Forschende Komplementärmedizin und Klassische Naturheilkunde

Review Article · Übersichtsarbeit

Forsch Komplementärmed Klass Naturheilkd 2005;12:77–83
DOI: 10.1159/000083763

Published online: March 7, 2005

An Introduction to Human Biophoton Emission

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Key Words
Ultraweak photon emission · Biophotons · Skin · Consciousness · Acupuncture

Summary
Background: Biophoton emission is the spontaneous emission of ultraweak light emanating from all living systems, including man. The emission is linked to the endogenous production of excited states within the living system. The detection and characterisation of human biophoton emission has led to suggestions that it has potential future applications in medicine. **Objectives:** An overview is presented of studies on ultraweak photon emission (UPE, biophotons) from the human whole body. **Methods:** Electronic searches of Medline, PsychLit, PubMed and references lists of relevant review articles and books were used to establish the literature database. Articles were then analysed for their main experimental setup and results. **Results:** The, mostly, single case studies have resulted in a collection of observations. The collection presents information on the following fields of research: (1) influence of biological rhythms, age, and gender on emission, (2) the intensity of emission and its left-right symmetry in health and disease, (3) emission from the perspective of Traditional Chinese and Korean Medicine, (4) emission in different consciousness studies, (5) procedures for analysis of the photon signal from hands, (6) detection of peroxidative processes in the skin. Of each article the main findings are presented in a qualitative manner, quantitative data are presented where useful, and the technological or methodological limitations are discussed. **Conclusion:** Photon emission recording techniques have reached a stage that allows resolution of the signal in time and space. The published material is presented and includes aspects like spatial resolution of intensity, its relation to health and disease, the aspect of colour, and methods for analysis of the photon signal. The limited number of studies only allows first conclusions about the implications and significance of biophotons in relation to health and disease, or to mental states, or acupuncture. However, with the present data we consider that further research in the field is justified.

Schlüsselwörter
Ultraschwache Lichtstrahlung · Biophotonen · Haut · Bewusstsein · Akupunktur

Zusammenfassung
Hintergrund: Die Abstrahlung von Biophotonen ist eine spontane ultraschwache Lichtstrahlung, die von allen lebenden Systemen ausgeht, auch vom Menschen. Diese Strahlung hängt mit der endogenen Erzeugung erregter Zustände im lebenden System zusammen. Die Entdeckung und genauere Charakterisierung der menschlichen Biophotonenstrahlung hat zur Annahme geführt, dass es dafür zukünftige medizinische Anwendungen geben könnte. **Zielsetzung:** Die Arbeit stellt einen Überblick dar über Studien zur ultraschwachen Photonenstrahlung (Biophotonen) des menschlichen Körpers. **Methode:** Elektronische Literatursuche in Medline, PsychLit, PubMed und Handsuche der Literaturverzeichnisse relevanter Überblicksartikel und Bücher wurden benutzt, um die Literaturbasis herzustellen. Einzelne Artikel wurden anschließend auf ihr experimentelles Design und ihre Ergebnisse hin analysiert. **Ergebnisse:** Die meisten Studien waren Einzelfallbeobachtungen und resultierten in einer Sammlung von Beobachtungen. Der Überblick präsentiert Informationen zu folgenden Forschungsgebieten: (1) Einfluss biologischer Rhythmen, des Alters und des Geschlechts auf die Biophotonenemission, (2) Intensität der Emission und Rechts-links-Asymmetrie oder -Symmetrie in Gesundheit und Krankheit, (3) Biophotonenstrahlung aus der Perspektive der Traditionellen Chinesischen und Koreanischen Medizin, (4) Biophotonenstrahlung in verschiedenen Studien zur Bewusstseinsforschung, (5) Vorgehensweisen zur Analyse des Photonensignals gemessen an den Händen, (6) Entdeckung peroxidativer Prozesse in der Haut. Die Hauptergebnisse jeder Arbeit werden qualitativ präsentiert, quantitative Daten werden dargestellt, wo sinnvoll und nützlich. Die technologischen und methodischen Begrenzungen werden diskutiert. **Schlussfolgerung:** Die Technik zur Erfassung der Biophotonenemission hat eine Stufe erreicht, die eine gute Auflösung des Signals in Zeit und Raum erlaubt. Die publizierte Literatur wird zusammengefasst und enthält Informationen über Aspekte wie räumliche Auflösung der Intensität, Beziehung der Strahlung zu Gesundheit und Krankheit, Aspekte der Farbe bzw. Wellenlänge der Strahlung und Methoden zur Analyse des Photonensignals. Die begrenzte Studienzahl erlaubt jedoch nur erste Schlussfolgerungen über die Implikationen und Reichweite der Biophotonen in Bezug auf Gesundheit und Krankheit, in Bezug auf Bewusstseinszustände oder in Bezug auf Anwendungen wie Akupunktur. Auf jeden Fall sind wir der Meinung, dass der gegenwärtige Forschungsstand weitere Forschung auf dem Gebiet rechtfertigt.

