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Anatomic Characterization of Human Ultra-Weak Photon Emission in Practitioners of Transcendental Meditation™ and Control Subjects

EDUARD P.A. VAN WIJK, Ph.D.,[1] HEIKE KOCH, M.A.,[1] SASKIA BOSMAN, Ph.D.,[1] and ROELAND VAN WIJK, Ph.D.[1,2]

ABSTRACT

Background: Research on human ultra-weak photon emission (UPE, biophoton emission) has raised the question whether a typical human emission anatomic percentage distribution pattern exists in addition to individual subject overall anatomic summation intensity differences. The lowest UPE intensities were observed in two subjects who regularly meditate. Spectral analysis of human UPE has suggested that ultra-weak emission is probably, at least in part, a reflection of free radical reactions in a living system. It has been documented that various physiologic and biochemical shifts follow the long-term practice of meditation and it is inferred that meditation may impact free radical activity.

Objective: To systematically quantify, in subjects with long-term transcendental meditation (TM) experience and subjects without this experience, the UPE emission of the anterior torso, head and neck plus the hands in an attempt to document the differences by the two groups.

Subjects: Subjects were 20 men reported to be healthy and nonsmokers. Each of the subjects in the meditation group had practiced TM twice daily for at least the past 10 years.

Methods: UPE in 20 subjects was recorded in a dark room using a highly sensitive, cooled photomultiplier system designed for manipulation in three directions. The protocol for multisite registration of spontaneous emission includes recording of 12 anatomic locations of anterior torso, head, and hands.

Results: Data demonstrate emission intensities that are lower in TM practitioners as compared to control subjects. The percent contribution of emission from most anatomic locations was not significantly different for TM practitioners and control subjects. Exceptions are the contributions of throat and palm.

Conclusion: In subjects with long-term TM experience, the UPE emission is different from control subjects. Data support the hypothesis that free radical reactions can be influenced by TM.

INTRODUCTION

Ultra-weak light, spontaneously emitted from humans is commonly referred to as "human biophoton emission." The intensity of this emission in the visible range of the spectrum is estimated to be on the order of less than $\sim 10^2$ photons/per cm^2 body surface.[1–5] It is thus, even though in the visible spectrum, not visible to the naked eye and cannot be captured with commonly used optical detectors. Ultra-weak photon emission is a constituent of the metabolic process of any living system. The wavelength spectrum of this emission recorded within the sensitivity of the multiplier is in the range of 450 to 630 nm, corresponding with lipid peroxidation processes documented from animal tissue.[6–8]

To study topographic variation in emission intensity, low-noise photomultipliers systems capable of single photon

[1]International Institute of Biophysics, Neuss, Germany.
[2]Faculty of Biology, Utrecht University, Utrecht, The Netherlands.

counting with high signal stability have been constructed that can be positioned over a subject laying supine.[3] Van Wijk and Van Wijk[4,9] described a protocol for quantitative multisite recording of subjects. Data demonstrated the variability in patterns among subjects. Some generic features were observed: (1) the fluctuation of photon counts over the body was lower in the morning than in the afternoon; (2) the thorax-abdomen region emits the lowest and most constant emission; and (3) the upper extremities and the head region emit the highest levels and increase during the day. The existence of a generic pattern of anatomic distribution of ultra-weak photon emission was also suggested from recent studies using a highly sensitive charge-coupled device (CCD) imaging system, developed by Kobayashi.[10]

In the search of the preceding protocol for an explanation of the quantitative differences among subjects, it was learned that the two subjects with lowest emission happened to be experienced meditation practitioners.[11] Long- as well as short-term physiologic effects of meditation have been described for over 30 years.[12] Long-term effects on aging processes[13] and in subjects with chronic diseases have been reported.[14,15] Transcendental Meditation (TM) has been implicated in impacting free radical activity as demonstrated by documenting lower blood peroxide levels.[16] Davidson et al.[17] demonstrated emission alterations of left anterior activation as well as antibody titers to influenza vaccine of subjects who meditated 45 min daily for 6 weeks.

The preceding publications can serve as a foundation to raise the hypothesis that human photon emission may be influenced by regular use of meditation. Meditation refers to a family of techniques that share a conscious attempt to not dwell on discursive, ruminating thoughts but rather to focus attention in a nonanalytic way.[18] People who meditate often develop their own mix of techniques. These can embrace mindfulness meditation, concentrative meditation, passive breathing exercises, yoga stretching, imagery, and autonomic training. In general, it is difficult to estimate exactly which part of the technique is responsible for the results of the meditation experience. The present study examined the biophoton emission from the upper frontal torso, head, neck, and hands of 10 subjects who practiced specifically Transcendental Meditation™ as taught by Maharishi Mahesh Yogi.

