MEASUREMENT OF STRESS LEVEL TO PREVENT POST-TRAUMATIC STRESS DISORDER DEVELOPED BY IDENTIFYING DEAD BODIES

Masakazu Higuchi[1], Isao Yamamoto[2], Yasuhiro Omiya[3], Shuji Shinohara[1], Mitsuteru Nakamura[1], Naoki Hagiwara[3], Takeshi Takano[3], Shunji Mitsuyoshi[1], Shinichi Tokuno[1]

[1]Graduate School of Medicine, The University of Tokyo, 113-0033, Japan, e-mail: {higuchi, shinokan99, m-nakamura, mitsuyoshi, tokuno}@m.u-tokyo.ac.jp
[2]Department of Disaster Relief Medicine/Dentistry, Kanagawa Dental University, 238-8580, Japan, e-mail: yamamoto@kdu.ac.jp
[3]Research and Product Development, PST Inc., 231-0023, Japan, e-mail: {omiya, hagiwara, takano}@medical-pst.com

Abstract. *Mental health issues in individuals who interact with dead bodies during a disaster have been issue of interest. Therefore, there is increased demand for technologies that enable simple and easy-to-perform stress checks. The authors have been pursuing research on technologies that can be used to estimate an individual's mental state based on voice. Analyses of voice have the benefits of being non-invasive and simple to perform. In the present study, we investigated the usefulness of stress measurements using voice in Identification Workshop of Dead Bodies. The participants comprised dentists and other concerned individuals. Participants who underwent training using a mannequin prior to training with an actual body tended to have more similar mental states before and after the body training than those with no mannequin training before the body training. Although the differences we observed were not statistically significant, we do believe that prior training with a mannequin did have an effect on the mental state before and after the body training. Our results suggest that mannequin training may induce increased stress resistance during the body training. We thus believe that stress evaluations using voice analysis are efficacious, easy-to-use, and can be performed even during the limited amount of time set aside for training. We also believe that this technology can be used at actual disaster-response sites.*

Keywords: *mental health care, voice analysis, body-related work*

PACS numbers: 89.65.Gh, 89.75.Fb, and 05.45.Tp

1. INTRODUCTION

Work involving dead bodies at medical sites following disasters is extremely stressful. At times, this work can even be detrimental to health and lead to post-traumatic stress disorder and other issues [1, 2]. Identification of bodies, which is a task involving corpses, requires the collection of dental information from dead bodies, comparing this information with pre-death dental treatment records, and confirming the identity of the body. Dentists are often asked to participate in the coroner's inquest and to perform post-mortem examinations. Regular meetings of " identification workshop" including dentists and other physicians are held [3]. In these groups, mannequins or actual corpses are used in training drills for large-scale disasters involving numerous dead bodies. In their daily work, dentists almost never encounter a corpse, and while exposure to stress is expected in this type of training, measurements of the effects of such training and related stress levels are almost never made.

Self-administered psychological tests are generally used to assess stress and depression. These assessment tools include the General Health Questionnaire [4] and Beck Depression Inventory [5]. While such tests are non-invasive and relatively easy to perform, the effects of reporting bias cannot be excluded when using these tests. Reporting bias occurs when specific information is, either consciously or unconsciously, selectively underestimated or exaggerated [6]. Evaluations of mental states using biomarkers such as saliva [7] or blood [8] have been proposed, yet biomarker evaluations are still under development. In addition, these tests are expensive, invasive, and are certainly not easy to perform.

The authors have been pursuing research on technology that can estimate stress states based on one's voice [9]. Voice analysis has the advantages of being objective, non-invasive, and easy to perform.

Here we aimed to verify the efficacy of using voice in individuals in identification workshop to measure stress. We especially were interested in learning whether the use of mannequins for training helps reduce the stress associated with practice with actual dead bodies. We thus evaluated the participants' mental states based on their voices before and after training with dead bodies. We studied both participants who performed the actual-body practice after mannequin practice, and those who did not undergo mannequin training.

