APG(Acceleration Plethysmography) Correlate with Moods in Nursing Workers with Fatigue after Work

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Research

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Abstract

Fatigue or stress in the workplace is a serious problem. The profession of nursing, in particular, is physically and mentally stressful, which often leads to job retrenchment, and shortage of workers. Solving this problem requires a deeper understanding of the fatigue and stress caused by work, and there is a need to consider countermeasures.

Purpose: The purpose of this study is to assess the correlation between the psychological and physiological fatigue of healthy nurses during normal work, and to measure nursing stress and fatigue more conveniently.

Method: We examined healthy nurses’ physiology (Acceleration Plethysmography: APG and Blood Pressure: BP) and psychology (Visual Analogue Scale: VAS and Mood Inventory Scale: MIS) before and after a normal workday.

Results: We observed that after a normal days’ work, the nurses’ autonomic activity, high-frequency component power (HF), low-frequency component power/high-component power ratio (LF/HF ratio), and total power (LF□HF) increased significantly. Psychologically, VAS increased significantly, while the MIS Refreshing Mood decreased remarkably. The HF value correlated significantly with VAS and the MIS Refreshing Mood. The MIS Refreshing Mood correlates significantly with increased sympathetic and autonomic nervous function. Thus, an MIS test may alternative for physiological tests to detect fatigue more quickly and easily.

Conclusion: These findings may help nurses and other workers reduce fatigue, cope with stress, and prevent illness. We hope this study will contribute towards addressing the issues related to workers’ mental health in the workplace.

Introduction

Workplace fatigue impacts workers’ physical and mental health (Holmes & Raha 1976). Large-scale sociological investigations reveal that more than 50% adults suffer from fatigue (Watanabe 2008). Fatigue not only impairs concentration and work efficiency, but, in worst cases, it can lead to sickness and death (Chaudhuri & Behan 2004). Japan’s aged society faces a chronic shortage of nurses and other care-staff members. Many nurses were physically and mentally tired. Long working hours and interpersonal challenges increase this fatigue, causing many to leave the work force. Therefore, understanding nursing fatigue is important to improve the nurses’ mental and physical health, and to reduce job attrition.

Many people think that feeling of figure expressed as “tired” can be overcome by “spirit”, and it is difficult to make an accurate evaluation. The phenomenon of fatigue is recognized by everyone, and it is an unquestionable fact that it has a quantitative nature. Fatigue can be classified as physical and mental. Physical fatigue, also known as peripheral fatigue, results from repeated muscle actions. By contrast, mental fatigue represents a failure to complete mental tasks that require self-motivation and internal cues in the absence of demonstrable cognitive failure or motor weakness (Chaudhuri & Behan 2000). And fatigue can have various effects on autonomous functions such as cardiac function and hemodynamics (Tanaka et al. 2009; Mizuno et al. 2011). Thus, mental fatigue decreases the sufferers' work efficiency in daily life. Previous studies have consistently demonstrated the decrease in sympathetic nervous activity due to mental stress (Mezzacappa, Kindlon, Saul & Earls 1998; Johnson et al. 2006). Mental fatigue not only increases sympathetic nervous activity but it also decreases parasympathetic nervous agility (Blitz, Hoogstraten & Mulder 1970; Hyndman & Gregory 1975; Pagani et al. 1986; Pagani et al. 1989; Lucini et al. 1997). In general, it is a question of whether fatigue is evaluated as a subjective sensation by recognizing reaction, and time delay, increased false reaction, and multiple attention difficulties. The difficulty in measuring and evaluating fatigue as a medical subject may be due to its delay as another medical research area. Questionnaires typically used to evaluate subjective fatigue (Chalder et al. 1993; Amagasa & Nakayama 2012; Amagasa & Nakayama 2013) fail to achieve objectivity, while physiological studies of fatigue fall short of capturing its subjective feeling.

Pulse waves contain a lot of information about hemodynamics from the heart to peripheral blood vessels. In the volume pulse wave, the pulsation generated at the origin of the aorta propagates to the peripheral artery site, and the volume change of the peripheral artery is recorded accordingly (Otuka et al., 2006). Digital plethysmogram (DPG) is a measurement of blood flow fluctuations from changes in the absorbance of hemoglobin at the fingertips. Accelertion pletymogram (APG) is an improvement of the DPG waveform to a second derivative waveform for quantitative analysis of pulse waves. It is mainly used as a test that reflects peripheral vascular hemodynamics and autonomic nervous function. The APG waveform is composed of the five components, a,b,c,d, and e. the a-a interval of APG has the same physiological significance as the autonomic nerve analysis by the R-R interval of the electrocardiogram (Akselrod et al.1985). It has become possible to evaluate autonomic nervous function more easily. Autonomic nerve fatigue may cause chronic fatigue syndrome (CFS) (Stewart 2000; Freeman 2002; Winkler et al. 2004; Wyller, Saul, Amlie & Thaulow 2007; Burton et al. 2010), multiple sclerosis (MS) (Keselbrener et al. 2000; Merkelbach et al. 2001; Flacheneckr et al. 2003), and primary biliary cirrhosis (Newton et al. 2007). These reports suggest that changes in autonomic nervous activity are related to the mechanisms underlying fatigue. However, this relationship has between demonstrated only in patients with specific diseases, but not in healthy subjects.