MATERIALS AND METHODS

Subjects

The study included 10 male experienced practitioners of TM (mean age 50.4 ± 4.3 y) and 10 male control subjects without experience with any form of meditation (mean age 50.1 ± 14.8). Each of the subjects in the TM group had practiced meditation for at least 10 years. It is a mental technique practiced for 20 min twice a day sitting easily with the eyes closed. The technique is taught by Maharishi Mahesh Yogi and learned from an authorized teacher under the auspices of the Maharishi's Global Administration Through Natural Law, Ltd. Some of the practitioners also practiced the more advanced TM-Sidhi program. Subjects practiced no other meditation technique.

All subjects were selected by posting a flyer on different internet news groups recommended by TM headquarters in The Netherlands. The subjects by self-report were healthy and free of medications. They also were interviewed to exclude any physical or emotional disorder. Exclusion criteria included the use of any antioxidant (i.e., vitamins E and C). Subjects ranged in age from 20 to 65 years. Written consent to participate in the study was obtained after they were thoroughly informed about the research. Each subject was measured with photomultiplier technology only once.

Recording human emission with the photomultiplier

The photomultiplier (9235 QB, selected type; Electron Tubes Limited, Ruislip, England, previously EMI) with a range of 200 to 650 nm was designed for manipulation in three directions. It was mounted in a sealed housing under vacuum with a 52-mm diameter quartz window maintained at −25°C to reduce the dark current (electronic background noise). Dark current was measured before and after each experiment. During the experimental period, the average background noise was 5.2 ± 0.3 cps (counts per second). A spacer (a ring 7 cm high) at the front of the photomultiplier tube allowed the measurement of a 9-cm diameter anatomic area at a fixed distance. The front ring was vented inside, avoiding the condensation of moisture in the quartz window.

The photomultiplier was hung in a dark room in a manner designed for manipulation in three directions. The walls and ceiling of the dark room were covered with mat black paint. The inner size of the dark room was 2 m × 1.5 m × 2 m with an average temperature of 20°C. The room could be vented; the resulting small fluctuations in room temperature gave negligible change in the dark current of the photon-counting device. A bed was positioned in the dark room. The dark room was juxtaposition to the control room, which housed the computer system.

Subjects were commonly recorded between 11 AM and 2 PM. Before measurement, subjects were shielded from ambient light for at least 1 hour. The shielding was an effort to avoid delayed luminescence interference from previous exposure to daylight or artificial light prior to recording.[9] During this period subjects remained in the red dim light of the control room. Subjects then walked into the dark room and were positioned on the bed for at least 10 minutes. The photomultiplier tube was placed above the body, the ring at the front port of the photomultiplier touching a particular anatomic area. The duration of each recording was 120 seconds, consisting of 2400 time intervals of 50 ms. Maximum duration of the measurement cycle inside the dark room was 45 minutes.

The anatomic locations used for recording were selected in such a way that the distribution of emission along the longitudinal ventral axis and the left and right hands over both palm and dorsal sides were recorded. Exceptions were made at the mouth and navel areas. Both left and right sides were measured to provide homogeneous skin assessment.

Data analysis

Statistical analysis of photon count data was performed with Statistica 6.1 (StatSoft, Tulsa, OK, version 2004). Groups were compared by exact nonparametric two-sample Wilcoxon tests. In contrast to *t*-tests, these tests neither assume that the data are normally distributed, nor assume that the variances in both groups are equal. Consequently, Wilcoxon tests do not test whether two groups do differ only by a shift of means but rather the more general hypothesis whether high values are more likely in one group than in the other.

RESULTS

Anatomic locations for biophoton recording

The pattern of sites for multisite registration of spontaneous emission includes recording of 12 anatomic locations: frontal torso, head, and hands (Fig. 1). The pattern corresponds with CCD images of a previous dark-adapted subject revealing the topography of spontaneous ultra-weak photon emission (Fig. 2). CCD images were obtained in the laboratory of M. Kobayashi (Department of Electronics, Tohoku Institute of Technology, Sendai, Japan).

