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The Effects of Horizontal Eye Movement on Mental Health Indices and Psychophysiological Activities in Healthy Subjects

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Objectives The eye movement (EM) has been reported to play a role in enhancing the retrieval of episodic memories and reducing effects of fearful episodes in the past and worries for the futures. However, it is still unclear in the mechanism of EM in normal subjects. We examined the horizontal eye movement (HEM) effect using an aiding apparatus on mental health indices including negative and positive psychological factors, and psychophysiological measures such as heart rate variability and quantitative electroencepaholography (qEEG) in healthy subjects.

Methods Twenty eight healthy subjects were recruited and randomly allocated into two groups : active HEM group and control group. The active HEM group conducted the HEM training with usual stress management audio-intervention using the apparatus inducing eye movement once a day for 14 days. The control group also conducted the same training once a day for 14 days, however, the saccadic eye movement was not included in this training. Psychological measurements, neurocognitive function tests, heart rate variability measurement and qEEG were conducted before and after the training in both groups.

Results In the active HEM group, sleep status using Sleep Quality Scale (SQS) positive factors significantly increased after the training. By contrast, scores on the negative items of Psychological Well-Being Scale (PWBS), and negative items of the Life Orientation Test-Revised (LOT-R) were significantly decreased after the training. The percentage of delta amplitude (1–3 Hz) in qEEG significantly decreased after the HEM training. The percentage of alpha amplitude (8–12 Hz) significantly increased after HEM training. The change of delta amplitude in the active HEM group was positively correlated with the change of sleep satisfaction of Visual Analogue Scale (VAS), and the change of alpha amplitude was negatively correlated with depression of VAS, anxiety of VAS and Beck Anxiety Inventory (BAI).

Conclusions The HEM training improved sleep quality and well-being, and sense of optimism. The HEM training also increased alpha amplitude and decreased delta amplitude in qEEG. The qEEG changes were well correlated with subjective improvement of mental health indices in healthy subjects. These results suggest some evidences that HEM training using the apparatus that induces EM would be helpful in improving subjective mental health in healthy subjects. Further study with larger samples size would be needed.

Key Words Horizontal eye movement · Subjective psychological symptoms · Heart rate variability · Cognitive function · qEEG.

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Introduction

Eye Movement Desensitization and Reprocessing (EMDR) was originally developed by Shapiro1)2) and has been used for relieving anxiety attacks, sleep disturbances, flashbacks, and intrusive thoughts related to a traumatic event in patients with post-traumatic stress disorder (PTSD). EMDR using bilateral stimuli including EM, alternative tapping or sound has repeatedly demonstrated effectiveness in treatment for patients with PTSD in numerous studies.3)4) Many researchers studying the

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effect of EMDR have also supported significant improvement after the treatment in population suffering from various mental problems such as phobias, panic disorder, depression,5)6) and dissociative disorders.7)8) The probable mode of action of the EMDR is congruent with the hypothesis of REM, which is supported by the results of a study by Lavie et al.9) in which combat veterans suffering from PTSD showed longer latency to enter REM sleep and spent less time in REM sleep than did a control group. As the preconscious processing of information during dreaming can be partially desensitized by rapid eye movements (REM), EMDR serves as a similar role in patients with mental problem.2)

Recently, using high-resolution brain single photon emission computed tomography (SPECT) imaging, Lansing et al.10) demonstrated that there was significantly increased perfusion in the left inferior frontal, middle frontal, and superior frontal gyri in PTSD patients after the EMDR treatment. In a case study, a PTSD patient showed decreased PTSD symptoms and increased the bilateral hippocampal volumes after 8 weeks of EMDR treatment.11) Another case study showed that the anterior cingulate gyrus and the left frontal lobe were hyperactive in four of six subjects after EMDR treatment.12) A voxel-based morphometry (VBM) study on the effect of EMDR on PTSD patients showed a significantly lower gray matter density in the left posterior cingulate and parahippocampal gyri in patients who developed PTSD as compared to patients who did not. Interestingly, those who were not responsive to the EMDR treatment showed significantly lower gray matter density in the posterior cingulate, the anterior insula, the anterior parahippocampal gyrus and the amygdala as compared to those who were responsive to the treatment.13) On the other hand, Lamprecht et al.'s ERP study for PTSD patients14) demonstrated that the PTSD patients showed the marked reduction of the P3a amplitude after the EMDR treatment, whereas normal control group that underwent sham treatment did not show any difference. Thus, EMDR treatment might reduce attentional orienting to novel stimuli and arousal level in PTSD patients.

