原著論文

Evoked Photon からみる運動時の生体エネルギーに関する研究
ー運動による人間バイオエネルギーの変動ー

Evaluation of bioenergy after exercise using evoked photons
− Fluctuation of Human bioenergy by exercise −

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Abstract

Introduction: Living organisms emit extremely weak light particles called biophotons generated by biochemical reactions associated with various in vivo physiological metabolic activities. In this study, we focused on adult males and recorded their evoked biophotons using a Gas Discharge Visualization (GDV) device. Next, we examined whether exercise alters biophoton parameters and the GDV results correlated with other indices of the stress.
Methods: Biophotons were measured using a GDV device that was developed to measure the luminescence phenomenon of evoked biophotons and to evaluate in vivo energy using the parameters of area and intensity. The exercise load comprised running for 1 h on a treadmill at the 70% HRmax level. The following measurements were made before and after running: evoked photon imaging using GDV; salivary secretory immunoglobulin A (s-IgA) using a sandwich enzyme immunoassay; and a profile of mood state (POMS) psychological assessment.
Results: The average in the area and intensity of the evoked-photon energy field indices was found to decrease significantly ($p < 0.05$) after exercise, and a significant decrease ($p < 0.05$) was also observed for s-IgA. In addition, POMS score decreased significantly ($p < 0.05$) after exercise. Furthermore, the area and intensity parameters significantly correlated with s-IgA ($p < 0.05$).
Conclusions: Evaluation of in vivo energy of evoked photons appears to be a useful method for the assessment of physiological stress and produces similar results to conventional s-IgA and POMS testing.

キーワード　誘発光 , GDV, s-IgA, POMS, 運動負荷
Evoked photon, GDV, s-IgA, POMS, Exercise load

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1. Introduction

Living organisms emit extremely weak light that reflects their physical activity and physiological metabolic states. This extremely weak light (consisting of biophotons) was first measured in the 1930s by Alexander Gurwitsch（Alexander, 1935）and is emitted in the ultraviolet range, and these biophotons are thought to be particularly reflective of biological oxdation-reduction reactions（Korotkov K, 2002).

A Gas Discharge Visualization (GDV) device has been recently developed by Prof. Kostatin Korotkov (St. Petersburg University) that can detect biophotons, now making it possible to evaluate the bioenergy (Cioca G et al., 2004; Korotkov K, 2002a; Korotkov K, 2002b; Korotkov K et al.,; Rizzo-Roberts N et al., 2004). GDV device is specially designed to detect corona discharges induced by biophotons at the tips of 10 fingers and is essentially a carefully designed Kirlian effect imaging device that meets the reproducibility and sensitivity required for scientific research. By applying computer image analysis, the digital photographs of the electronic photonic glow are reduced to several convenient parameters based on the size and distribution of the recorded flashes. By using arithmetic means of repeated recordings of the glow image area of all fingers, GDV can reliably detect responses to external stress factors (Augner C et al., 2010; Dobson P and O'Keefe E, 2000; Hacker GW et al., 2011). In addition, the GDV technology is safe and has produced reproducible results; it has been widely described in the literature (Bascom R et al., 2002; Bundzen PV et al., 2002; Deinzer R et al., 2000; Dobson P and O'Keefe E, 2000; Francomano CA et al., 2002; Rizzo-Roberts N, 2002; Russo M et al., 2001). This method, therefore, has great potential for generating biological and health information. To date, evoked photon research using GDV has been conducted mainly in the United States and Russia, and there have been numerous reports on the topic from organizations such as the Applied Physics Society (Giacomoni P et al., 2003; Pehek JO et al., 1976; Yamagiwa M and Niiyama R, 1999). The method is currently spreading across medical facilities in Europe and the United States for diagnostic purposes; however, there have been little research on the subject in Japan (Tsubouchi S et al., 2018).

To the best of our knowledge, our study is the first to assess the effects of the exercise load on biophtons using a GDV device on Japanese people. We aimed to determine the magnitude of energy change in a living body that could be recognized upon exercising using evoked photons imaged by GDV as an index. In order to produce an energy change from exercise load, subjects were asked to run for 1 h. Evoked photon using GDV as an index before and after the exercise load was analyzed its energy by a scientific laboratory software. Intraoral immunity as the ratio of secretory immunoglobulin A (s-IgA) to total protein that decreases with increasing stress, and the profile of mood states (POMS) that reflect factor of "tension", "depression-dejection", "anger-hostility","vigor", "fatigue" and "confusion" were used to evaluate physiological and psychological fluctuations due to exercise.