The large anatomic CCD image of the superior anatomic area (see Fig. 2, left side) was obtained by recording from a subject continuously for 30 min with cryogenic cooled CCD camera at a distance of 100 cm.[10] As illustrated in the image, photon emission intensity around the face and neck was highest and gradually decreased over the torso and subsequently over the abdomen. A gradual decrease in intensity also was documented from the superior central torso to its lateral dimensions. The CCD image of the hands (see Fig. 2, right side) was obtained by recording at approximately 40 cm. It is interesting to note the strong emission from the nails, and its inequality for the different fingers. The images illustrate a rather homogeneous photon distribution over the palm and back of the hand.

All selected locations are full skin areas with reasonable homogeneous distribution of photon emission. The various anatomic areas represent the wide range of emission intensities: low over the abdomen to high over the palm of the hand and forehead.

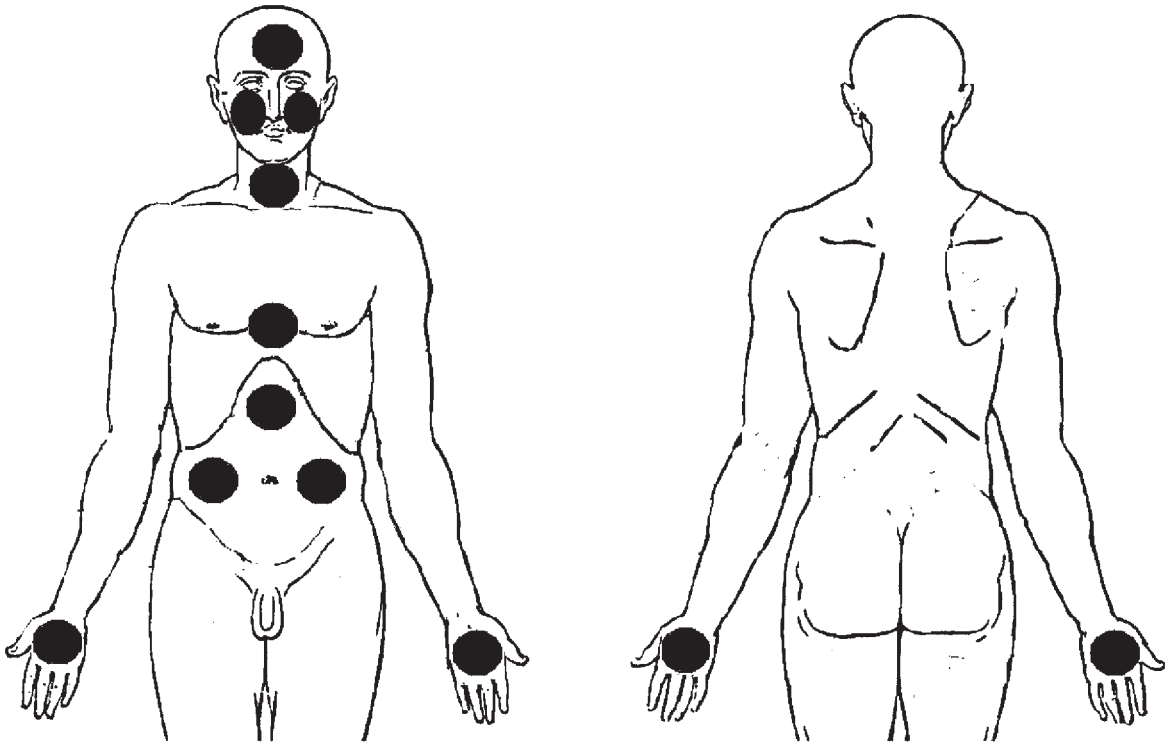

FIG. 1. Anatomic locations used for multisite registration of spontaneous emission of a group of male subjects.