However, it has been reported that eye movement (EM) only showed treatment effects.15)16) EM has influence on memory, emotion, autonomic nervous system (ANS), brain wave, and orienting response, extensively. In case of memory and emotion, EM plays roles in making future recollections of autobiographical memories less vivid,17) enhancing the retrieval of episodic memories,18) enhancing recognition and correct recall for context,19) and reducing vividness and emotionality of visual images about past and future feared events.20) According to Gunter and Bodner's study, EM also influence unpleasant autobiographical memories. When participants performed an auditory shadowing task, or a drawing task while holding an unpleasant autobiographical memory in mind, participants with EM training showed lower ratings of the vividness, emotionality, and completeness of those memories compared to an eyes stationary control. Especially, the study demonstrated that the central-executive component of working memory was taxed by the competing demands of holding a memory in mind while performing another task requiring executive control.21) Also, bilateral EMs increased true memory for the event, increased recollection, and decreased the magnitude of the misinformation effect.22) A study for individuals experiencing significant loss or trauma showed that EM decreased reaction times to unexpected stimuli among those reporting traumatic distress and increased reaction times among those reporting separation distress including vivid reminiscences and the sense of a foreshortened future.23) Relevant to brain wave, there are conflicting results of the effect of EM. A study for healthy subjects performing free recall test showed no evidence that the EM altered participants' interhemispheric coherence,24) but other study showed that relative to non eye-movement controls, engaging in bilateral EMs led to decreased frontal interhemispheric gamma electroencephalogram coherence.25) Also, an orienting response which is a reaction to changes in the environment involving alignment of attention with a source of sensory signals facilitates continuing attention to the memory without avoidance26) and EM are associated with physiological responses underlying the orienting response.27) In addition, EM has been reported to induce relaxation and reduce arousal by influencing ANS.28-32)

Although there is accumulated evidence suggesting that the EMDR or EM may be effective in relieving psychological problems in people who suffer from psychiatric disorders including PTSD to date, it is still unclear whether EM could improve mental capacities in normal subjects. Thus, it is important to study whether EM would be effective in improving mental health indices and psychophysiological activities in healthy individuals.

In this study, our hypotheses are as follows.

First of all, HEM training would lead to positive changes in psychological indices, which was measured by self reported questionnaire in normal subjects. Secondly, HEM training would lead to positive change in physiological states such as heart rate variability (HRV) and quantitative electroencepaholography (qEEG) in normal subjects.

Methods

Subjects

Twenty eight healthy subjects were recruited and randomly allocated into two groups : active HEM group (n = 14) and control group (n = 14). Subjects were recruited from the local community through internet advertisement. An initial screening interview excluded subjects if they had any identifiable neurological disorder or head injury, any personal history of psychiatric disease, and a family history of psychiatric illness, any acute diseases related to internal or surgical medicine, and seizure. All subjects had normal or corrected-normal vision and were right-handed. Handedness was determined by asking which hand the subject tended to use for writing and other precise motor skills. According to our study criteria, they were all non-smokers, abstained from alcohol for at least 3 days before the start and the last tests of this study, and took in caffeine of less than at most 3 or less cups of coffee.

All subjects signed a written informed consent form that was approved by the Institutional Review Boards of Inje University Ilsan Paik Hospital and The Catholic Univeriesty of Korea prior to their participation in the study. The demographics of the two groups are given in Table 1. Active HEM group and control group did not differ significantly in age, sex, and education year. All tests were performed at Seoul St. Mary's Hospital, The Catholic University of Korea.