2. METHODS

2.1 Detail of Identification workshop

Members of this identification workshop practiced using actual corpses (below, "bodies"), mannequins, and case files. Participants were divided into three groups (A, B, and C) rotating through the different training paradigms to ensure that there was no simultaneous overlapping of training between the groups. Before and after each training type, the voices of participants were recorded in a room separate from the practice room. These recordings were then analyzed. Figure 1 shows a flow scheme for each group's practice types and voice recordings.

Group	1st Training	2nd Training	3rd Training
A	Case File	Mannequin	Body
B	Mannequin	Body	Case File
C	Body	Case File	Mannequin

↑ Voice Recording ↑ Voice Recording ↑ Voice Recording ↑ Voice Recording

Fig. 1 Flow scheme for training and voice recordings.

The participants ranged in age from 27 to 67 years. The study included 27 individuals (23 men and 4 women), as follows: police dentists (6 individuals), Dental Association members in charge of identification team (5), general dentists (8), university-affiliated dentists (8), other (1), and unknown (1) (it is noted that 2 participants were affiliated with two separate institutions). Group A included 10 participants, Group B included 7 participants, and Group C included 10 participants. The mean age of the participants was 46 years, with a standard deviation of 11.77.

2.2 Voice recordings

Voice recordings were performed in a small area blocked off by partitions to minimize the effects of noise. The participants were asked to read the same standard phrases before and after each training period. We used the 17 standard phrases shown in Table 1. The participants were asked to pause for 1 or 2 seconds before reading each phrase, and all phrases were read in order, from top to bottom.

Noise levels in the recording space were approximately 26 dB. The noise levels were measured using a high-function sound level meter, LA-3570 (Ono Sokki; Kanagawa, Japan).

The voices were recorded using a ME52W (Olympus; Tokyo, Japan) pin microphone attached to the chest approximately 10 cm from each participant's mouth. The recording device was a Portable Recorder R-26 (Roland; Shizuoka, Japan) and the recording format were 96 kHz and 24-bit.

2.3 Voice analysis

Voice analysis was performed using the Mind Monitoring System (MIMOSYS, PST Inc.) developed by the authors' research group. Recorded voices were analyzed after conversion to 11 kHz, 16-bit voice data.

Table 1 Standard phrases.

No.	Phrase
1	"i, ro, ha, ni, ho, he, to" [former Japanese equivalent of "a, b, c, d, e, f, g," and still (mostly) taught to children today]
2	It is a fine [clear] day today.
3	"with nothing better to do" [Donald Keene translation of the beginning line of "Essays in Idleness," a classical work from the 14th century familiar to most educated Japanese individuals, especially this opening phrase.]
4	"I am a cat." [title of a novel by Soseki Natsume]
5	"Long, long ago, in a certain place . . . " [Japanese equivalent of "Once upon a time . . . "]
6	"a, i, u, e, o" [this phrase and those in nos. 7, 8, and 9 below are sequential sounds, equivalent in ways to the English alphabet, and just as familiar]
7	"ka, ki, ku, ke, ko"
8	"ra, ri, ru, re, ro"
9	"pa, pi, pu, pe, po"
10	"When I think of the path of life, I can't believe I've come this far." [Title of a popular song, then a movie, and then a television drama from the late 1970s and early 1980s.]
11	Galapagos Islands
12	I am tired and listless.
13	I'm feeling fine! [I'm in good spirits.]
14	I slept well last night.
15	I have a good appetite.
16	I'm easily irritated. ["I tend to get angry easily."]
17	I feel calm and peaceful.

The free software EcoDecoTooL ver. 1.14 was used for the voice conversion.