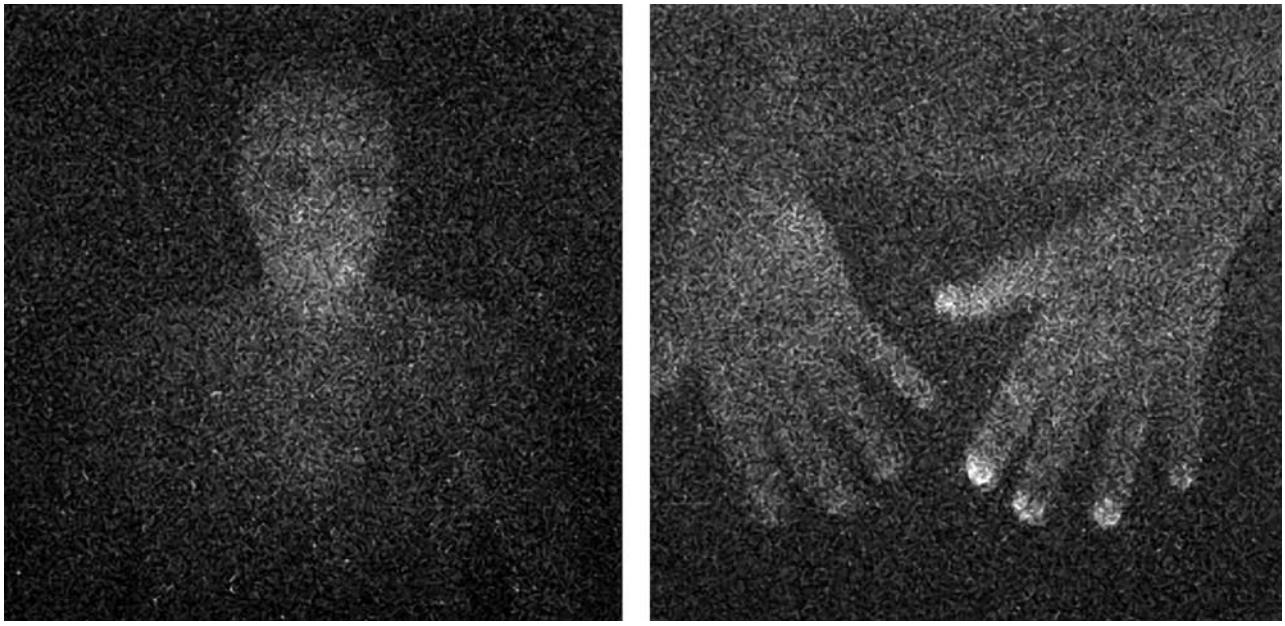

FIG. 2. Biophoton emission images of a human subject. **Left panel:** Biophoton image of ventral torso. **Right panel:** Biophoton image of palm (*left*) and dorsal (*right*) of the hands measured with the CCD imaging system. Biophoton images were taken with observation time of 30 min.

Multi-site registration of spontaneous emission from anatomic locations of TM practitioners and control subjects

The recordings at 12 anatomic locations were carried out with 10 TM practitioners and 10 control subjects. Each recording consisted of 2400 consecutive intervals of 50 ms. Electronic background was measured before and after the measurement of each subject. Because the recording of the subjects was performed over a period of 2 months, the electronic background varied slightly at times. Average background noise in this period was 5.2 ± 0.3 cps; values ranged between 4.9 ± 0.3 cps and 5.7 ± 0.4 cps. Mean emission of each of the 12 anatomic locations of each subject was determined after subtracting the background value of the corresponding subject's recording session. The average intensity was calculated for the group of 10 TM practitioners of each of the 12 specific anatomic locations and for the group of 10 control subjects (Table 1).

TM practitioners demonstrated for all recorded anatomic locations lower emissions than control subjects. The average photon emission in the TM group was 35% lower than the control group. The emission of the throat, forehead, and heart location were decreased 52%, 44%, and 45%, respectively; the palm of the right and left hand 16% and 23%, respectively. The large differences demonstrated for the solar plexus and heart locations on the torso, and for the throat, right cheek, and forehead locations on the head were significant as confirmed by the nonparametric Wilcoxon test. Although TM practitioners demonstrated lower mean emission from both sides of the hands, the differences demonstrated for locations on the hand were not found to be statistically significant.

A typical pattern of emission of TM practitioners and control subjects

Figure 3 portrays the contribution of each anatomic location to total emission for each subject. Data demonstrate that the sum of emissions from 12 anatomic locations of each subject could differ approximately five times between subjects; total emission can fluctuate between 50 and 235 cps. For both TM practitioners and control subjects, the percent emission contribution of each anatomic location to total emission for each group is represented in Table 2. The contributions of almost all locations to total emission are very similar for both groups. Exceptions are the contributions of throat and palm of the hand to total emission. Data demonstrate higher contributions of hand emission and lower contribution of throat to total emission in TM practitioners as compared to control subjects (Wilcoxon test; $p < 0.05$). This suggests that superimposed on the "common" human emission pattern, a fluctuation occurs in TM practitioners.