Procedures

The active HEM group conducted the HEM training with usual stress management audio-intervention using the Eyescan (Humanline Co., Ltd., Korea) apparatus once a day for 14 days. The Eyescan is a goggles-shaped instrument that induces EM in the bilateral horizontal direction by making the eyes of user follow two blue-light vertical bars that move synchronized. The user listened to instructions for meditation through an earphone attached to the machine alternatively with HEM. During the meditation, subjects were instructed to think about their stress levels, and various emotional experiences and to make positive and negative appraisal of self, others and their current situations. They were asked to focusing on breathing and relaxation of their body. It takes about 27 minutes per one session, and participants were asked to perform one session a day. Within one session, total EM duration was 14 minutes (2 minutes × 7 times) and duration of narration for meditation was 13 minutes 22 seconds. EM and narration was presented alternatively (2 minutes 33 seconds' narration - 2 minutes' EM - 1 minutes 34 seconds' narration - 2 minutes' EM - 1 minutes 34 minutes' narration - 2 minutes' EM - 1 minutes 47 seconds' narration - 2 minutes' EM - 1 minutes 6 seconds' narration - 2 minutes' EM - 1 minutes 18 seconds' narration - 2 minutes' EM - 37 seconds' narration - 2 minutes' EM - 2 minutes 52 seconds' narration). Subjects could adjust the speed of EM as they feel comfortable (EM speed condition 1 : 17 saccadic eye movements for 2 minutes, EM speed condition 2 : 21 for 2 minutes, EM speed condition 3 : 24 for 2 minutes, EM speed condition 4 : 28 for 2 minutes, EM speed condition 5 : 34 for 2 minutes, EM speed condition 6 : 45 for 2 minutes, EM speed condition 7 : 64 for 2 minutes, EM speed condition 8 : 105 for 2 minutes and The durations of each set of EM for respective conditions are expressed consecutively as follows : 7.06, 5.71, 5.00, 4.29, 3.53, 2.67, 1.88, 1.14 secs).

The control group also conducted the same training without the saccadic eye movement once a day for 14 days. Psychological measurements, neurocognitive function tests, HRV, and QEEG were measured before and after the training in both groups

Psychological measurements

To measure mental health, Visual Analogue Scale (VAS) of depressive mood, anxious mood, stress, sleep satisfaction, concentration, memory,[33)34)] Beck Depression Inventory (BDI),[35)36)] Beck Anxiety Inventory (BAI),[37)] Perceived Stress Scale (PSS) [38)39)] Stress Response Inventory (SRI),[40)] Positive Affect and Negative Affect Schedule (PANAS),[41)42)] Sleep Quality Scale (SQS),[43)44)] Satisfaction With Life Scale (SWLS),[45)] Psychological Well-Being Scale (PWBS),[46)47)] Connor-Davidson Resilience Scale (CD-RISC),[48)] Life Orientation Test-Revised (LOT-R),[49)50)] Gratitude Questionnaire-Six Item Form,[51)52)] Sense of Humor Questionnaire-6,[53)] State Hope Scale,[54)] Functional Assessment of Chronic Illness Therapy-Spiritual Well-Being Scale (FACIT-Sp),[55)] and Purpose in Life Test[56)57)] were used.

Neurocognitive function tests

For measuring neurocognitive function, we conducted Trail Making Test, Auditory Continuous Performance Test (CPT), and Visual Span Test using computerized neurocognitive tests, the Computerized Neurocognitive Function Test (CNT, Max-Medica, Seoul, Korea).

HRV

Using ECG (Wise-8000, MooYoo Instrument, Seongnam,

Table 1. Comparisons of clinical characteristics between active horizontal eye movement (HEM) and control groups

	Active HEM group (n = 4)	Control group (n = 14)	Statistics and p value
Age (year)	27.0 ± 4.6	27.0 ± 2.9	t = 0.000, p = 1.000
Sex (M : F)	7 : 7	5 : 9	χ^2 = 0.583, p = 0.445
Education (year)	15.4 ± 2.9	16.2 ± 1.8	t = −0.927, p = 0.362

Korea), RMSSD (the square root of the mean squared differences of successive normal to normal intervals) and high frequency (HF) which indicate cardiac vagal function were analyzed.[58)]

EEG recording

EEG activity was recorded and amplified using a NeuroScan NuAmps amplifier (Compumedics USA, El Paso, TX, USA) and 32 Ag-AgCl electrodes mounted in a Quik Cap using a modified 10–20 placement scheme. The vertical electrooculogram (EOG) was recorded using two electrodes, one located above and one below the right eye. The horizontal EOG was recorded at the outer canthus of each eye. EEG data were recorded with a 0.1- to 100-Hz band-pass filter at a sampling rate of 1,000 Hz. The ground electrode was placed on the forehead and the reference was bilateral mastoids. Quantitative electroencephalograph (qEEG) was measured for approximately 1 minutes alternatively with eye open and closed and total about 5 minutes. qEEG was analyzed as follows : delta (1–3 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–25 Hz), gamma (30–50 Hz) waves.

Statistical analysis

To evaluate effectiveness of HEM training between two groups and the differences between before and after the training, repeated measures ANOVA and paired t-tests were conducted. In addition, the correlation analyses were performed for analyzing the relation between the difference scores of the tests (psychological measurements, neurocognitive function tests, HRV) and brain waves before and after the training in the active HEM group.