Fatigue is not only a symptom common to such specific diseases, but it is also observed in healthy individuals (Chen 1986; Pawliknowska et al. 1994). Recent research using 30 minutes of fatigue-inducing mental tasks has shown decreased parasympathetic activity and increased sympathetic activity even in healthy volunteers (Nozaki et al. 2009). Similarly, a comparison of autonomic activity and mental fatigue after eight hours of fatigue-inducing mental tasks (corresponding to a normal workday for healthy adults) has indicated decreased parasympathetic activity (HF) and increased autonomic function (LF/HF ratio). However, that study examined subjective fatigue only with a visual analogue scale (VAS), and did not address nurses in particular (Mizuno et al. 2011).

Our study aims to advance current research by (1) specifically targeting nurses, and (2) comparing psychological mood tests with physiological fatigue trials after eight hours of work.

Method

Ethics committee and ethical consideration

This study examined the nurses' physiology and moods, with the approval of the Medical College Ethical Review Board. Both orally and in writing, we explained the study contents, privacy policy, and right to withdraw, to receive participants' consent.

Subject recruitment

We enrolled 33 nurses (23 women, 10 men, aged 20-65; mean 44.87±12.6 years) working in an elderly care institution. We confirmed their health through medical checkups and preliminary interviews, excluding candidates with suspicion of physical or mental instability.

Research design

We measured the nurses' physical and mental conditions before (7:45-9:30 a.m.) and after (17:00-19:00 p.m.) their working day. We gauged their autonomic nervous system at rest in sitting position using acceleration plethysmography (APG) (Arttet, Umedica, Osaka), and then their systolic and diastolic blood pressure, and heart rate using a sphygmomanometer (HEM-6300, Omron Health Care, Kyoto) on their upper arm. We measured APG and BP twice in three minutes both before working and after working. We adopted the stable recorded data that showed the least deviation from the baseline (Heart rate variability 1996; Piccirillo et al. 2009). After each physiological examination, we administered VAS and MIS questionnaires.

Questionnaires

Like Mizuno (2011), we asked subjects to record their fatigue on a visual analogue scale (VAS) based on Japanese Fatigue Society guidelines, rating their fatigue from 0 (no fatigue) to 100 (complete exhaustion) (Lee, Hicks & Nino-murcia 1991). Going beyond Mizuno, we used the Sakano's Mood Inventory scale, with confirmed reliability and validity in its Japanese version (1994). The Sakano's Mood Inventory comprises five groups (Tension and Excitement, Feeling Refreshed, Fatigue, Depressive Mood, and Anxiety) with eight questions in each, totaling 40 items, using a 4-point Likert scale. The total score for each factor ranges from 8 to 32, with higher scores indicating greater conformity.

Accelerated Plethysmography (APG)

Photoplethysmography was used to measure changes in the absorption of light by hemoglobin, related to blood flow volume. We used accelerated plethysmography (APG) (Yamaguchi 2007; Tajima et al. 2008; Mizuno et al. 2010; Takada, Ebara & Kamijima 2010) to evaluate autonomic function, using a pulsimeter

(Artett, U-Medica, Osaka) with a sensor positioned on the tip of the ventral side of the index finger. The pulsimeter automatically analyzed the APG wave form consisting of four waves in systole (a-d) and one in diastole (e). The output of the pulsimeter sensor was preprocessed by an analogue filter (2^{nd} order, low pass filter with 23 Hz of cutoff frequency). The data were recorded using an analogue-to-digital converter (3.3 volt to 10 bit) with a real time sampling rate of 1,000 samples per second. These digital data were processed with a 67^{th} order finite impulse response filter using the Hanning window, interpolated to sub-millisecond order. Frequency analyses for pulse-interval variation were diagnosed with fast Fourier transformation.

Resolution ability for power spectrum was 0.001 Hz. For the frequency analyses, the total power was calculated as the power within a frequency range of 0-0.4 Hz. We classified frequency range of 0.04-0.15 Hz as low frequency component power (LF), and high frequency (HF) as the frequency range of 0.15-0.4 Hz. The HF is vagally mediated (Akselrod et al. 1981; Pomeranz et al. 1985; Malliani, Pagani, Lombardi & Cerutti 1991), whereas the LF originates from a variety of sympathetic and vagal mechanisms (Akselrod et al. 1981; Appel et al. 1989). The low-frequency component power/high-frequency component power ratio (LF/HF) reflects autonomic function (Pagani et al. 1997).