MIMOSYS is based on vocal emotion recognition technology (ST: Sensibility Technology) [10]. Briefly, a mental state is quantified and output based on the voice. The emotions of the speaker are measure based on patterns of changes in fundamental frequencies within speech. Altered patterns of fundamental frequencies were analyzed, and the emotions included in the voice were quantified as levels of "Calmness," "Anger" "Joy," "Sorrow," and "Excitement." Using our

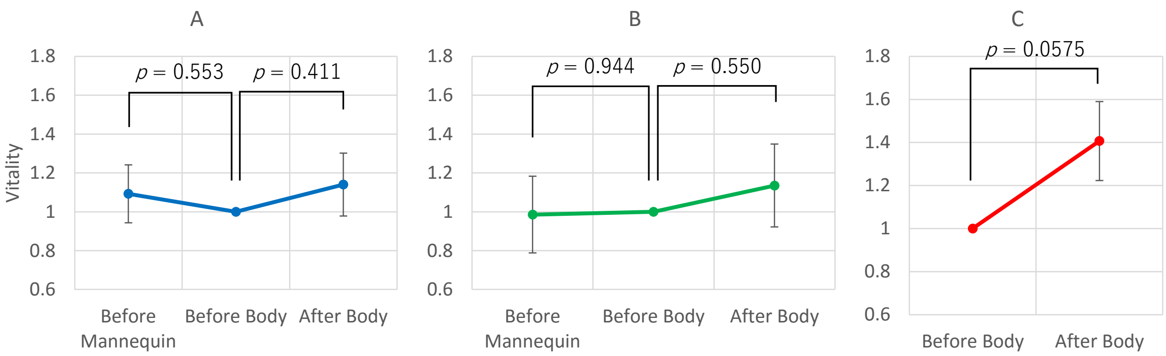

Fig. 2 T-test significance probabilities (p values) corresponding to changes in the mean vitality of Groups A and B when comparing before mannequin training to after body training, as well as changes in the mean vitality of Group C from before body training to after body training.

technology, we quantified "vitality", which is the mental state immediately after speech analyzed using ST. The "Mental Activity" was output as the quantification of the mid-term mental state. The values used were "1" or "0", and higher values, were reflective of more favorable mental states. We evaluated vitality and the emotional components of different mental states before and after each training type.

The shortest unit in voice-emotion analysis is the "utterance," which signifies a unit of continuous voice that is divided by breathing (intake or expulsion of breath). In actual practice, the beginning of an utterance is detected as the time when there is a change from silence (a non-sound state) to a vocalization state that continues for a certain length of time. The termination of that utterance is when there is transition from a vocalization state to a state of silence that continues for a certain length of time. Judgements of vocal utterance state or silence state are performed by setting threshold values for the amplitude of the time waveform of a vocalization. A minimum of seven utterances is required for voice analysis using MIMOSYS. Using the phrases shown in Table 1, a one-time recording of the set enables sufficient capture of more than seven utterances.

The following free software were used for statistical test: R ver. 3.3.2 and G*Power ver. 3.1.9.2 [11].

3. RESULTS

3.1 Vitality

Groups A and B performed mannequin training before body training, while Group C performed body training before mannequin training. Figure 2 shows changes in the mean vitality value from before mannequin training to after body training for Groups A and B, and from before body training to after body training for Group C. Note that vitality levels for each Group before body training have been standardized for comparison. Error bars show standard errors. T-tests were performed to determine whether there were significant changes in vitality before vs. after mannequin training and before vs. after body training for Groups A and B, and before vs. after body training for Group C. Figure 2 also shows significance probabilities (*p*-value).