Results

Psychological measurements

We performed repeated measures ANOVA between two groups. Positive items' score in SQS showed a significant interaction between timing and group [F (1, 26) = 4.495, p = 0.044]. Further analyses were conducted using two-tailed t-tests. Positive items' score in SQS before the training didn't differ significantly between two groups [t (26) = 0.348, p = 0.731], but positive items' score after the training showed a marginally significant difference between two groups [t (26) = 1.78, p = 0.086]. Negative items' score in SQS showed a significant interaction effect between timing and group [F (1, 26) = 4.286, p = 0.048]. Negative items' score in SQS before the training didn't differ significantly between two groups [t (26) = −0.049, p = 0.961], and negative items' score after the training didn't differ significantly between two groups [t (26) = −1.609, p = 0.120]. CD-RISC showed a marginally significant interaction effect between timing and group [F (1, 26) = 4.200, p = 0.051]. CD-RISC before the training didn't differ significantly between two groups [t (26) = 1.607, p = 0.120], and CD-RISC after the training didn't differ significantly between two groups [t (26) = 0.058, p = 0.954]. However, the other psychological measurements didn't show significant interaction effects.

We performed paired t-tests in order to find the differences between before and after the training for each group. In active HEM group, sleep status using positive items' score in SQS increased significantly after the training [before : 16.4 ± 4.9, after : 19.8 ± 4.9, t (13) = −3.094, p = 0.009]. Negative items' score in PWBS [before : 48.9 ± 12.6, after : 43.1 ± 12.0, t (13) = 3.202, p = 0.007], and negative items' score in LOT-R [before : 4.3 ± 2.4, after : 2.9 ± 2.2, t (13) = 2.421, p = 0.031] were significantly decreased after the training. In control group, VAS memory was significantly increased after training [before : 5.4 ± 1.6, after : 6.3 ± 1.9, t (13) = −2.375, p = 0.034] and negative items' score in PWBS [before : 49.0 ± 11.5, after : 45.4 ± 11.3, t (13) = 2.400, p = 0.032] were significantly decreased after the training. Negative items' score in LOT-R showed marginally significant decrease after the training [before : 4.7 ± 2.0, after : 4.0 ± 1.6, t (13) = 1.933, p = 0.075]. However, the other psychological measurements did not show significant differences between the scores before and after the training in both groups (Table 2).

Neurocognitive function tests

There were no significant interaction effects for neurocognitive function tests. In active HEM group, the time to complete TMT set A showed a significant increase after the training [before : 15.6 ± 2.7 sec, after : 17.1 ± 3.4 sec, t (13) = −2.654, p = 0.020], whereas other neurocognitive function tests did not show significant differences between the scores before and after the training in both groups (Table 3).

HRV

There were no significant interaction effects for RMSSD and HF HRV. RMSSD and HF HRV did not differ significantly between the scores before and after the training in both groups (Table 4).

QEEG

Alpha amplitude showed a marginally significant interaction effect between timing and group [F (1, 26) = 3.758, p = 0.063]. Further analyses were conducted using two-tailed t-tests. The percentage of alpha amplitude before the training didn't differ significantly between two groups [t (26) = −1.646, p = 0.112], and the percentage of alpha amplitude after the training didn't differ significantly between two groups [t (26) = −0.075, p =

Table 2. Comparisons of subjective psychological symptoms before and after training in active horizontal eye movement (HEM) and control groups