DISCUSSION

This study presents evidence that the intensity of photon emission is less in experienced TM practitioners. For both

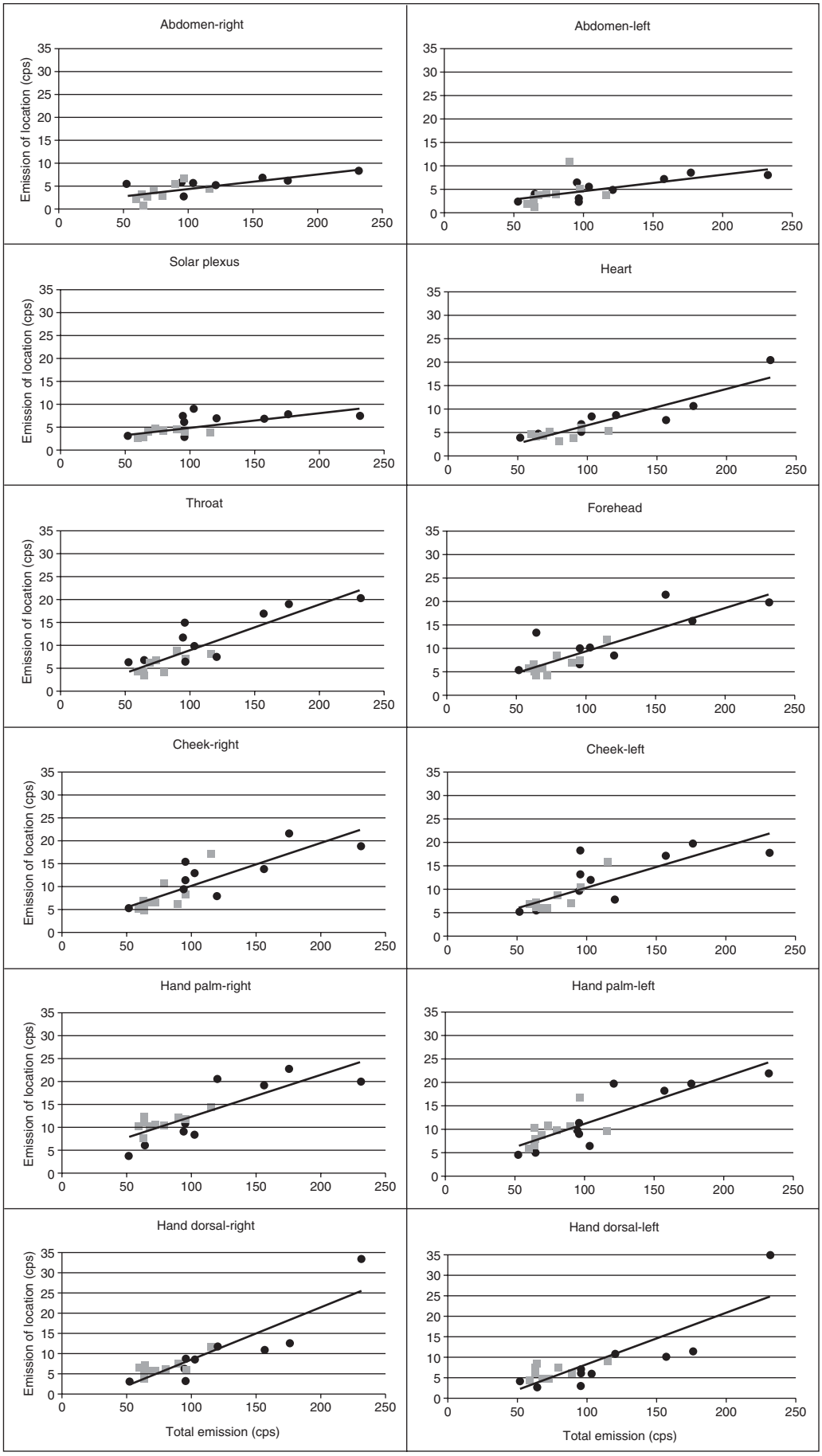

FIG. 3. Contribution of photon emission from individual anatomic locations to total emission for each subject. X-axis indicates total photon emission (counts/s); Y-axis indicates photon emission (counts/s) for each anatomic location. Each point represents one subject (gray square = TM practitioners; black circle = control subjects).