Statistical analysis

The pulse rate and the VAS value for fatigue are shown as the mean±SD. We evaluated the difference between before work and after work with a paired *t*-test and used Spearman's correlation analysis to compare (VAS value, Mood Scale) with fatigue and LF/HF ratio. All *p* values were 2-tailed, and *p* values less than 0.05 were considered statistically significant. Statistical analysis was performed using Stata IC 15 (Light Stone Inc.).

Results

Table 1 shows blood pressure and autonomic activities measured by accelerated plethysmography (APG) before and after working. Pulse rate (bpm) increased, but not significantly. Total Power (HF□LF) (ms^2) gained significant momentum in comparison with before working ($p<0.05$). LF increased significantly after work ($p<0.01$), while the HF did not differ significantly. LF/HF rate increased significantly from the baseline after working ($p<0.01$). Results not listed on the table (Systolic and diastolic blood pressure (SBP and DBP) did not significantly differ.

Table 2 shows questionnaire evaluation before (baseline) and after work. The visual analogue scale (VAS) value for fatigue increased significantly after work ($p<0.01$). In the Mood Inventory, the only statistically significant change after work ($p<0.05$) was that of Feeling Refreshed. The component of Tension and Excitement of the Mood Inventory increased, but not significantly. The other constituents such as Fatigue, Depression, and Anxiety did not significantly differ.

Figures 1 and 2 show the correlation between physiology and questionnaire. The HF correlated negatively with VAS values for fatigue (r=-0.31, p<0.01) (Figure 1). The HF correlated positively with the component of Feeling Refreshed in the Mood Inventory ($r=0.21$, $p<0.05$) (Figure 2).

Discussion

Our study showed that, after 8 hours of work, autonomic activity, the LF, and LF/HF ratio changed significantly. In other words, fatigue increased objectively. It must be mentioned, but after 8 hours of work, it cannot be denied that there is also the influence of the circadian rhythm. However, nursing labor requires considerable physical and mental additions. However, nursing labor requires considerable physical and mental additions. Therefore, the effects of inducing fatigue and affecting autonomic nervous function are fully expected. The present finding that mental fatigue affects the sympathetic nervous system (increased LF/HF ratio) is consistent with previously reported results (Toichi & Kamio 2003), in which fatigue-inducing mental tasks increased sympathetic activity and decreased parasympathetic activity (Tanaka et al. 2009; Mizuno et al. 2011).

Our finding that HF negatively associated with the visual analogue scale (VAS) replicates previous studies. More interestingly, the positive association of the LF/HF with the Feeling Refreshed item of Sakano's Mood Inventory, is a new finding of the present study. This finding suggests that subjective evaluation by questionnaire might be a valid index of evaluation of autonomic activity. Stressful mental fatigue affects not only mental but physical bodily functions as well. Increased sympathetic activity and decreased parasympathetic activity suggest autonomic hypervigilance. The prefrontal cortex (PFC) and anterior cingulate cortex (ACC) play an important role in the regulation of autonomic nervous activities (Tanaka et al. 2011). The PFC normally inhibits sympathy-excitatory subcortical circuits (Tang et al. 2009; Thayer 2006; Thayer & Sternberg 2006), while the ACC regulates parasympathetic activity (Amat et al. 2005; Kubota et al. 2001). Several studies have reported that prolonged mental tasks lasting an hour or longer gradually reduced brain activity related to mental task processing (Takahashi & Arito 1996; Tanaka et al. 2006). Our study suggests that nursing work entails continuous activation of the PFC, and that acute mental tasks might temporarily cause the PFC and ACC to dysfunction, increasing sympathetic and decreasing parasympathetic activities (Caseras et al. 2008; Danckert et al. 2000; Weissman et al. 2003; Schreppel et al. 2008; Morishima et al. 2009). Neuroimaging studies may be required to confirm this hypothesis.

Conclusion

Our results provide evidence that nurses' fatigue increases sympathetic activity and autonomic function and is also related to mood. The nurses' subjective psychological state after work affects their autonomous function, so physiological indicators may provide an objective assessment of nursing fatigue. Our new finding is that the eight questions in Sakano's Feeling Refreshed category correlate with physiological indicators; hence, Sakano's Questionnaire may be an alternative to physiological test when assessing nursing fatigue and can be tested more quickly and concisely. These findings may lead to stress coping and prevention not only for nurses but also for workers with fatigue. We hope this study will contribute towards addressing the issues related to workers' mental health in the workplace.

Limitations

The present study has several limitations. First, we should be noted that fatigue is not only physiological and psychological, but also under the influence of human circadian rhythms. Second, our study included only a small number of participants, limited to nursing care facilities in Fukushima. Third, our study's cross-sectional correlations cannot clarify cause-and-effect relationships. To generalize our results, studies involving a larger number of participants with better cause-and-effect analyses are essential.