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Introduction

Research on human biophoton emission has appeared in the literature since the 1970's. Its nature is generally descriptive and aetiology and the emission is generally understood to reflect the physiology of the human organism [1–6]. The ultraweak light emission originating spontaneously from living systems (UPE, ultraweak photon emission, biophoton emission, or short: biophotons) ranges in intensity from a few to approximately 10^2 photons / (s × cm^2). It is thus not visible to the naked eye and cannot be captured with commonly used optical detectors. The spectral range is 400–720 nm. The biological origins and concrete mechanisms of this light emission are not yet well understood. To study the role of biophoton emission in living systems and in order to clarify its basic mechanisms, highly sensitive measuring instruments are required that allow non-invasive and non-destructive recording. Basically, three types of systems have been developed to register UPE. Photomultipliers have evolved to extremely low-noise single photon counting systems in which cooled photomultiplier tubes are placed in a vacuum chamber to provide absolute stability of the signal and maximum noise reduction. Photomultipliers allow the study of biophoton emission utilising quantum statistical properties in actual living systems to clarify its basic mechanisms. A second system utilised to study UPE also provides spectral analysis. For spectral characterisation a spectral analyser system using a set of sharp cut-off, optical filters in the wavelength range from ultraviolet (UV) to infrared (IR) is commonly used. A third system to fundamentally characterise UPE utilises a spatial distribution measurement or imaging of biophoton emission. This is usually performed with ultra-sensitive two-dimensional photon counting devices, as special equipped charged-coupled devices [7].
This introductory review comprises two parts. The first part presents historical aspects of biophoton research and touches upon pilot work of many professional disciplines from the period 1975–1995. The second part informs about additional research and systematically presents information on human biophoton emission in relation to health and disease, the aspect of colour, and methods for analysis of the photon signal. Of each article, the main findings are presented in a qualitative manner, quantitative data are presented where useful; technological or methodological limitations are discussed.

Method

This review concentrates on biophoton emission as extremely weak light emanating from the whole and intact human body. It does not take into account UPE from special internal organs or isolated body fluids. On the basis of our own databases, we systematically compiled all citations found in literature searches until end 2003: bibliographic database by electronic search of Medline, PsychLit, PubMed, references lists of relevant review articles [8, 9], books [10–12], and by contact with researchers in the field. Each article was analysed for its main experimental question(s).

Historical Aspects

Early Attempts to Record the Human Envelope of Radiation
Research in human photon emission started at least three decades ago. Early publications [13, 14] illustrate how fascinated their authors were by previous reports of 'an envelope of radiation surrounding living organisms'. Utilising a DC-photomultiplier, their studies produced a graphic record on a XY recorder. The photomultiplier was mounted in a light-tight darkroom scanned with a photomultiplier tube to demonstrate that there were no leaks of light. The subjects stood in front of the photomultiplier tube without clothes from the waist up. The protocol avoided signals which resulted from static electricity and fluorescence of dyes. The researchers utilised a photocathode with a maximal sensitivity at 400 nm and almost zero activity at 650 nm, thus minimising thermal effects. A major difficulty encountered in these early experiments was the inherent internal noise produced by the photomultiplier tube, which was of the same order of magnitude as the measured signal. To differentiate between signal and noise, the signal was integrated and the average current for the integration period was determined. The researchers reported a statistically significant 11% increase of the signal above background noise.
In this early research, experimental subjects were asked to voluntarily increase emission intensity by breathing deeply and by producing vibratory movements of the body. Only some subjects were able to produce an increased signal, others failed to do so. However, the increase of the signal did coincide with the subjects' attempts to increase their 'energy fields'. Controls did not produce an increase in the signal. According to the researchers temperature changes could be ruled out as the cause for signal increase. Different inanimate objects with emissions similar to that of the human skin, and heated to varying temperatures between 30–90 °C, did not increase the phototube output. Moreover, small fluctuations in room temperature gave a negligible increase in dark current.