Test name	Test time	Active HEM group (n = 14)					Control group (n = 14)				
		Mean	SD	t	df	p	Mean	SD	t	df	p
VAS : Depression	Before	2.4	2.1	0.159	13	0.876	2.4	1.8	−0.824	13	0.425
	After	2.3	1.7		13		2.9	2.2		13	
VAS : Anxiety	Before	2.4	1.6	1.249	13	0.234	2.9	1.8	−0.525	13	0.609
	After	1.9	1.5		13		3.1	1.8		13	
VAS : Stress	Before	3.8	2.1	0.114	13	0.911	4.9	2.4	−0.396	13	0.699
	After	3.7	2.3		13		5.0	2.5		13	
VAS : Sleep satisfaction	Before	4.7	2.6	−2.248	13	0.043	4.9	2.1	−0.626	13	0.542
	After	6.4	2.1		13		5.2	2.4		13	
VAS : Concentration	Before	5.1	2.0	−1.344	13	0.202	5.4	1.6	−1.735	13	0.106
	After	6.1	1.5		13		6.1	2.1		13	
VAS : Memory	Before	5.2	2.2	−1.246	13	0.235	5.4	1.6	−2.375	13	0.034*
	After	6.0	1.7		13		6.3	1.9		13	
BID	Before	8.1	4.7	−0.181	13	0.859	10.6	6.9	2.041	13	0.062
	After	8.4	7.3		13		8.0	6.6		13	
BAI	Before	7.6	6.8	0.056	13	0.956	10.1	6.5	1.346	13	0.201
	After	7.5	5.6		13		8.1	7.3		13	
PSS	Before	12.4	5.6	−0.435	13	0.670	15.4	6.9	0.767	13	0.457
	After	13.0	5.4		13		14.2	8.6		13	
SRI	Before	25.8	21.5	0.147	13	0.886	32.0	25.4	1.436	13	0.175
	After	25.2	23.6		13		23.6	24.0		13	
PANAS (+)	Before	13.9	6.9	−1.430	13	0.176	12.6	5.4	0.704	13	0.494
	After	15.9	6.7		13		11..8	7.4		13	
PANAS (−)	Before	8.1	6.2	1.375	13	0.192	9.5	6.0	1.718	13	0.109
	After	6.8	6.2		13		6.7	4.7		13	
SQS (+)	Before	16.4	4.9	−3.094	13	0.009*	15.6	5.9	−1.114	13	0.286
	After	19.8	4.9		13		16.4	5.3		13	
SQS (−)	Before	33.4	7.2	1.115	13	0.285	33.6	8.0	−1.843	13	0.088
	After	31.0	10.3		13		37.3	10.4		13	
SWLS	Before	21.6	6.0	−1.321	13	0.209	19.2	6.4	−0.116	13	0.910
	After	23.2	6.6		13		19.4	6.8		13	
PWBS (+)	Before	92.3	16.2	−0.394	13	0.700	88.9	14.8	0.474	13	0.643
	After	93.1	14.9		13		87.7	15.5		13	
PWBS (−)	Before	48.9	12.6	3.202	13	0.007*	49.0	11.5	2.400	13	0.032*
	After	43.1	12.0		13		45.4	11.3		13	
CD-RISC	Before	75.6	10.9	1.608	13	0.132	67.0	16.9	−1316	13	0.211
	After	71.4	12.5		13		71.0	19.4		13	
LOT-R (+)	Before	18.8	4.3	0.571	13	0.578	17.9	4.1	−1.490	13	0.160
	After	18.4	3.5		13		18.9	5.6		13	
LOT-R (−)	Before	4.3	2.4	2.421	13	0.031*	4.7	2.0	1.933	13	0.075†
	After	2.9	2.2		13		4.0	1.6		13	
Gratitude (+)	Before	23.7	3.7	−1.529	13	0.150	22.8	4.1	0.890	13	0.390
	After	24.3	3.8		13		22.3	3.9		13	
Gratitude (−)	Before	6.4	2.6	0.000	13	1.000	7.0	2.0	−1.295	13	0.218
	After	6.4	2.1		13		7.6	1.7		13	
Humor (+)	Before	9.1	2.0	0.000	13	1.000	8.4	1.6	−1.000	13	0.336
	After	9.1	1.9		13		8.5	1.7		13	

Table 2. Continued

Test name	Test time	Active HEM group (n = 14)					Control group (n = 14)				
		Mean	SD	t	df	p	Mean	SD	t	df	p
Humor (−)	Before	10.1	2.0	−0.763	13	0.459	10.8	1.1	0.268	13	0.793
	After	10.4	1..8		13		10.7	1.1		13	
Hope	Before	37.8	5.1	−0.076	13	0.941	35.6	8.8	−0.532	13	0.603
	After	37.9	5.9		13		36.4	9.4		13	
FACIT-Sp (+)	Before	26.8	7.6	0.760	13	0.461	24.3	9.7	−0.786	13	0.446
	After	26.0	8.3		13		25.5	8.7		13	
FACIT-Sp (−)	Before	2.0	2.0	1.000	13	0.336	2.7	2.0	1.023	13	0.325
	After	1.8	2.0		13		2.2	2.0		13	
Purpose	Before	102.4	16.9	1.255	13	0.231	97.5	20.4	−2.176	13	0.049
	After	105.1	17.9		13		101.7	21.5		13	