Declarations

We delate that manuscript is original, has not been published before and is not currently being considered for publication elsewhere. We know of no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. We have confirmed the availability to the "minimal dataset "required for reproduction and development. As corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors.

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In carrying out this work, no subsidies have been received.

Conflict of interest

All authors declare that they have no conflicts of interest.

Ethics approval

This study was conducted with the approval of the Fukushima Medical University Ethics Committee according to guidelines.

Consent to participate

Both orally and in writing, we explained the study contents, privacy policy, and right to withdraw, to receive participants' consent.

Consent for publication

All authors contributed to and have approved the final manuscript.

Availability of date and material

We have confirmed the availability to the "minimal dataset "required for reproduction and development.

Author's contributions

Miki Ishizuka, Shin-ichiro Katsuda, and Akihiro Hazama designed the study and wrote the protocol. Miki Ishizuka managed the literature searches and wrote the first draft of the manuscript. Miki Ishizuka performed statistical analyses under technical supervision by Shin-ichiro Katsuda, and Akihiro Hazama. Shin-ichiro Katsuda, and Akihiro Hazama helped with interpretation of data.

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References

Akselrod, S., Gordon, D., Ubel, FA., Shannon, D.C., Barger, A.C. & Cohen, R.J. (1981). Power spectrum analysis of heart rate fluctuation: a quantitative probe of beatto-beat cardiovascular control. Science. 213, 220-222.

Akselrod, S., Gordon, D., Madwad, J.B., Snidman, N.C., Shannon, D.C., & Cohen, R.J. (1985). Hemodynamic regulation: Investigation by spectral analysis. *Am J Physiol*. 249, 867-875.

Amagasa, T., & Nakayama, T. (2012). Relationship between long workig hours and depression in two working populations. A suructural equation model approach. *JOEM*. 54, 868-874.

Amagasa, T., & Nakayama, T. (2013). Relationship Between Long Working Hours and Depression A 3-Year Longitudinal Study of Clerical Workers. *JOEM*. 55, 863-872.

Amat, J., Baratta, M.V., Paul, E., Bland, S.T., Watkins, L.R., & Maier, S.F. (2005). Medial prefrontal cortex determines how stressor controllability affects behavior and dorsal raphe nucleus. *Nat Neurosci*. 8,365-371.

Appel, M.L., Berger, R.D., Saul, J.P., Smith, J.M., & Cohen, R.J. (1989). Beat to beat variability in cardiovascular variables: noise or music? *J Am Coll Cardiol*. 14, 1139-1148.

Benson, H. (1985). Assessment of autonomic function in humans by heart rate spectral analysis. *Am J Physiol*. 248, 151-153.

Blitz, P.S., Hoogstraten, J., & Mulder, G., (1970). Mental load, heart rate and heart rate variability. *Psychologische Forschung*. 33, 277-288.

Burton, A.R., Rahman, K., Kadota, Y., Lioyd, A., & Vollmer-Conna, U. (2010). Reducaced heart rare variability predicts poor sleep quality in a case-control study of chronic fatigue syndrome. *Exp brain res*. 204, 71-78.

Caseras, X., Mataix-Cols, D., Rimes, K.A., Giampietro, V., Brammer, M., Zelaya, F., … Godfrey, E. (2008). The neural correlates of fatigue: an exploratory imaginal fatigue provocation study in chronic fatigue syndrome. *Psychol Med*. 38, 41-951.

Chalder, T., Berelowiz, G., Pawliknowska, T., Watts, L., Wessely, L., Wright, D., … Wallace, E.P. (1993). Development of a fatigue scale. *J Psychosom Res.* 37,147-153.

Chaudhuri, A., & Behan, P.O., (2000). Fatigue and basal ganglia. *J Neurol Sci*. 179, 34-38.

Chaudhuri, A., & Behan, P.O. (2004). Fatigue in neurological disorder. *Lancent*. 363, 978-988.

Chen, M.K., (1986). The Epidemiology of self-perceired fatigue among adults. *Prev Med.* 15, 74- 81.

Danckert, J., Maruff, P., Ymer, C., Kinsella, G., Yucel, M., De Graaff, S., & Currie, J. (2000). Goaldirected selective attention and response competition monitoring: evidence from unilateral parietal and anterior cingulate lesions. *Neuropsychology*. 14, 16-28.

Flacheneckr, P., Rufer, A., Bihle,r I., Hippel, C., Reiners, K., Toyka, KV., … Kesseelring, J. (2003). Fatigue in ms is related to sympathetic vasomotor dyfunction. *Neurology*. 61, 851-853.

Freeman, R. (2002). The chronic fatigue syndrome is a disease of the autonomic nervous system. Sometimes. *Clin auton res*. 12, 231-233.