Introduction of Sensitive Photomultipliers to Characterise Human Biophoton Emission
Edwards and colleagues published a study on human body photon emission in 1989 [15] and 1990 [16]. This study was carried out as part of the Dove Project, in United Kingdom. Its setup consisted of a photon detection system mounted in a sealed housing with a quartz window, at a constant temperature of –23 °C. The mean dark noise in these experimental conditions was around 60 counts per second (cps). The darkroom was specially constructed, and the researchers took care for the use of special materials in that room as well as regarding subjects' clothing. The authors recorded the temporal variation of the emission of the hand with measurements every 1.5 h over a 28-h period. Variation with time was observed, but the data were not sufficient to allow any conclusion about

Table 1. Topographical variation in photon emission (cps) in 2 subjects as reported in early studies [15, 16]

Body location	Subject 1	Subject 2
Abdomen	4.05	4.14
Lower back	6.60	4.87
Chest	5.42	5.63
Forehead	23.47	7.71
Hand	27.08	20.87

diurnal periodicities. With respect to topographical variation the count rate for five different body areas was recorded in two subjects. Table 1 illustrates differences in count rate over the body as well as between the foreheads and hands of both subjects. These early findings already revealed that flat body parts (abdomen, back, chest) emit at a lower intensity than topologically complicated parts (head, hands). If a tourniquet was applied around the upper arm, photon emission of the palm was about 15% lower than otherwise. For spectral analysis of hand emission coloured gelatin filters were interposed between hand and photomultiplier. These filters divided the visible spectrum into four bands, approximately corresponding to the colours blue (410–495 nm), green (495–540 nm), yellow (540–570 nm) and red (570–650 nm). There was a clear trend of increasing flux towards the red but due to temporal variations the authors were not sure of the shape of the spectral curve in more detail. In the wavelength region below 410 nm they were unable to reveal a significant departure from the noise rate.

Introduction of Two-Dimensional Photon Counting

A special project on biophoton emission, the 'Inaba Biophoton Project' was started by H. Inaba in Japan, in 1986. The project was funded by the Exploratory Research for Advanced Technology (ERATO), a subsidiary of the Research Development Corporation of Japan (presently, Japan Science and Technology Corporation). Human biophoton emission was investigated with two-dimensional photomultipliers in order to record the two-dimensional pattern of UPE from the human body surface. A two-dimensional image from the left hand showed that photon emission was not uniform; it exhibited a pattern with high intensity levels in the region of the index and middle fingers and low intensity in the middle of the palm [1, 17]. Photon emission could also be measured at other regions of the body, but Inaba et al. limited their study to human hands with the perspective of developing a simple and easy non-invasive imaging technique for diagnostic purposes (see section on Traditional Chinese and Korean Medicine). In its early studies, the Japanese group had also posed the question if hand photon emission was correlated with body temperature [2]. With a small-size photomultiplier tube intensity distributions of biophoton emission from the hand of a healthy male subject were recorded. Data were correlated with parallel recordings of the body surface temperature at the same spots. No positive correlation between intensity distributions of biophoton emission and surface temperature was found, although differences in their distribution existed, depending on the individual subject.

Introduction of Large-Scale Scanning with a Moveable Photomultiplier

In Germany, F.A. Popp and colleagues started pioneering research in human biophoton emission in 1993 by building a light-tight darkroom with black interior walls for the instalment of a detector head that, by hanging on runners, could be moved over the whole body of a subject lying on a bed underneath. The first cooled photomultiplier had a noise level of about 20 cps and enabled registration of a real count rate of 3 cps in a measurement time of 30 min at a significance level of 95%. The photon detector was moveable through a stepper motor along 3 dimensions, and should allow the scanning of the spontaneous photon emission. The largest scan area for a two-dimensional image was 2×1 m [18]. Time of scanning depended on several factors: time required to localise the photon detector, measuring time, and number of scanning points. In the automatic programme, the time required to position the detector was approximately 1 s, and the measurement time could be adjusted between 10^{-3} and 10^{2} s. A high resolution requires a large number of scanning points. On the other hand, the low photon count rates require a long measurement time in order to yield reliable values. As nobody can keep his posture over several hours, a compromise had to be found between measuring time and resolution of a scan, in dependence of the intensity of biophoton emission.

During the period from July 1994 to November 1995 the device was utilised to record biophoton emission in 80 healthy and diseased subjects at a variety of body sites [18]. In each subject, however, only few locations were recorded, and no systematic measurement schedule was followed. The aim of this initial research was to find features at specific body locations, which could characterise states of health and disease in an integral manner.

It can be concluded from this historical overview that the resolution of human emission in time and space not only entails extreme technical difficulties but also requires special techniques for signal analysis. Notwithstanding these difficulties, research has continued over the past 10 years, predominantly in relation to health and disease.