Finally, we examined the changes in physiological and psychological state and correlated with evoked photons.

2. Methods

2.1 Subjects

Subjects were 25 adult males (age, 20.9 ± 1.2 y; height, 172.5 ± 5.6 cm; and weight, 62.4 ± 8.2 kg) who were medically verified as being healthy. This study was approved by the Ethics Committee of the Faculty of Liberal Arts and Sciences of Osaka Prefecture University

(2016.4.1. approved)

2.2 Exercise load

To verify the in vivo energy change in the experimental subjects under exercise load, examinations were performed before and after the subjects ran for 60 min on a treadmill as follows. The exercise load was set to 70% of the maximum heart rate intensity.

Maximum heart rate (HRmax), which is calculated from heart rate and age as a parameter of exercise intensity, was adopted (American Heart Association Committee on Exercise, 1972; Yamaji K, 1981), using the Karvonen formula ① as advocated by the American College of Sports Medicine (ACSM) (Pollock ML et al., 1998). The duration of exercise was set at 60 min.

Estimated HRmax: 220 – age　①

A Health jogger HJ - 5001 (Chuoh Health Co., Ltd., Tokyo, Japan) was used to produce the exercise load, and heart rate measurement was performed using an IX - TA–220 general purpose data acquisition/analysis system (manufactured by iWork Systems Inc. Washington, D.C, USA). The 70% HRmax exercise load of all subjects averaged 159 ± 15.9 beats/min.

2.3 Validation items and Data Analysis methods

Examinations before and after running on the treadmill were performed by measuring evoked photons, the s-IgA/protein ratio and POMS.

2.3.1 Evoked photons

The evoked photons were measured using a bioelectrography device, Impulse Analyzer EPA (GDV) Compact (manufactured by Kirlionics Technologies International, St. Peterburg, Russia). The GDV camera was connected to a computer, and the recorded glow image were digitally transferred using GDV capture software (version 1.9.9.2004).

The measurement was performed by placing a subject's fingertip on the GDV lens and keeping the angle of the finger to the lens at 15°– 40°. The coronal discharges of the ten fingertips of each subject were captured by sensitive digital imaging. An example of GDV image is shown in Fig.1.

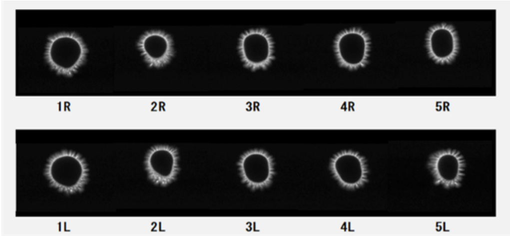


Fig.1. Example of GDV photography. Evoked-photon emission image from fingers taken as GDV. Photo 1R, right thumb; 2R, right forefinger; 3R, right middle finger; 4R, right ring finger; 5R, right little finger, 1L, left thumb; 2L, left forefinger; 3L, left middle finger; 4L, left ring finger; and 5L, left little finger.

Evoked-photon parameters were obtained using GDV meridian analysis with GDV diagram software version 1.9.9. and DV Scientific Lab software version 1.1.5 (Korotkov K,2002a).

All GDV software was developed using by Konstantin Korotkov. Area and intensity values were calculated as the energy field index of the evoked-photon parameter. When the (light emitting) area value is high, so is in vivo energy. When the (luminescence) intensity is high, the amounts of in vivo energy and neurotransmission are high.

2.3.2 s-IgA

For determination of s-IgA/protein ratio, saliva was directly collected from the mouth into a 50 ml centrifuge tube, frozen, thawed, transferred to a 1.5-ml micro tube, centrifuged at 15000 rpm for 5 min, and the supernatant was used for analysis. The s-IgA concentration was measured using a sandwich enzyme-linked immunoassay with anti s-IgA antibody and HRP-anti s-IgA antibody, acoording to Matsuura et al.(2014). The total protein concentration in saliva was measured using the Lowry method. The s-IgA/protein ratio was calculated using the following formula②: (Akimoto T et al., 1998; McKechnie AA et al., 1983; Nakata Y et al., 2000; Sakai K et al., 1986).

Ratio of s-IgA to salivary protein =
(s-IgA concentration) / (total protein concentration) ②

The s-IgA/protein ratio reflects high stress level when its value is low.