In the tests, the *p*-value was dependent on sample number and was not affected by actual sizes of differences. "Effect size" (ES) has been proposed as an index for the evaluation of differences. We have included ES in our evaluation. ES is an index that is not dependent on sample size. Cohen's *d* [12] is a representative ES of the corresponding difference between two paired groups and is defined by the standardized quantity of the difference between the respective sample means of the two groups. That is,

$$d = \frac{|\mu_X - \mu_Y|}{\sqrt{\frac{\sigma_X^2 + \sigma_Y^2}{2}}} \tag{1}$$

where μ_X, μ_Y, σ_X, and σ_Y express respectively the mean values of groups X and Y, the standard deviations of groups X and Y. The following have been proposed [12] as criteria for ES sizes corresponding to differences between paired groups:

Small: 0.2, medium: 0.5, and large: 0.8 (2)

Figure 3 presents summary graphs for each group shown in Fig. 2. These graphs show ES values for changes in the mean vitality of Groups A and B before and after mannequin training, and before and after body training, and the ES value of the change in mean vitality of Group C before and after body training.

3.2 Emotional component

Figure 4 shows changes in the means of emotion components before and after body training. Note that the emotional component values for each group before body training have been standardized for comparison. T-tests were performed to determine whether there were significant changes in the emotional components for each respective group before and after body training. Figure 4 also shows significance probabilities (*p*-values) for each of these comparisons. Figure 5 presents summary graphs for each emotional component in each group shown in Fig. 4. Figure 5 also shows the ES values for changes in mean emotional components of each group before and after body training.

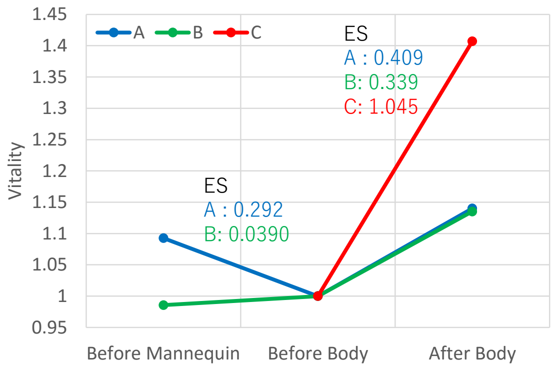

Fig. 3 Effect size (ES) values of changes in mean vitality in Groups A and B before and after mannequin training, and before and after body training, and the ES value of the change in mean vitality of Group C before and after body training.

4. DISCUSSION

In Groups A and B, no significant differences were found in mean vitality differences, neither before or after mannequin training, nor before or after body training. Inasmuch as the ES was also small, no actual differences were detected. We thus believe that there were no differences in vitality mean changes from before mannequin training to after body training in Groups A and B. Our results suggest that mannequin training improved tolerance to the stress of contacting a dead body.

Compared to Groups A and B, Group C displayed a major increase in mean vitality from before to after body training. Group C came into contact with a dead body before training with a mannequin. This was expected to lead to a decline in mean vitality after body training due to excessive stress. However, our results did not confirm our hypothesis. Nevertheless, a state of temporary excitement is said to exist immediately after exposure to intense stress [13]. Therefore, the increase in mean vitality after body training is thought to have been a manifestation of a mood upswing directly after exposure to intense stress. In Group C, we observed a tendency for a difference in mean vitality before vs. after training. Since the ES for this difference was an extremely high value, it is highly likely that there was an actual difference in mean vitality.

Based on the above findings, we believe that stress evaluation based on an individual's voice is useful, easy to perform, and can be performed in a limited amount of time during practice sessions.

In the present study, we were unable to obtain sufficient statistical significance. We believe that this is due to the low power of the test used. However, given the power of this test, it is probable that if a significant difference were to in fact exist, this test would correctly detect that significance, as there is a tendency for decreased power when there are insufficient sample numbers [12]. We thus believe that the numbers of individuals assessed in this study were insufficient.