Fields of Research on Human Biophoton Emission

What knowledge do studies on human photon emission provide? The documentation of experimental studies shows recent progress in the investigations on the feasibility of medical application of emission recordings.

Biophoton Emission: Intensity and Left-Right Symmetry in Diseased Patients

Several studies suggest that the intensity of photon emission changes in a state of disease [1–3, 17–21]. In this respect, it is necessary to distinguish between studies on wounding and studies on patients with specific (chronic) diseases. The human body shows photon emission from abnormal areas such as wounds, sites of skin disease, and other injuries that affect the skin surface [19]. Two-dimensional photon counting images were taken of a scratch on the skin of the leg. About 30 h after the injury, part of the scab was removed which caused body fluid to exude from the affected part. At this site, an increased emission could be imaged. An affected part of chronically diseased skin that exuded body fluid also showed increased biophoton emission. In both cases, the very weak signal was obtained in a 30-min observation time for photon counting. Long-time observations have the merit of obtaining a higher signal-to-noise ratio, however, a person normally cannot keep still for a long time.

Several research groups presented data on a change in intensity of photon emission in the case of chronic diseases without affection of the skin surface. The Japanese study [1, 2, 17] of the two-dimensional pattern from the index and middle fingers was used to differentiate hypothyroidism, a lower state of metabolic activity than normal. Biophoton emission in patients with hypothyroidism was always less intense than normal. This lower emission was also found in patients whose thyroid glands had been removed. These results connect in a general way the intensity of UPE with the basic metabolic rate.

In contrast, Cohen and Popp [18, 20, 21] reported of a multiple sclerosis patient who emitted more biophotons than ordinary healthy subjects. The authors introduced a second parameter for disease, e.g., percentage of difference in emission between left and right hand. They suggested that in certain diseases left-right symmetry of UPE from hands is broken.

Jung et al. [3] studied left-right symmetry of photon emission from the palm and the dorsum of the hands of 7 Korean hemiparesis patients, and compared these data with similar data from the hands of 20 self-reportedly healthy subjects. Measurements were taken with two non-cooled photomultiplier tubes inside a darkroom assembly specially fabricated to simultaneously measure biophoton emission from both hands of one subject. According to the authors, the variation among healthy people was not large; the largest deviation was about 25% of the average value. In the hemiparesis patients though, the left and right differences of biophoton emission rates were reported very large in 4 out of 7 patients, compared to the 20 healthy subjects both for the palm and the dorsum of the hand. In the 3 other patients the differences were within normal range.

Biophoton Emission from Hands: Influence of Biological Rhythms, Age, Gender

Since left-right asymmetry in photon emission intensity from hands has been particularly investigated for the feasibility of medical applications, other influences, e.g., of age, gender, time of day and other biological rhythms, must also be taken into account. Several studies have focused on these latter aspects. Edwards and colleagues [15, 16] studied daily variation of the emission from the hands. In their study, measurements were carried out every 1.5 h over a 28-h period, during which the subject maintained usual eating and sleeping patterns. Although variation with time was observed, the authors did not find evidence for diurnal periodicities. Our group examined 29 body locations in 4 subjects for the emission in the morning and afternoon [22]. Data demonstrate that the intensity increased during the day depending on the subject as well as the body location.

Cohen and Popp [20, 23] considered long-term periodicity in a systematic study on photon emission from hands and forehead, using the moveable photon detector in the light-tight darkroom. The authors examined both the palms of the hand and the forehead of one subject, daily, over a period of 9 months. Recordings demonstrate a clear preference of left and right hand correlation. Long-term biological rhythms of spontaneous emission of that subject became evident with Fourier analysis. The authors explained the rhythmic patterns in terms of an oscillating body-photon field that follows definite rhythms and in which oscillations become stronger with decreasing oscillation frequency. The phases of the oscillations depended on the location within the body. Bilateral emission from hands was higher in summer than in other seasons of the year. A deviating pattern was observed for the forehead.

Bieske and colleagues [24] utilised a similar device to record low-level emission from defined points of the hands and the inside of the lower arm. From 3 subjects who took part in the measurements series in summer and winter, it was concluded that the subjects gave lower readings at all measurement points in the winter series than in the summer series. The latter observation is in line with the observation by Cohen and Popp [20, 23].