2.3.3 POMS

The Japanese version of POMS of self-filling formula with an abbreviated version of the inspection form was used. In order to evaluate the psychological change before and after the exercise, the subject wrote in a self-filled form. POMS testing assessed the following six factors: "tension-anxiety", "depression-dejection", "anger-hostility", "vigor", "fatigue", and "confusion", according to the scoring the evaluation criteria (Lorr M et al., 2015; McNair DM et al., 1971; Yokoyama K, 2015). Results of T-scores obtained by POMS survey were expressed as mean ± standard error.

2.4 Statistics Analysis

All experimental descriptive data were calculated using Microsoft Excel 2016, including averages, standard deviations and t-test values. To examine differences between average values, the effect size (ES) expressed by Cohen's d was employed. For bivariate correlation analysis, Pearson's product-moment correlation coefficient was used. The significance level of the statistical hypothesis acceptance was defined as 5%.

3. Results

3.1 Changes in biophoton parameters after applying exercise load.

The area and intensity biophoton parameters before and after applying exercise load were analyzed (Fig. 2). The average value for the energy field indices of subjects decreased significantly ($p < 0.01$). The area after exercise was 10831.4 ± 1012.1 pixels compared with 11995.4 ± 1217.1 pixels before exercise. The intensity given in "arbitrary units" by the GDV diagram software, was 84.9 ± 4.4 units before exercise and 75.6 ± 7.0 units after exercise.

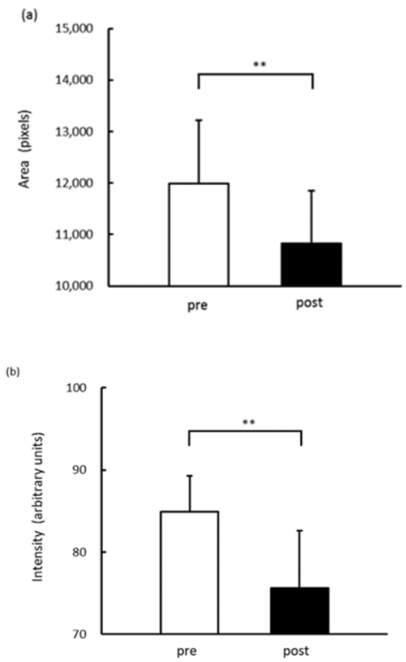


Fig. 2. Changes in evoked-photon parameters after exercise.

(a) Average values for the energy field area parameter before(pre) and after(post) exercise ($n = 25$). Error bars indicate SD. After exercise the energy field parameter area decreased significantly ($t = 2.86$, $^{**}p < 0.01$). (b) Average values for the energy field intensity parameter before and after exercise ($n = 25$). Error bars indicate SD. After exercise the energy field parameter intensity decreased significantly ($t = 3.36$, $^{**}p < 0.01$).

3.2 Changes in s-IgA/total protein ratio after applying exercise load

The average value of the s-IgA/total protein ratio of the subjects was 13.5 ± 0.8 % before exercise and 12.5 ± 1.0 % afterwards, which presented a significant decrease ($p < 0.01$)(Fig. 3). Therefore, the increase in "fatigue" due to exercise resulted in a significant decrease in the salivary s-IgA/protein ratio indicating the increase of stress level.

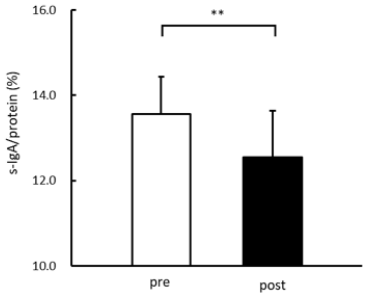
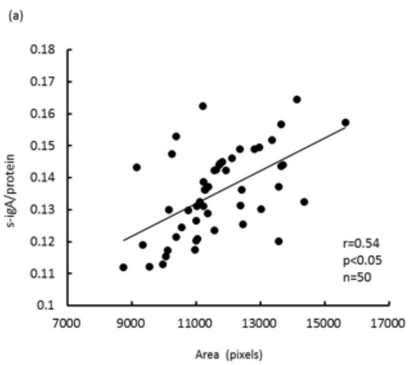


Fig. 3. Change in s-IgA/protein ratio after exercise.
Average values for s-IgA/protein ratio before and after exercise (n = 25). Error bars indicate SD. s-IgA/protein decreased significantly after exercise ($t = 2.97$, $^{**}p < 0.01$).