Table 1. Average Intensity of Each of the 12 Specific Anatomic Locations for the Group of 10 Transcendental Meditation™ Practitioners and for the Group of Control Subjects

	Photo counts (cps)		
Anatomic location	*Controls (mean ± SEM)*	*TM practitioners (mean ± SEM)*	p-*Value (Wilcoxon test)*
Torso			
Abdomen—right	5.27 ± 0.59	3.54 ± 0.54	ns
Abdomen—left	5.26 ± 0.71	3.99 ± 0.84	ns
Solar plexus	6.18 ± 0.70	3.62 ± 0.23	0.02
Heart	8.33 ± 1.52	4.55 ± 0.30	0.007
Head			
Throat	12.02 ± 1.72	5.75 ± 0.60	0.004
Cheek—right	12.27 ± 1.68	7.71 ± 1.18	0.04
Cheek—left	12.67 ± 1.73	7.96 ± 0.99	ns
Forehead	11.82 ± 1.78	6.58 ± 0.74	0.02
Hand			
Hand palm—right	13.12 ± 2.16	11.03 ± 0.58	ns
Hand palm—left	12.56 ± 2.15	9.72 ± 0.68	ns
Hand dorsal—right	10.36 ± 2.82	6.53 ± 0.97	ns
Hand dorsal—left	9.51 ± 3.00	6.48 ± 0.51	ns
Total	119.36 ± 17.26	77.48 ± 5.71	0.03

Groups were compared by nonparametric two-sample Wilcoxon test. ns = not significant.

groups, the abdomen emits the lowest intensity; this gradually increases rostally and is the highest around the face. Higher intensity also was documented for the palms. Data also illustrate that human subjects have a "common" pattern of ultra-weak photon emission. This pattern of emission was not completely identical for TM practitioners and control subjects. TM practitioners demonstrate higher contributions of hand emission and lower contribution of throat emission to total emission as compared to control subjects. Data were derived from registrations using multisite recording with a hanging and movable photomultiplier system. CCD imaging of different subjects in Japan validates the intensity variances as supported by images of the superior anterior (including head and neck) anatomic parts of the body.[10] The preceding patterns do not reflect delayed luminescence. Such is excluded as in previous studies by sufficient adaptation to dark room conditions prior to measurements.[4,9]

Ultra-weak photon emission in the optical spectrum is generally thought to reflect random imperfections accompanying the normal physiologic processes of oxygen consumption as well as the destructive activity of reactive oxygen species.[6–8,19,20] Historically, spectral analysis of human photon emission provided some initial information about the phenomenon.[1,2,4,9] The wavelengths of emission were cap-

Table 2. Contribution of Each Anatomic Location to Total Emission for the Group of 10 Trancendental Meditation™ Practitioners and for the Group of Control Subjects

Anatomic location	*Control group % contribution (mean ± SEM)*	*TM practitioners % contribution (mean ± SEM)*	p-*Value (Wilcoxon test)*
Abdomen—right	4.87 ± 0.72	4.44 ± 0.51	ns
Abdomen—left	4.57 ± 0.44	5.02 ± 0.87	ns
Solar plexus	5.56 ± 0.59	4.78 ± 0.29	ns
Heart	6.92 ± 0.38	6.03 ± 0.42	ns
Throat	10.36 ± 0.88	7.38 ± 0.48	0.02
Cheek—right	10.57 ± 0.85	9.67 ± 0.82	ns
Cheek—left	10.96 ± 1.12	10.11 ± 0.58	ns
Forehead	10.36 ± 1.31	8.42 ± 0.54	ns
Hand palm—right	10.73 ± 0.93	14.54 ± 0.77	0.003
Hand palm—left	10.22 ± 0.90	12.61 ± 0.92	0.05
Hand dorsal—right	7.84 ± 0.94	8.44 ± 0.59	ns
Hand dorsal—left	7.04 ± 1.04	8.56 ± 0.73	ns

Groups were compared by nonparametric two-sample Wilcoxon test.
ns = not significant.

tured by photomultipliers in the late 1970s and 1980s addressing different organ systems,[21–25] blood,[25–29] hepatic microsomal fractions,[30,31] enzymatic reactions and biochemical processes involving free radicals,[32–36] and lipid peroxidation.[25,30,37,38]

Such data demonstrated that human ultra-weak photon emission in the visible range corresponds to those emission bands (480, 520, and 575 nm) previously reported for ultra-weak photon emission of systems undergoing lipid peroxidation and the production of $^1O_2$ paired molecules.

Several lines of evidence have suggested that the lower emission values from TM practitioners are connected to a lower level of stress. Stress is connected to increased production of reactive oxygen species and related chemical reactions resulting in cell and tissue damage.[8,39] Schneider et al.[16] reported preliminary findings suggesting that lower peroxide levels are associated with the use of TM. Altogether, it can be hypothesized that a persistent program of TM meditation might well change the oxidative status of the human body. In the present study long-term TM practitioners participated, some of whom practiced additionally the more advanced TM-Sidhi program. Future studies are aimed to relate photon emission intensity and years of experience with TM and the Sidhi program. Also, it needs to be established whether these findings are the case for other meditation techniques.