Below we will consider changes in the emotional components of Group C before and after body training. We observed a tendency for larger changes in Group C than in Groups A and B in components other than "Joy." While the change in the "Joy" component was larger for Group C than for Group A, the change for Group B in this component was larger than that for Group C. In Group C, the components "Anger," "Joy," and "Excitement" changed in the positive direction, while "Calmness" and "Sorrow" changed in the negative direction. We thus believe that Group C members were in a state of raised mood excitement after body training. Of the ES values corresponding to changes in mean emotional components in Group C, the ES of calmness was slightly lower than the medium effect from (2), that of the "Anger" component was extremely high, and those of the "Joy," "Sorrow," and "Excitement" components was larger than the medium effect from (2). These values thus had some differences. These tests also had low power, which is thought to be the reason for our inability to detect significant differences.

Changes in the means of the emotional components in Group B before and after body training showed similar tendencies to those in Group C. However, since the ES values were small for components other than "Joy," no actual differences are thought to have existed. While the ES of changes in the "Joy" component was higher than the medium effect from (2), the standard error was larger for Group B than for Group C. Thus, despite the change in the medium ES value in Group B, the reliability of this change in the "Joy" component was less than that for Group C. In fact, the ES of changes in the "Joy" component for Group B was smaller than that for Group C.

5. CONCLUSION

To ascertain the efficacy of stress measurements using voice analysis, this study used voice analysis to perform stress evaluations of dentists and other individuals in identification workshop.

Our results suggest that the use of practice mannequins may have improved resistance to the stress following interaction with the dead bodies. We were thus able to confirm the efficacy of stress evaluations using voices of individuals. We also believe that this technology can be used at actual disaster-response sites.

6. REFERENCES

[1] Shigemura, J., Takei, E., Tokuno, S. (2008). *Disaster workers and exposure to dead bodies:*