3.3 Correlation between energy field index and s-IgA in saliva

The evoked-photon energy parameter area was significantly ($p < 0.05$) correlated to s-IgA in saliva (Fig.4-a), as was the evoked-photon energy parameter intensity (Fig.4-b; $p < 0.05$).



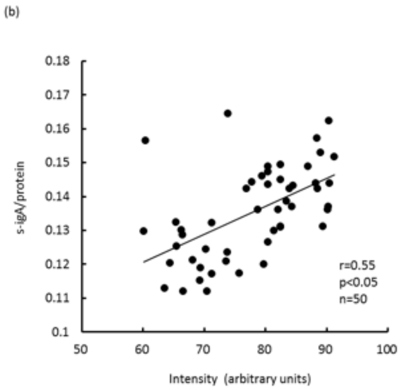


Fig.4. Relationship between evoked-photon energy field parameters and saliva s-IgA before and after exercise.
(a) There was a significant correlation between the evoked-photon energy field parameter area and s-IgA/total protein ($p < 0.05$, $r = 0.54$, $n = 50$). (b) There was a significant correlation between the evoked-photon energy field parameter intensity and saliva s-IgA/total protein ($p < 0.05$, $r = 0.55$, $n = 50$).

3.4 Fluctuation of POMS before and after applying exercise load

The result of the POMS test was that "tension -anxiety" did not change from 47.7 ± 8.1 points before exercise to 47.6 ± 7.8 points afterwards, "depression-dejection" decreased from 49.2 ± 5.6 points before exercise to 48.4 ± 5.4 points afterwards, "anger-hostility" decreased from 48.8 ± 6.7 points before exercise to 44.4 ± 5.6 points afterwards ($p < 0.01$), "vigor" decreased from 46.6 ± 8.2 points before exercise to 44.9 ± 7.9 points afterwards, "fatigue" increased from 47.5 ± 7.2 points before exercise to 52.4 ± 7.8 points afterwards ($p < 0.05$) and "confusion", decreased from 47.5 ± 7.2 points before exercise to 45.9 ± 6.9 points afterwards.

The average values of two of the six mood factors "anger-hostility" and "fatigue" exhibited significant differences before and after applying the exercise load.

4. Discussion

In the present study, we examined whether the change of energy state of the human body after exercise can be captured using evoked photons detected by GDV.

Many studies have reported that appropriate exercise has benefits for the maintenance and improvement of health (Chodzko-Zajko WJ et al., 2009; Yan T et al., 2009; Rosenbaum S et al., 2011; Morikawa M et al., 2011; Deborch R, 2014). However, it has also been noted that excessive exercise stimulation can have adverse effects, including the induction of dysfunctions and disorders in immune competence (Linde F, 1987; Mackinnon LT et al., 1933; Nieman DC et al., 1990; Peters EM, 1997).

Furthermore, it is known that this kind of stimulation can result in stress, a concept that was advocated by Hans Selye in 1936 (Selye H. A , 1936).

The type and intensity of stressful stimulation and the physical and mental state of the exercising person should be judged using appropriate parameters to monitor the level of stimulation in the body. The heart rate has been widely used to this purpose as an indicator of exercise intensity (Bootsma BK et al., 1970; Roscoe AH, 1975; Tsubouchi S et al., 1985; Tsubouchi S et al., 1986).

POMS test (Ishiguro C et al., 1971; Kawakubo. K et al., 1996; Kawashima S, 2006; Nakamura K et al., 2004), is generally used in research to evaluate exercise and psychological state. Since we can measure the state of temporary mood/emotion which changes depending on the subject's condition placed, it was used for evaluation of the psychological state.

Biochemical techniques were used to measure stress-related substances in biological samples such as blood and saliva: salivary α-amylase (Haginoya H and Saeki Y, 2012), that is a physiologically active substance and the secretion is stimulated by the sympathetic nerve-adrenal medulla; cortisol (Izawa S et al., 2010), whose secretion increases upon activation of the cerebral-hypothalamic-pituitary-adrenal cortical pathway due to acute stress; and s-IgA, which is generally decrease by acute and chronic stress and emotion. Notably, the substances secreted in saliva have been attracting attention because they can be noninvasively examined.

The physiologically active substance of the mucosal immune system s-IgA is an antibody molecule present on mucosal surfaces of the oral cavity, respiratory and digestive tracts. Because mucosal surfaces are in contact with the external environment and are therefore prone to invasion of bacteria and viruses, the s-IgA secretion is very important for protecting the body from infection (Hucklebridge F et al., 2000; Mestecky J, 1993).