Heart rate variability: standards of measurement, physiological interpretation and clinical use. (1996). Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*. 93(5), 1043-1065.

Holmes, T.H., & Raha, R.H. (1976). The social readjustment rating scale. *Jounal of psychosomatic research*. 11, 213-218.

Hyndman, B.W., & Gregory, J.R., (1975). Spectral analysis of sinus arrhythmia during mental loading. *Ergonomics*. 18, 255-270.

Johnson, S.A., Yechiam, E., Murphy, R.R., Queller, S., & Stout, J.C. (2006). Motivational processes and autonomic responsivity in Asperger's disorder: evidence from the Iowa Gambling Task. *J Int Neuropsychol Soc*. 12, 668-676.

Keselbrener, L., Akselrod, S., Ahiron, A., Elder, M., Barak, Y., & Rotstein, Z. (2000). Is fatigue in patients with multiple sclerosis related to autonomic dysfunction? *Clin auton res.* 10, 169-175.

Kubota, Y., Sato, W., Toichi, M., Murai, T., Okada, T., Hayashi, A., & Sengoku, A. (2001). Frontal midline theta rhythm is correlated with cardiac autonomic activities during the performance of an attention demanding meditation procedure. *Brain Res Cogn Brain Res.* 11, 281-287.

Lee, K., Hicks, G., & Nino-murcia, G., (1991). Validity and reliability of a scale to assess fatigue. *Psychiatry res*. 36, 291-298.

Lucini, D., Covacci, G., Milani, R., Mela, G.S., Malliani, A., & Pagani, M. (1997). A controlled study of the effects of mental relaxation on autonomic excitatory responses in healthy subjects. *Psychosom Med*. 59, 541-552. 37.

Malliani, A., Pagani, M., Lombardi, F., & Cerutti, S. (1991). Cardiovascular neural regulation explored in the frequency domain. *Circulation*. 84, 482-492.

Merkelbach, S., Dillmann, U., Kolmel, C., Holz, I., & Muller, M. (2001). Cardiovascular autonomic dysregulation and fatigue in multiple sclerosis. *Mult scler*.; 7, 320-326.

Mezzacappa, E., Kindlon, D., Saul, J.P., & Earls F. (1998). Executive and motivational control of performance task behavior, and autonomic heart-rate regulation in children: physiologic validation of two-factor solution inhibitory control. *J Child Psychol Psychiatry*. 39, 525-531.

Mizuno, K., Tanaka, M., Tajima, K., Okada, N., Rokushima, K., & Watanabe, Y. (2010). Effects of mild-stream bathing on recovery from mental fatigue. *Med Sci Monit*. 16, 8-14.

Mizuno, K., Tanaka, M., Yamaguchi, K., Kajimoto, O., Kuratsune, H., & Watanabe, Y. (2011). Mental fatigue caused by prolonged cognitive load associated with sympathetic hyperactivity. *Behavioral and brain functions*. 23, 7-17.

Morishima, Y., Akaishi, R., Yamada, Y., Okuda, J., Toma, K., & Sakai, K. (2009). Task-specific signal transmission from prefrontal cortex in visual selective attention. *Nat Neurosci*. 12, 85-91.

Newton, J.L., Okonkwo, O., Sutcliffe, K., Seth, A., Shin, J., & Jones, D.E. (2007). Symptoms of autonomic dysfunction in chronic fatigue syndrome. *QJM*. 100, 519-526.

Nozaki, S., Tanaka, M., Mizuno, K., Ataka, S., Mizuma, H., Tahara, T., … Watanabe, Y. (2009). Mental and physical fatigue-related biochemical alterations. *Nutrition*. 25,51-55

Otuka, T., Kawada, T., Katsumata, M., & Ibuki, C. (2006). Utility of second derivative of finger photoplethysmogram for the estimation of risk of coronary heart disease in the general poplation. *Circ J*. 70(3), 304-310.

Pagani, M., Lombardi, F., Guzzetti, S., Rimoldi, O., Furlan, R., Pizzinelli, P., … Malliani, A. (1986). Power spectral analysis of heart rate and arterial pressure variabilities as a marker of sympatho-vagal interaction in man and conscious dog. *Circ Res*. 59, 178-193.

Pagani, M., Furlan, R., Pizzinelli, P., Crivellaro, W., Cerutti, S., & Malliani, A. (1989). Spectral analysis of R-R and arterial pressure variabilities to assess sympathovagal interaction during mental stress in humans. *J Hypertens Suppl*. 7, 14-15.

Pawliknowska, T., Chalder, T., Hirsch, S.R., Wallace, P., Wringhy, D.J., & Wessely, S.C. (1994). Population based distress. *BMJ*. 308, 763-766.