+ : Positive items, − : Negative items, ∗ : statistical significance, † : marginal significance. VAS : Visual analogue scale, BDI : Beck depression inventory, BAI : Beck Anxiety Inventory, PSS : Perceived stress scale, SRI : Stress Response Inventory, PANAS : Positive Affect and Negative Affect Schedule, SQS : Sleep Quality Scale, SWLS : Satisfaction With Life Scale, PWBS : Psychological Well-Being Scale, CD-RISC : Connor-Davidson Resilience Scale, LOT-R : Life Orientation Test-Revised, Gratitude : Gratitude Questionnaire-Six Item Form, Humor : Sense of Humor Questionnaire-6, Hope : State Hope Scale, FACIT-Sp : Functional Assessment of Chronic Illness Therapy-Spiritual Well-Being Scale, Purpose : Purpose in Life Test

Table 3. Comparisons of neurocognitive function tests before and after training in active horizontal eye movement (HEM) and control groups

Test name	Test time	Active HEM group (n = 14)					Control group (n = 14)				
		Mean	SD	t	df	p	Mean	SD	t	df	p
Trail making test											
Set (A)	Before	15.6	2.7	−2.654	13	0.020*	17.7	3.4	−0.537	13	0.601
	After	18.1	3.6				17.7	4.9			
Set (B)	Before	28.6	2.3	0.707	13	0.492	26.7	6.2	−1.129	13	0.279
	After	26.6	5.4				28.6	5.5			
Auditory CPT*											
Correct response	Before	132.9	2.9	0.922	13	0.373	133.2	1.8	1.408	13	0.183
	After	131.8	5.2				130.6	8.2			
Omission error	Before	2.1	2.9	−0.922	13	0.373	1.8	1.8	−1.408	13	0.183
	After	3.2	5.2				4.4	8.2			
Commission error	Before	1.9	2.1	−0.885	13	0.392	1.9	1.4	−1.149	13	0.271
	After	3.0	3.6				2.9	2.8			
Reaction time (sec)	Before	0.6	0.0	0.094	13	0.926	0.6	0.0	1.575	13	0.139
	After	0.6	0.0				0.6	0.0			
Visual span test											
Forword	Before	7.2	0.8	−1.612	13	0.131	7.1	1.2	−0.929	13	0.370
	After	7.5	0.9				7.4	0.9			
Backward	Before	6.4	0.7	−0.421	13	0.681	6.5	0.9	0.328	13	0.748
	After	6.5	0.7				6.5	0.7			

∗ : statistical significance. CPT : Continuous Performance Test

Table 4. Comparisons of the heart rate variability before and after training in active horizontal eye movement (HEM) and control groups

Test name	Test time	Active HEM group (n = 14)					Control group (n = 14)				
		Mean	SD	t	df	p	Mean	SD	t	df	p
HRV : RMSSD	Before	25.7	9.0	−0.013	13	0.990	26.1	9.9	1.803	13	0.095
	After	25.7	11.3				23.2	7.2			
HRV : HF	Before	5.2	0.6	0.769	13	0.456	5.0	1.0	0.447	13	0.662
	After	5.1	0.8				4.9	0.8			

RMSSD : the square root of the mean squared difference of successive NNs. The term “NN” is used in place of RR to emphasize the fact that the processed beats are “normal” beats. HF : high frequency

0.940]. However, the other brain waves didn't show a significant interaction effects.

In active HEM group, the percentage of delta amplitude (1–3 Hz) in qEEG significantly decreased after HEM training [before : 15.2 ± 3.2, after : 13.2 ± 2.3, t (13) = 2.382, p = 0.033]. The percentage of alpha amplitude (8–12 Hz) significantly increased after HEM training [before : 20.1 ± 4.7, after : 22.2 ± 4.7, t (13) = −2.656, p = 0.020](Table 5 & Fig. 1). However, the other brain waves didn't show significant differences between the scores before and after the training in both groups.

Correlations between tests

The change of delta amplitude in active HEM group was positively correlated with the change of sleep satisfaction of VAS [r (14) = 0.597, p = 0.024] and the change of alpha amplitude was negatively correlated with depression of VAS [r (14) = −0.560, p = 0.037], anxiety of VAS [r (14) = −0.640), p = 0.014] and BAI [r (14) = −0.555, p = 0.040].

Discussion

This study was conducted to examine the effects of HEM on mental health and psychophysiological indices in the healthy controls using the apparatus inducing eye movement. We found that HEM training improves sleep quality and well-being, and decreases the sense of pessimism. HEM training also increased alpha amplitude and decreased delta amplitude in qEEG. The qEEG changes were well correlated with subjective improvement of mental health indices.