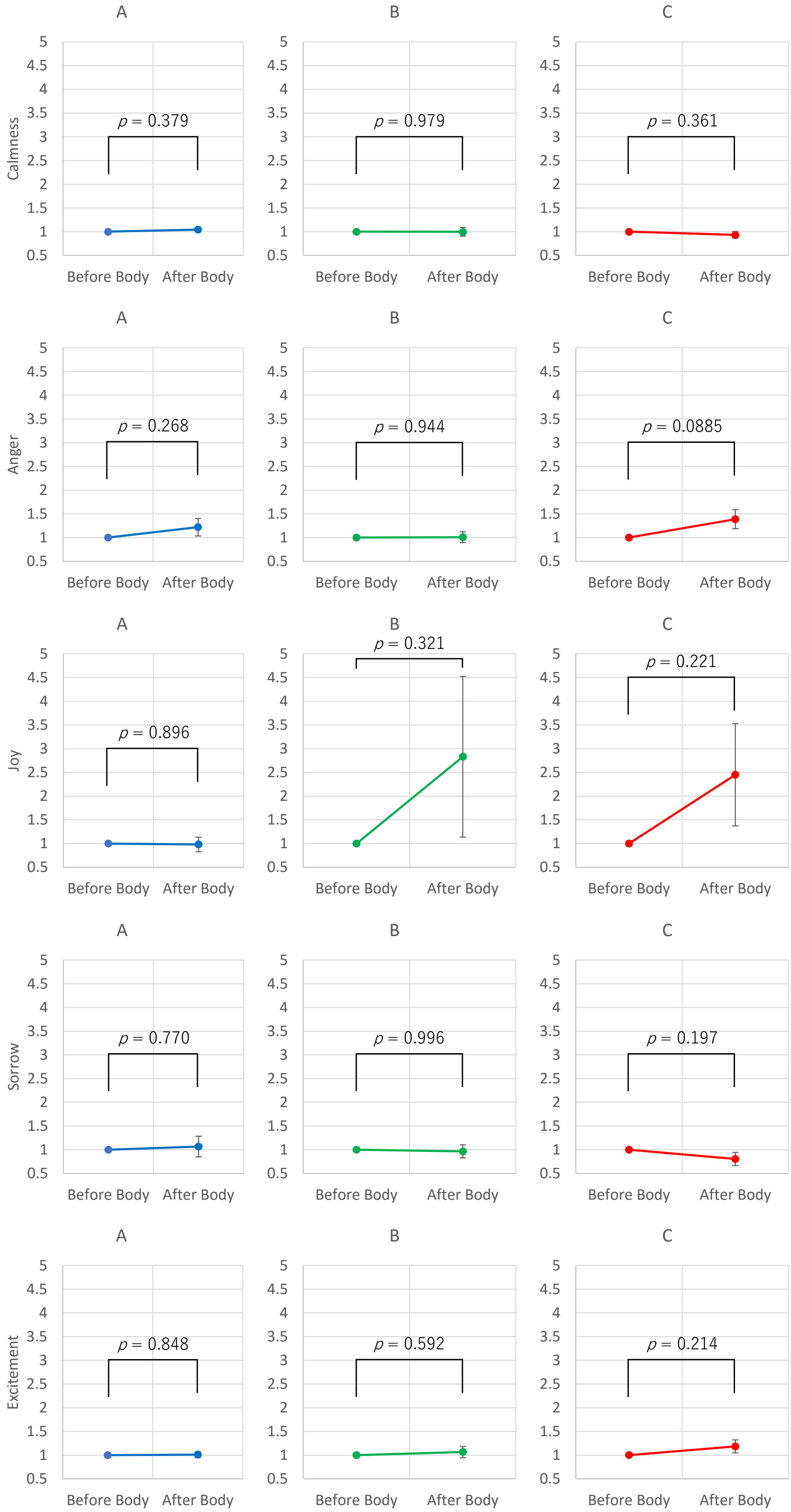

Fig. 4 Changes in the means of emotion components for each group before and after body training, and t-test significance probabilities (p values) corresponding to these changes.