Piccirillo, G., Ogawa, M., Song, J., Chong, V.J., Joung, B., Han, S., … Chen, P.S. (2009). Power spectral analysis of heart rate variability and autonomic nervous system activity measured directly in healthy dogs and dogs with tachycardia-induced heart failure. *Heart Rhythm*. 6 ,546-552.

Pomeranz, B., Macaulay, R.J., Caudill, M.A., Kutz, I., Adam, D., Gordon, D., … Pagani, M., Montano, N., Porta, A., Malliani, A., Abboud, F.M., Birkett, C., & Somers, V.K. (1997). Relationship between spectral components of cardiovascular variabilities and direct measures of muscle sympathetic nerve activity in humans. *Circulation*. 95, 1441-1448.

Sakano, Y., Fukui, T., Kuano, H., Horie, H., Kaashima, K., Yamamoto, H., … Suematsu, H. (1994). Development and Validation of a New Mood Inventory. *Japanese Society of Psychosomatic Medicine*. 34, 629-636.

Schreppel, T.J., Pauli, P., Ellgring, H., Fallgatter, A.J., & Herrmann, M.J. (2008). The impact of prefrontal cortex for selective attention in a visual working memory task. *Int J Neurosci.* 118, 1673-1688.

Stewart, J.M. (2000). Autonomic nervous system dysfunction in adolescents with postural orthostatic tachycardia syndrome vagal baroreflex and potentiated sympathetic vasomotion. *Pediatr res*. 48, 218-226.

Tajima, K., Tanaka, M., Mizuno, K., Okada, N., Rokushima, K., & Watanabe, Y. (2008). Effects of bathing in micro-bubbles on recovery from moderate mental fatigue. *Ergonomia IJE&HF*. 30, 135-145.

Takada, M., Ebara, T., & Kamijima, M., (2010). Heart rate variability assessment in Japanese workers recovered from depressive disorders resulting from job stress: measurements in the workplace. *Int Arch Occup Environ Health*. 83, 521-529.

Takahashi, M., & Arito, H., (1996). Effects of single and repeated cognitive tasks on autonomic balance as observed by an analysis of R-R intervals. *Eur J Appl Physiol Occup Physiol*. 72, 316-322.

Tanaka, M., Sadato, N., Okada, T., Mizuno, K., Sasabe, T., Tanabe, H.C., Saito, D.N., …Watanabe, Y. (2006). Reduced responsiveness is an essential feature of chronic fatigue syndrome: a fMRI study. *BMC Neurol*. 6,9.

Tanaka, M., Mizuno, K., Tajima, S., Sasabe, T., & Watanabe, Y. (2009). Central nervous system fatigue alters autonomic nerve activity. *Life Sci.* 84, 235-239.

Tanaka, M., Mizuno, K., Yamaguchi, K., Kuratsune, H., Fujii, A., Baba, H., …Watanabe, Y. (2011). Autonomic nervous alterations associated with daily level of fatigue. *Behavioral and brain functions*. 7,1-46.

Tang, Y.Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., … Fan M. (2009). Centra l and autonomic nervous system interaction is altered by short-term meditation. *Proc Natl Acad Sci USA*. 106,8865-8870.

Thayer, J.F., (2006). On the importance of inhibition: central and peripheral manifestations of nonlinear inhibitory processes in neural systems. *Dose Response*. 4, 2-21.

Thayer, J.F., & Sternberg, E., (2006). Beyond heart rate variability: vagal regulation of allostatic systems. *Ann N Y Acad Sci*. 1088, 361-372.

Toichi, M., & Kamio, Y., (2003). Paradoxical autonomic response to mental tasks in autism. *J Autism Dev Disord*. 33, 417-426.

Yamaguchi, K., (2007). The evaluation of fatigue by using acceleration plethysmography. *Nippon Rinsho*. 65, 1034-1042.

Watanabe, Y. (2008). Preface and mini-review: fatigue science for human health. In Fatigue Science for Human Health. Edited by Watanabe, Y., Evengård, B., Natelson, B.H., Jason, L.A., Kuratsune, H., *New York: Springer*. 5-11.

Weissman, D.H., Giesbrecht, B., Song, A.W., Mangun, G.R., & Woldorff, M.G. (2003). Conflict monitoring in the human anterior cingulate cortex during selective attention to global and local object features. *Neuroimage*. 19, 1361-1368.

Winkler, A.S., Blair, D., Marsden, J.T., Peters, Y.J., Wessely, S., & Cleare, AJ. (2004). Autonomic function and serum erythropoietin levels in chronic fatigue syndrome. *J psydhosom res*. 56, 179-183.

Wyller, V.B., Saul, J.P., Amlie, J.P., & Thaulow, E. (2007). Sympathetic predominance of with chronic fatigue. *Clin physiol funct imaging*. 27, 231-238.