A few other physiologic conditions that influence levels of oxidative damage must be taken into account.[9] It is interesting to note that caloric restriction, which decreases the rate of aging, also decreases oxidative damage.[40–42] The levels of oxidative damage generally increase with age. In the present study, the lower emission of TM practitioners as compared to control subjects could not be ascribed to age differences because both groups have similar mean age and no correlation could be observed by plotting age against photon emission. One cannot exclude that differences in intensity, at least in part, result from differences in dietary habits. Further research is needed to clarify such issues.

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REFERENCES

1. Edwards R, Ibison MC, Jessel-Kenyon J, Taylor RB. Light emission from the human body. Complement Med Res 1989;3: 16–19.
2. Edwards R, Ibison MC, Jessel-Kenyon J, Taylor RB. Measurements of human bioluminescence. Acupunct Electrother Res 1990;15:85–94.
3. Cohen S, Popp FA. Whole-body counting of biophotons and its relation to biological rhythms. In: Chang JJ, Fisch J, Popp FA, eds. Biophotons. Dordrecht: Kluwer Academic Publishers, 1998: 183–191.
4. Van Wijk R, Van Wijk EPA. Human biophoton emission. Recent Res Devel Photochem Photobiol 2004;7:139–173.
5. Van Wijk EPA, Van Wijk R. Multi-site recording and spectral analysis of human body spontaneous photon emission. Forsch Komplementarmed Klss Naturheilkd 2005a;12:96–106.
6. Sies H. Oxidative Stress: Oxidants and Antioxidants. New York: Academic Press, 1991.
7. Van Wijk R, Schamhart DHJ. Regulatory aspects of low intensity photon emission. Experientia 1988;44:586–593.
8. Van Wijk R, Tilbury RN, Slawinski J, et al. Biophoton emission, stress and disease. Experientia 1992;48:1029–1102.
9. Van Wijk R, Van Wijk EPA. Introduction to human biophoton emission. Forsch Komplementarmed Klss Naturheilkd 2005b;12:77–83.
10. Kobayashi M. Modern technology on physical analysis of biophoton emission and its potential extracting the physiological information. In: Musumeci F, Brizhik LS, Ho MW, eds. Energy and Information Transfer in Biological Systems. London: World Scientific Publishers, 2003: 157–187.
11. Van Wijk EPA, Ackerman J, Van Wijk R. Effect of meditation on ultraweak photon emission from hands and forehead. Forsch Komplementarmed Klss Naturheilkd 2005a;12:107–112.
12. Wallace RK. Physiological effects of Transcendental Meditation. Science 1970;167:1751–1754.
13. Wallace RK, Dillbeck M, Jacobe E, Harrington B. The effects of the Transcendental Meditation and TM-Sidhi Program on the aging process. Int J Neurosci 1982;16:53–58.
14. Petermann F, Vaitl D. Handbuch der Entspannungsverfahren Band 2: Anwendungen. Weinheim, Germany: Psychologie-Verlag-Union, 1994.
15. Majundar M. Meditation und Gesundheit: Eine Beobachtungsstudie. Essen, Germany: KVC Verlag, 2000.
16. Schneider RH, Nidich SI, Salerno JW, et al. Lower lipid peroxide levels in practitioners of the transcendental meditation program. Psychosom Med 1999;60:38–41.
17. Davidson R, Kabat-Zinn J, Schumacher J, et al. Alterations in brain and immune function produced by mindfulness meditation. Psychosom Med 2003;65:564–570.
18. Shapiro DH. Clinical and physiological comparison of meditation with other self-control strategies. Amer J Psychiatry 1982;139:267–274.
19. Halliswell B, Gutteridge JMC. Free radicals in biology and medicine. Oxford, UK: Clarendon Press, 1989.
20. Sauermann G, Mei WP, Hoppe U, Stäb F. Ultraweak photon emission of human skin *in vivo*: Influence of topically applied antioxidants on human skin. Meth Enzymol 1999;300:419–428.
21. Shimizu Y, Inaba H, Kumaki K, et al. Measuring methods for ultra-low light intensity and their application to extra-weak spontaneous bioluminescence from living tissues. IEEE Trans Instrum Meas 1973;22:153–157.