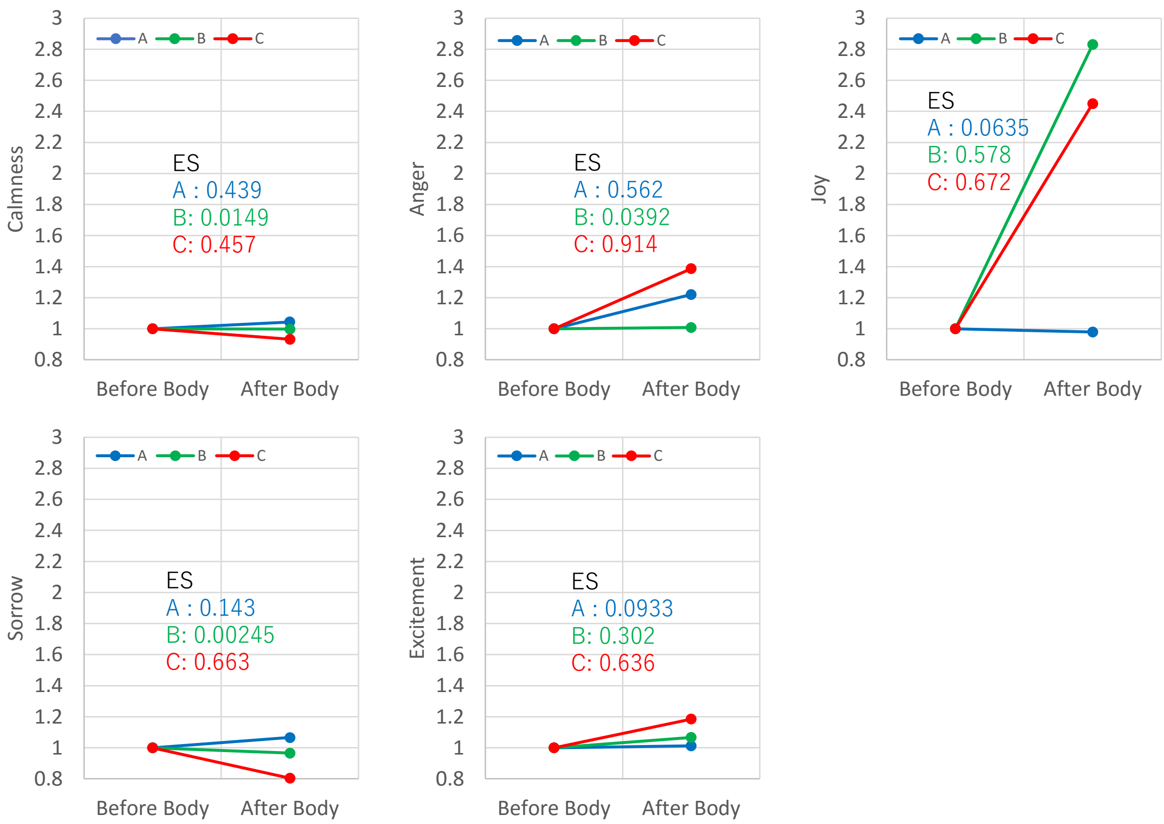

Fig. 5 Changes in the means of emotion components for each group before and after body training, and effect sizes (ES) corresponding to these changes.

psychological responses and stress coping strategies. National Defense Medical Journal, **55**(10), 163-168. [in Japanese]

[2] Katayama, K., Itoga, H., Someda, H. (2912). *Lessons learned from dental activities in the Great East Japan Earthquake disaster relief mission (First Report): Disaster victim identification activities conducted by Japan Self-Defense Forces Dental Officers*. National Defense Medical Journal, **59**(12), 131-139. [in Japanese]

[3] Yamamoto, I., Ohira, H., Yamado, Y., Kimoto, K., Nihei, T., Hamada, N., Lee, M., Tsukino, K. (2016). *Identification training program using a cadaver-like dental mannequin*. Japanese Journal of Disaster Medicine (Japanese Association for Disaster Medicine, JADM), **21**(2), 173-178. [in Japanese]

[4] Goldberg D.P. (1978). *Manual of the General Health Questionnaire*. Windsor: NFER Publishing.

[5] Beck A.T., Ward C.H., Mendelson M., Mock J., Erbaugh J. (1961). *An Inventory for Measuring Depression*. Arch. Gen. Psychiatry, **4**, 561-571.

[6] Delgado-Rodriguez M., Llorca J. (2004). *Bias*. J Epidemiol Community Health 2004, **58**(8), 635-641.

[7] Izawa S., Sugaya N., Shirotsuki K., Yamada K.C., Ogawa N., Ouchi Y., Nagano Y., Suzuki K., Nomura S. (2008). *Salivary dehydroepiandrosterone secretion in response to acute psychosocial stress and its correlations with biological and psychological changes*. Biological Psychology, **79**(3), 294-298.

[8] Sekiyama A. (2007). *Interleukin-18 is involved in Alteration of Hipothalamic-pituitary-adrenal axis activity by Stress*. Society of Biological Psychiatry Annual Meeting, San Diego.

[9] Tokuno S., Mitsuyoshi S., Suzuki G., Tsumatori G. (2014). *STRESS EVALUATION BY VOICE: a novel stress evaluation technology*. Proc of 9th International Conference on Early Psychosis, Tokyo, 17-19.

[10] Mitsuyoshi S. (2015). *Development of Verbal Analysis Pathophysiology*. Econophysics, Sociophysics & Other Multidisciplinary Sciences Journal, **5**(1), 11-16.

[11] Faul F., Erdfelder E., Lang A.G., Buchner A. (2007). *G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences*. Behavior Research Methods, **39**(2), 175-191.

[12] Cohen J. (1988). *Statistical Power Analysis for the Behavioral Sciences*. London: Routledge.

[13] Herman J.P., Cullinan W.E. (1977). *Neurocircuitry of stress: central control of the hypothalamo-pituitary-adrenocortical axis*. Trends in Neurosciences, **20**(2), 78-84.