Tables

Table 1 Autonomic activityes before (baseline) and after the working (8hr)
(Mean±SD)

	Accelerated	Plethsmography	
	Before	After	p value
Pulse Rate (bpm)	77.2±9.7	95.6±11.3	p=0.36
Total Power(ms^2)	758.6±778.7	1130.5±119.4	p<0.01
LF(ms2)	525.8±615.8	877.3±939.8	p<0.01
HF(ms2)	261.1±205.3	248.2±225.5	p=0.73
LF/HF ratio	2.38±1.65	4.93±3.66	p<0.01

LF: low-frequency component power, HF: high-frequency component power
LH/HF ratio: low-frequency component power/high-frequency component power ratio,
Total Power: low-frequency component power＋high-frequency component power ratio.
Values are presented as the mean and SD (paied-t-test).

Table 2 Questionnaire before (baseline) and after the working (8-hr)
(Mean±SD)

	Questionnaire		
	Before	After	p value
VAS value	5.07±1.97	6.5＋1.45	p<0.01
Mood Inventory			
Tension and Excitement	12.87±5.8	13.72＋5.55	p=0.24
Refreshing Mood	18.43±4.51	17.00±4.19	p=0.03
Fatigue	16.12±5.27	16.87＋6.27	p=0.11

VAS :Visual Analogue Scale
Values are presented as the mean and SD (paied-t-test).

Figures

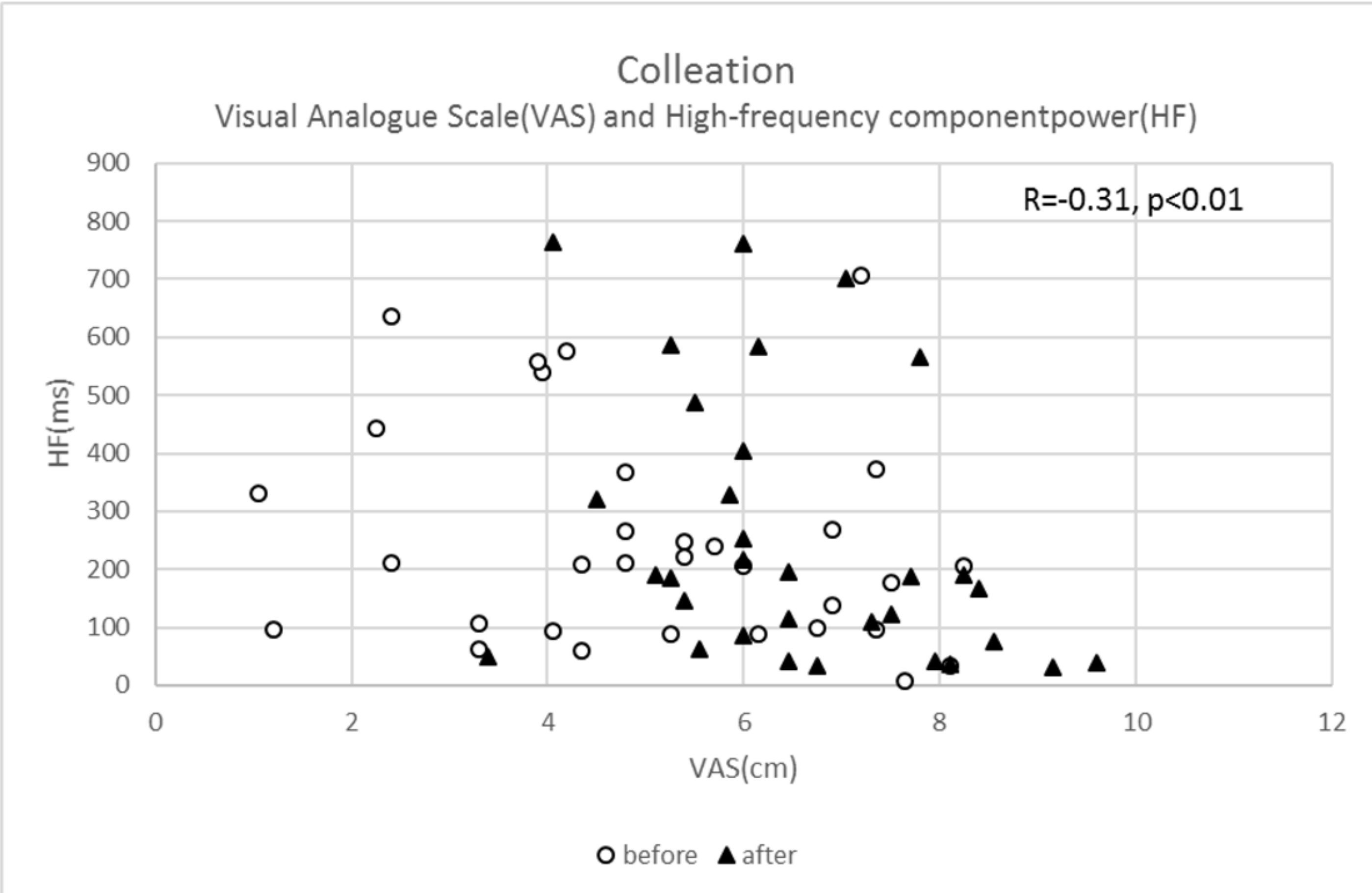

Figure 1

Collation between Visual Analogue Scale (VAS) and autonomic activity High-frequency component power (HF) obtain on a wave interval analysis using accelerated plethysmography in all measurement point before and after 8-hr. working. Spearman's correlation coefficients and p-values are shown.