In repeated measures ANOVA and independent sample t-tests for all tests, positive and negative items in sleep quality (SQS), resilience (CD-RISC), and alpha amplitude showed significant or marginally significant interaction effects, but positive items' score in SQS after the training only showed a marginally signif-

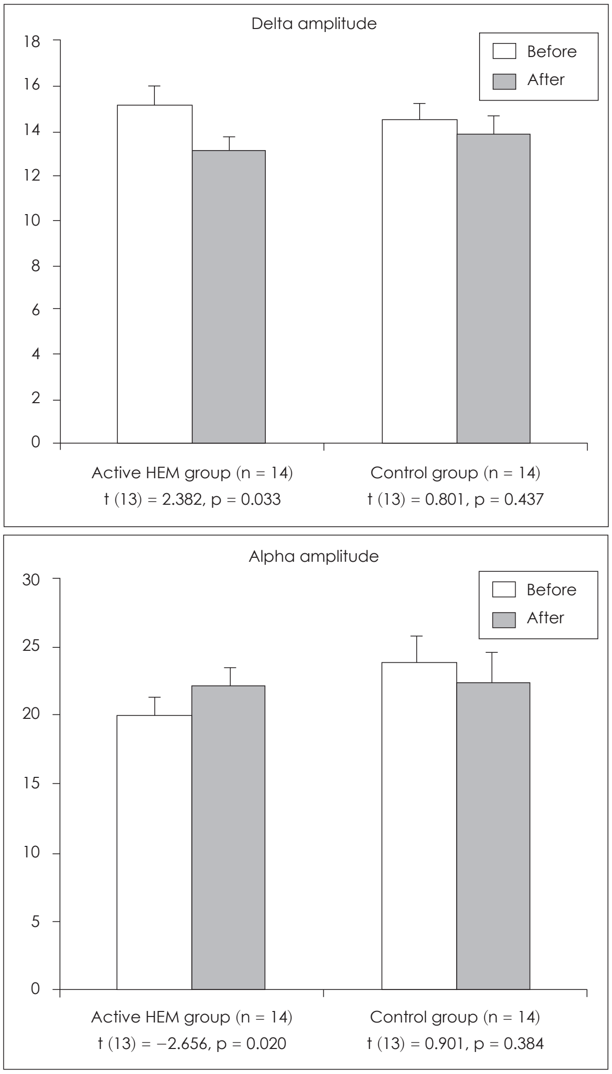

Fig. 1. Comparisons of qEEG change for the percentage of delta (1–3 Hz) and alpha amplitude (8–12 Hz) before and after training in active horizontal eye movement (HEM) and control groups. The Y-axis means the percentage of specific frequency band in whole frequency range. The error bar means the standard error of the mean.

Table 5. Comparisons of the qEEG before and after training in active horizontal hye movement (HEM) and control groups

Test name	Test time	Active HEM group (n=14)					Control group (n=14)				
		Mean	SD	t	df	p	Mean	SD	t	df	p
Delta amplitude (%)	Before	15.2	3.2	2.382	13	0.033*	14.6	2.5	0.801	13	0.437
	After	13.2	2.3				13.9	3.3			
Theta amplitude (%)	Before	10.3	1.9	−0.728	13	0.479	10.2	1.4	−1.048	13	0.314
	After	10.6	2.1				10.8	2.4			
Alpha amplitude (%)	Before	20.1	4.7	−2.656	13	0.020*	23.9	7.3	0.901	13	0.384
	After	22.2	4.7				22.4	8.7			
Beta amplitude (%)	Before	28.2	3.3	−0.254	13	0.803	26.7	3.5	0.636	13	0.536
	After	28.4	3.7				26.2	2.6			
Gamma amplitude (%)	Before	26.1	6.4	0.333	13	0.744	24.6	7.1	−1.212	13	0.247
	After	25.7	6.7				26.7	10.2			

＊ : statistical significance

icant difference between two groups [t (26) = 1.78, p = 0.086]. However, in paired t-tests to investigate the differences between before and after the training in active HEM and control groups respectively, active HEM group showed improvement in SQS and PWBS, LOT-R, increase of alpha amplitude and decrease of delta amplitude in qEEG, although control group showed improvement in VAS memory and decrease in sense of pessimism. Overall, these results indicate improvements in sleep quality, psychological well-being, life orientation and brain function.