22. Cadenas E, Arad ID, Boveris A, et al. Partial spectral analysis of the hydroperoxide-induced chemiluminescence of the perfused lung. FEBS Lett 1980a;111:413–418.
23. Cadenas E, Boveris A, Chance B. Low-level chemiluminescence of bovine heart submitochondrial particles. Biochem J 1980b;186:659–667.
24. Cadenas E, Varsavsky AI, Boveris E, Chance B. Oxygen- or organic hydroperoxide-included chemiluminescence of brain and liver homogenates. Biochem J 1981;198:645–654.
25. Inaba H. Applications of measuring techniques of extremely weak light to medicine and life sciences. Kogaku (Optics) 1983;12:166–179.
26. Miyazawa T, Kaneda T. Extra-weak chemiluminescence of organ homogenate and blood in tocopherol-deficient rats. J Nutr Sci Vitaminol 1981;24:415–423.
27. Inaba H, Takyu C, Yoda B, et al. Detection of ultraweak light emission of human blood: Intensity difference between cigarette smoker and nonsmoker. J Opt Soc Am 1983;73:1926.
28. Yoda B, Abe R, Goto Y, et al. Spontaneous chemiluminescence of smoker's blood. In: Kricka LJ, Stanley PE, Thorpe GHG, Whitehead TP, eds. Analytical Applications of Bioluminescence and Chemiluminescence. London: Academic Press, 1984: 587–590.
29. Yoda B, Goto Y, Sato K, et al. Ultra-weak chemiluminescence of smoker's blood. Arch Environ Health 1985;40:148–150.
30. Nakano M, Noguchi T, Sugioka K, et al. Spectroscopic evidence for the generation of singlet oxygen in the reduced nicotinamide adinine dinucleotide phosphate-dependent microsomal lipid peroxidation system. J Biol Chem 1975;250: 2404–2406.
31. Cadenas E, Sies H. Low level chemiluminescence of liver microsomal fractions initiated by tert-butyl hydroperoxide. Relation to microsomal hemoproteins, oxygen dependence and lipid peroxidation. Eur J Biochem 1982;124:349–356.
32. Nakano M, Takayama K, Shimizu Y, et al. Spectroscopic evidence for the generation of singlet oxygen in self-reaction of sec-peroxy radicals. J Am Chem Soc 1976;98:1874–1975.
33. Ushijima Y, Nakano M, Tsuji Y, Inaba H. Excitation of indole analogs by phagocytosing leukocytes. Biochem Biophys Res Commun 1978;82:855–858.
34. Ando W, Kabe Y, Kobayashi S, et al. Formation of sulfinyl oxide and singlet oxygen in the reaction of thianthrene cation radical and superoxide ion. J Am Chem Soc 1980;102: 4526–4528.
35. Yoshimoto T, Yamamoto S, Sugioka K, et al. Studies on the tryptophan-dependent light emission by prostaglandin hydroperoxidase reaction. J Biol Chem 1980;255:10199–10204.
36. Kobayashi S, Sugioka K, Nakano M, et al. Excitation of indole acetate in myeloperoxidase-H_2O_2 system: possible formation of indole acetate cation radical. Biochem Biophys Res Commun 1989;93:967–973.
37. Miyazama T, Kaneda T, Takyu C, et al. Generation of singlet molecular oxygen in rat liver homogenate on adding autoxidized linseed oil. Agric Biol Chem 1981;45:1597–1601.
38. Miyazawa T, Kaneda T, Takyu C, Inaba H. Characteristics of tissue ultraweak chemiluminescence in rats fed with autoxidized linseed oil. J Nutr Sci Vitaminol 1983;29:53–64.
39. Cernak I, Savic V, Kotur J, et al. Alterations in magnesium and oxidative status during chronic emotional stress. Magnes Res 2000;13:29–36.
40. Tahara S, Matsuo M, Kaneko T. Age-related changes in oxidative damage to lipids and DNA in rat skin. Mech Ageing Dev 2001;122:415–426.
41. Barja G. Endogenous oxidative stress: Relationship to aging, longevity and caloric restriction. Ageing Res Rev 2002a;1: 397–411.
42. Barja G. Rate of generation of oxidative stress-related damage and animal longevity. Free Radic Biol Med 2002b;33: 1167–1172.

Address reprint requests to:
Roeland Van Wijk, Ph.D.
Faculty of Biology
Utrecht University
Padualaan 8, 3584 CH, Utrecht
The Netherlands

E-mail: meluna.wijk@wxs.nl