Table 2. Comparisons of changes in PVEP and CFF before and after VDT work between taurine supplementation group and control group

	Change (%)			
	T-group (n = 13)		C-group (n = 12)	
	Before supp	After supp	Before supp	After supp
PVEP latency				
N75	− 3.8 ± 4.5	− 2.0 ± 5.0	− 1.7 ± 3.4	− 1.5 ± 3.4
P100	− 1.7 ± 2.0	− 1.7 ± 1.8	− 1.4 ± 1.8	− 0.6 ± 2.4
N145	− 0.8 ± 1.5	0.1 ± 1.6	− 0.3 ± 4.1	− 1.6 ± 1.4
PVEP amplitude				
P100	33.3 ± 15.5	6.9 ± 28.4*	26.6 ± 20.1	14.1 ± 22.7
CFF	12.0 ± 8.2	5.4 ± 7.2	11.6 ± 9.9	9.4 ± 9.9

Change (%) = (1- the value after VDT/the value before VDT) × 100. * $P < 0.05$, compared with the value before supplementation by Wilcoxon signed rank test. T-group: taurine supplementation group; C-group: placebo supplementation control group. Before supp: before supplementation; After supp: after supplementation

vs. 866 ± 80; control group: 862 ± 97 vs. 881 ± 109) or the scores obtained (taurine group: 82.0 ± 10.1 vs. 84.7 ± 8.8; control group: 81.3 ± 12.8 vs. 82.4 ± 12.6).

Changes (%) in the latencies and amplitude of PVEP and CFF before and after VDT work are shown in Table 2. Changes in N75, P100 and N145 latencies of PVEP after VDT work showed no significant between pre- and post-supplementation, both in the taurine or control groups. However, the reduction in P100 PVEP amplitude after VDT work was lessened significantly after taurine supplementation compared with the value before supplementation ($P < 0.05$), while there was no significant difference between the values before and after placebo supplementation in the control group. The tendency for alleviation in CFF decrease after VDT work was found in taurine supplementation group although the change was not significant (12.0% before taurine supplementation vs. 5.4% after taurine supplementation, $P = 0.057$).

Discussion

PVEP reflects the neurological function of the visual pathway between the retina and visual cortex and is widely used as an objective indication of visual pathophysiology. Delays in PVEP latencies and amplitude attenuation in patients with optic nerve diseases and macular disease have been widely reported (Alshuaib et al., 2000; Andersson et al., 1995; Negishi et al., 2001). Recently, PVEP has been used for the objective estimation of visual fatigue induced by VDT work (Iwasaki et al., 1988; Murata et al., 1991, 1996; Ossenblok et al., 1988). In one of these studies, significant increases of 1.5–4.7 ms in N75, P100 and N145 latencies were found due to 2.5-hr VDT work in keypunchers, while no significant changes were seen in unexposed subjects (Murata et al., 1991); another research reported increases of 4.9–6.5 ms in P100 latency and decreases of 2.0–3.2 μV in N75-P100 amplitude after two different one-hour's visual tasks (Iwasaki et al., 1988). Although the absolute values of the measurement are difficult to compare in different studies because these changes vary largely depending on subjects, intensities of visual load and the stimulus condition used in PVEP recording, our present results show that the mean changes in latencies and amplitude were ∼2.0 ms and ∼2.5 μV, respectively, which concur with the results from the previous investigations. PVEP responses are highly sensitive to the quality of the retinal image. If the image is blurred, the amplitude of the response decreases and peak latency of the contour-specific component in the response increases (Berman et al., 1982). On the other hand, the changes in PVEP latencies suggest that VDT work may affect central nervous system transiently (Murata et al., 1991). Therefore, the decrease in amplitude and increase in latencies of PVEP observed in our study may be associated with a defocused retinal image due to decreased accommodation regulation and centrecephalic hypofunction induced by VDT work. Until now, there has been no report to exam how long the changes in PVEP last due to a single VDT load. However, even if these changes might be transient after a short time visual load, long term of VDT work may induce chronic visual fatigue. Accumulation of visual fatigue by long term VDT work has been found by observed prolongation of VEP latency from Monday to Friday (Murata et al., 1996) and the change of P100

latency, which was inversely correlated with the number of years in VDT work (Murata et al., 1991).

Taurine supplementation alleviated the reduction in PVEP amplitude after VDT work in our study. In Parkinson's disease patients and experimental animals with dopamine deficiency and in Alzheimer disease patients, prolongation in latencies and reduction in amplitudes of PVEP were observed (Bodis-Wollner, 1990; Partanen et al., 1994). Taurine administered to experimental animals has been able to increase the level of acetylcholine in the brain (Tomaszewski et al., 1982), and the injection of taurine into lateral brain ventricles of rats elevated hypothalamic dopamine concentration (Panula-Lehto et al., 1992). Thus, one possible explanation is that taurine may reconstitute PVEP amplitude by regulating the release of neurotransmitters. In addition, light stimulation induces an outflow of taurine from retinal photoreceptors (Salazar et al., 1986). As an antioxidant, taurine has been shown to inhibit light-induced lipid peroxidation and protect photoreceptor structure (Keys et al., 1999; Pasantes-Morales et al., 1985). Taurine has also been demonstrated to be high in iris-ciliary body, although the physiological function is not clear yet (Heinamaki et al., 1986). Decreased accommodation was found after VDT work (Saito et al., 1994). Therefore, we hypothesis that perhaps taurine also play a role in the recovery of visual fatigue by regulating the image on the retina via modulating accommodation of ciliary body, together with enabling photoreceptor cells to maintain normal retinal function. However, since we did not measure accommodative responses in this study, whether the recovery of PVEP amplitude is related with the improvement of accommodation by taurine supplementation and how VDT work, especially with the CRT screen, affects photoreceptor cells still need to be clarified in further studies.

The frequency of CFF declined significantly after VDT work in our study. This is consistent with the reports of Misawa et al. (1984) and Saito et al. (1994), in which decreased CFFs and increased subjective visual fatigue were observed after visual tasks. The tendency for alleviation in CFF reduction after taurine supplementation was observed in this study although it was not significant. This is perhaps due to large individual variance or limited subject number. On the other hand, CFF also has been found to be dependent on difficultly or monotony of tasks, which probably affect cerebral action (Iwasaki et al., 1988). In our study, the same performance scores of the two repeated vocabulary tests before and after taurine supplementation may suggest that taurine has no effect on cerebral response with reference to task performance. Therefore, even though visual fatigue might be alleviated by taurine supplementation, the centrencephalic fatigue induced by task itself perhaps still is remained.

In summary, the occurrence of visual fatigue after VDT work was confirmed by evaluation the latencies and amplitude of PVEP and the frequency of CFF. After taurine supplementation, the alleviated decrease in PVEP amplitude suggests that taurine may play an important role in lessening visual fatigue induced by VDT work.

Acknowledgements

This study was supported by a grant from Taisho Pharmaceutical Co., Ltd., Japan. We are grateful to the volunteers who participated in this study.

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