In psychological measurements, the quality of sleep measured by SQS positive factors was significantly improved in the active HEM group after the training. It was hypothesized that the rapid eye movement in REM sleep may be related to the training effect of HEM in the normal individuals.[59)60)] PTSD patients usually showed longer latency to enter REM sleep and spent less time in REM sleep than did healthy controls.[61)] PTSD patients after EMDR treatment showed an increase in sleep quality measured by polysomnograms.[62)] These results are suggesting that eye movement could be related to improving sleep quality in PTSD patients. Our present results suggest that HEM is likely to improve the sleep quality in healthy individuals. On the other hand, PTSD patients usually show an increase in REM density (ratio of total minutes of rapid eye movements for total minutes of REM sleep). An increase in REM density has been reported to occur when they experience intense learning or strong emotional events.[63-65)] It has been suggesting that memory for emotionally salient information may be consolidated during sleep.[66)] It was also revealed that sleep deprivation disrupted the normal emotional processing.[67)] Even though sleep status was measured subjectively in this study, improved sleep quality after HEM training may provide an important explanation for the effect of the EM in healthy subjects.

In the active HEM group, negative components of subjective well-being scales were significantly decreased after the training. The results suggest that HEM training using the apparatus inducing EM could also change the life quality in normal healthy people. Scheier, et al.[68)] suggested that highly optimistic individuals use more problem-solving strategy in a situation when stress is manageable, but accept the situation for what it is when it is impossible to control stress. In contrast, highly pessimistic individuals deny that a problem has occurred or avoid dealing with the problem. According to our results, HEM seems to reduce the pessimistic attitude for life. Further researches are needed to explore the mechanism by which HEM improves subjective well-being.

In the qEEG results, HEM training significantly decreased delta amplitude and significantly increased alpha amplitude in qEEG. Delta amplitude is usually associated with the deepest stages of sleep (3 and 4 NREM). The increase of delta amplitude usually suggest the drowsy or sleeping state thereby suggesting reduced mental function in healthy subjects. Previous studies showed an increase of delta activity in the subgenual prefrontal cortex (PFC) in patients with major depression.[69-71)] EEG delta-activity was reported to decrease in the subgenual PFC of melancholic subjects as compared to non-melancholic subjects after antidepressant treatment.[71)] Therefore, a decrease of delta amplitude after HEM training indicates the mentally alert state.

Furthermore, our results showed a significant increase of alpha amplitude after HEM training. Alpha wave is thought to be a dynamic signal with diverse properties sensitive to stimulus presentation and expectation.[72)] In addition, Martindale and Hasenfus[73)] showed that the creative group showed highly functional alpha activity than did the uncreative participants when both groups were developing their creative stories, although there were no differences in the EEGs during the resting condition. These findings may suggest that the creative participants were operating at a lower level of arousal than were the less creative participants.[74)] Recently, a study using the Remote Association Test (e.g., name alternative uses of a brick) reported that REM enhances the formation of associative networks and the integration of unassociated information for creative problem solving.[75)] The amplitude of delta amplitude in the active HEM group was positively correlated with the scores in sleep satisfaction of VAS and the magnitude of alpha amplitude was negatively correlated with depression and anxiety scores in VAS and BAI. These results demonstrate that the change of brain wave such as delta and alpha is related to the improvements of mental health indices. There exist previous studies about correlations between the improving mental health and EEG changes.[76)77)] As mentioned before, sleep deprivation causes many problems in immune regulation, metabolic control, memory, and emotional processing.[67)78)] Sleep is also very important in the optimal function of brain regions associated with emotional processing.[79)80)] The results from the present study suggested that positive effect of HEM training could be associated with qEEG changes.

In control group, increase in TMT Set A completion time, improvement in VAS memory and decrease of negative items' score in PWBS, marginally significant decrease of negative items' score in LOT-R seem to be due to the effect of meditation only without HEM.

Our study has several limitations. Firstly, a small number of subjects participated in our study. Secondly, since the present study was performed for normal subjects, it is unclear that the treatment used in this study can be applied to patients with severe psychopathology to date. Third, other factors except HEM, that is, the effects of meditation, attention and orienting response on our results couldn't be excluded in our study. In conclusion, the present study provided some limited evidences that the HEM training improved sleep quality, subjective wellbeing, and sense of optimism in healthy subjects. HEM training also increased alpha power and decrease delta power in qEEG. The qEEG changes were well correlated with subjective improvement of mental health indices. These results suggest that HEM training using the apparatus that induces eye movement would be helpful in improving subjective mental health indices in healthy subjects, and these positive effects might be associated with qEEG change. Further study with larger samples size should be conducted to confirm these findings.

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Conflicts of interest

The authors have no financial conflicts of interest.

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