For examination of these types of stresses, methods such as interviews and psychological tests are greatly influenced by subjective factors, so it is difficult to obtain objective results, while electrophysiological and biochemical tests require a great deal of processing and time to obtain results (Deinzer R et al., 2000; Fukazawa T and Tochihara Y, 2009; Izawa S et al., 2007; Kashima S et al., 2006; Rantonen PJF and Meurman JH, 2000; Rohleder N et al., 2004).

In this study, the area and intensity of GDV parameters, those are indicative of higher amounts of energy as their values become larger, significantly decreased ($p < 0.01$) after exercise. Furthermore, "fatigue" after exercise was found to result in a decrease in the s-IgA/protein ratio of saliva.

In the POMS trial, a significant decreaee ($p < 0.01$) was observed in the "anger-hostility" field after the exercise. This report agrees with Takenaka et al. that the score after exercise was significantly reduced in "anger-hostility"as a result of the POMS test after the exercise using the bicycle ergometer (Takenaka K et al., 2002). It is said that changes in these mood scales common to various exercises are caused by physiological changes. In this study, "anger-hostility" and "fatigue" significantly decreased and increased, respectively ($p < 0.05$), and decreased in the other three scales, "depression-dejection", "vigor" and "confusion", but no significant difference was found.

For the study of psychological state and exercise effect using POMS, it has been reported that negative feelings as "anger" and "vigor" decreased after exercise (Raglin, J. S et al., 1995). Also in this study, it was revealed that exercise stimulation significantly increased "fatigue" physically and mentally. POMS testing revealed a significant decrease in "anger-hostility" after exercise ($p < 0.01$) while the "fatigue" factor increased significantly ($p< 0.05$). The "depression-dejection", "vigor", and "confusion" factors also decreased, suggesting that physical and mental "fatigue" from exercise inversely correlated with other factors.

As shown in Fig. 4, a significant correlation ($p < 0.01$) was observed between the immune protein s-IgA with both energy field parameters the area and intensity. Hacker et al. (2011) reported that there was significant correlation between GDV field parameters and biochemical parameters measured in saliva and we obtained similar results in the present study. It has been frequently reported that the saliva immunoglobulin s-IgA reflects the level of the "fatigue" from daily life and exercise (Akimoto T et, al., 1998; Pate RR et al., 1995; Shimizu K et al., 2007).

Biophotons are extremely weak biological light emissions observed in living bodies and living tissues. These light emissions are indicative of the levels of cellular activity and chemical reactions and are attracting attention as an important diagnostic parameter.

The physical characteristics of the GDV device for measuring evoked biophotons means that it is less burdensome when used on a subject because measurement can be performed in a noninvasive manner in a short period of time. Furthermore, data can be accumulated easily so that the physiological state of the subject can be rapidly assessed.

In addition to conventional techniques, employing the data collected from each individual by continuous measurement as GDV parameters may be usable as a new method in the field of health technology, which is becoming more diversified and individualized. From the data presented here, it is apparent that the stress caused by load can be easily measured by monitoring evoked biophotons using the GDV device. Therefore, it is possible to easily measure stress from the extremely weak light emissions from living bodies, which facilitates a new useful method for evaluating health state from a new viewpoint. Because this study was an examination only before and after the exercise, it will be necessary to clarify the temporal changes during exercise in the future. Analysis of fluctuations of energy field parameters over time may provide new insights into health conditions that would be valuable in the medical and sports fields.

We have found a significant correlation between diurnal variation of area, intensity, and s-IgA value (Tsubouchi S et al., 2018). These data further highlight the possibilities of this technology for use in exercise health management.

5. Conclusion

In the present study, evoked biophotons were employed as a parameter to convey biological information about the extent of in vivo energy fluctuations occurring upon exercise.

Subjects were made to exercise by having them run for 1 h on a treadmill at the 70% HR max level, which resulted in a significant decrease in the area and intensity energy field parameters from the initial values ($p < 0.05$).

Salivary s-IgA exhibited a significant decrease from the initial value ($p < 0.05$), and POMS examination scores also decreased. Significant correlation ($p < 0.05$) was also observed between both area and intensity and saliva s-IgA.

Results of the biophoton evaluation under the exercise load were similar with those of the saliva s-IgA and POMS examinations, thereby indicating that stress and "fatigue" are reflected by evoked biophotons.

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