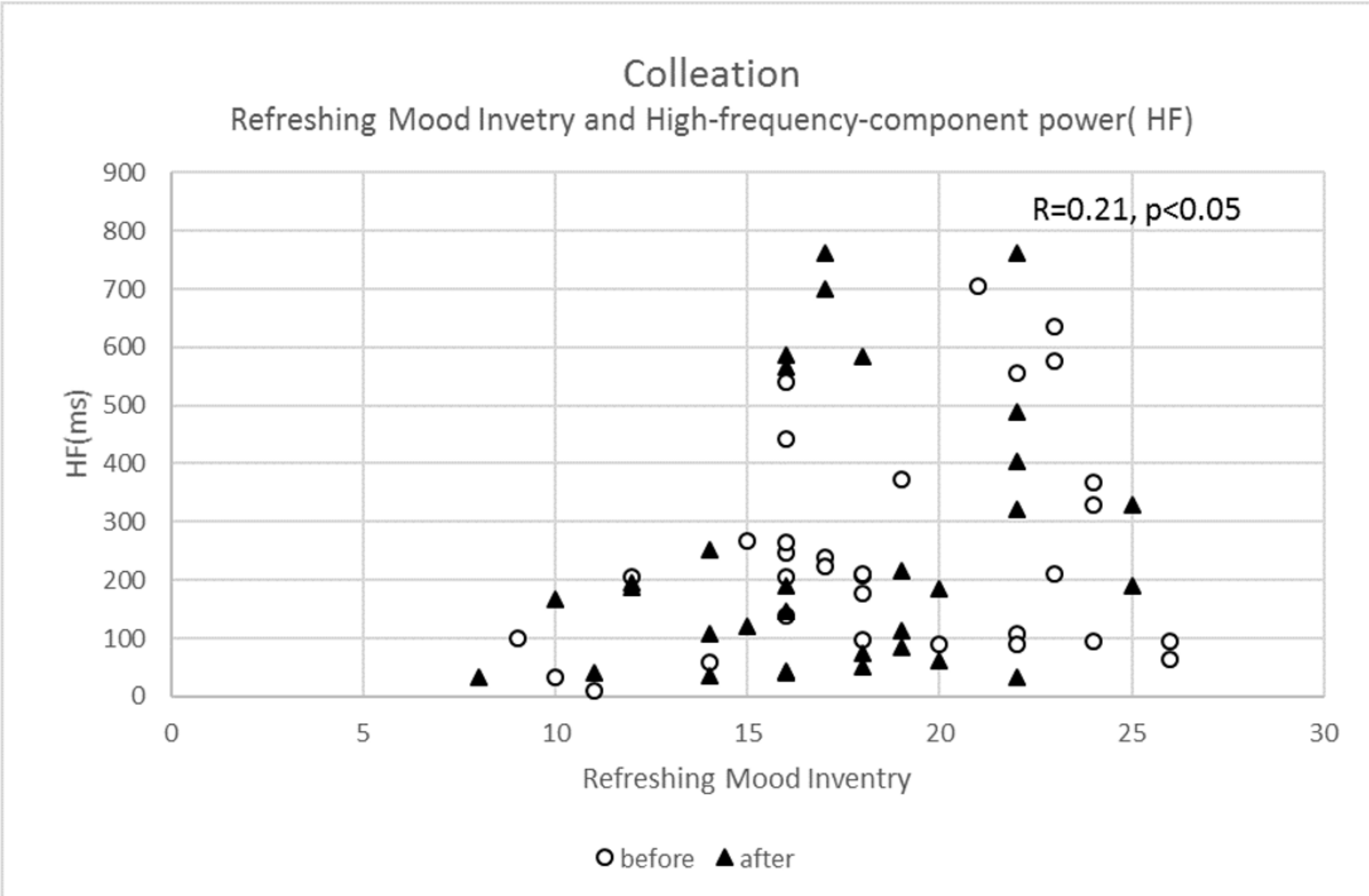

Figure 2

Collation between Refreshing of Mood Inventory and autonomic activity High-frequency component power (HF) obtain on a wave interval analysis using accelerated plethysmography in all measurement point before and after 8-hr. working. Spearman’s correlation coefficients and p-values are shown.