Influence of age on photon emission of hands has been reported in two studies. Sauermann et al. [6] investigated two age groups (n = 20, age 18–25 vs. n = 20, age 60–72). Spontaneous photon emission from the hands was increased in elderly subjects. The authors correlated this observation with the increased oxidative status of stratum corneum proteins in the skin of elderly human skin. Also in the study by Choi et al. [25] on 20 self-reportedly healthy subjects without any specific disease the effect of age on biophoton emission from the hands was examined. The subjects' age ranged between 14 to 56 years (mean age 24 years). The authors distinguished three age groups, in the teens, in the twenties, and over thirty, showing 42.4 ± 3.31, 39.7 ± 4.15, 44.4 ± 7.55 cps for these age groups (including a background of about 31 cps). They also analysed their data for the 15 male and 5 female participants in their study with respect to the influence of gender on biophoton emission from the hands. The data showed biophoton emission of 41.4 ± 5.69 and 42.7 ± 3.75 for males and females, respectively. The authors stated that the sample of subjects was not sufficiently large, therefore data were only considered as suggestive observations.

Biophoton Emission of Hands from the Perspective of Traditional Chinese and Korean Medicine

Several studies on biophoton emission from the hands have focused on special aspects of Traditional Chinese or Korean Medicine. In these studies biophoton emission was discussed in relation to the function of acupuncture meridians. The conditions of the meridians are basic elements of Traditional Chinese and Korean Medicine. According to this medical system, diseases are caused by an unbalance of vital forces called Yin and Yang, which for instance reflect left and right side of body, respectively [3]. In their article on 7 hemiparesis patients, the Korean researchers reported that left and right differences of photon emission rates from the palm and the dorsum of the hands were very large in 4 out of those 7 patients, compared to 20 healthy subjects [25]. They also reported that after acupuncture treatment, the left and right difference in biophoton emission was dramatically reduced: in each case the lateral difference was normalised after the treatment. The Korean research group also utilised a photomultiplier with an aperture of 8 mm diameter, such that photons from point-like sources could be detected [26]. Biophotons emitted from the fingernails and fingerprints of 20 healthy subjects were measured. Significantly more emission was recorded from fingernails than fingerprints for each finger of each subject. Some fingers emitted far stronger than others, and it depended on the subject which finger emitted strongest.

In early studies by Inaba [27], attention was focused on photon emission from acupuncture points distributed on the hand and finger. Emission intensity was compared to that from non-acupuncture points. The author reported that around the forearms and hands, photon emission tended to gradually decrease from the Shang-yang point to Ho-ku and then Chu-chih acupuncture points, and that their intensities differed between right and left. The author also suggested that emission from acupuncture points was normally higher than from non-acupuncture points. Moreover, insertion of a needle [28] and laser beam needle [29] into the acupuncture point enhanced photon emission from other acupuncture points.

Yanagawa and colleagues [19] reported on a trial on the effect of thermal stimulation by moxa, another method to influence acupuncture points. In order to avoid a local painful burn, moxa was selected and applied as sai-jyo on-kyu, i.e. warm moxa on the navel, with an adjustable moxa height container. After moxa treatment, in order to remove sweat or secretions from the skin surface the moxa point was wiped with a tissue paper that did not contain fluorescent substances. The authors reported that photon emission from the moxa point was observed. As a control condition, moxa treatment was carried out on a special moxa mat made of cowhide, which showed no effect on photon emission. The result was equal in control measurement of a sample of sweat.

Human Biophoton Emission in Consciousness Studies

The role of consciousness in biophoton emission has been investigated in some studies. In an early study by Dobrin et al. [13, 14] the experimental subjects' intention to influence emission as compared to control subjects was subject of research. The early equipment easily explains that this study could not provide a clear answer.

Nakamura et al. [5] studied the influence of Qigong on biophoton emission in 3 healthy men and 1 woman, aged 20–50 years. Photon emission was measured from the fingertip with a cooled photomultiplier tube. Typically, the middle finger of the right hand was used. In one 50-year-old male, biophoton emission was increased during qi emission and decreased during relaxation. In the other subjects, however, no such association between qi emission and biophoton emission was observed.

Vekaria [30] investigated the influence of intention on photon emission from the hand in 8 subjects – 6 females and 2 males. If a person tried to intentionally change his or her photon emission, the mean photon count decreased. Not all subjects were able to influence photon emission with similar success. Analyses revealed that there was an individual variation among as well as within subjects. In another study, 3 subjects were measured to check spectral characteristics of photon emission using intention. The blue-yellow ratio increased during the intention mode.

Recently, Van Wijk and colleagues [4] investigated the influence of meditation on photon emission from the hands and forehead in 5 subjects. Data indicated that photon emission changed after meditation. In one subject with high pre-meditation values, photon emission decreased during meditation and remained low in the post-meditation phase. Regarding the other subjects, the study mostly demonstrated only a slight decrease in photon emission, but commonly a decrease was observed in the kurtosis and skewness values of the photon count distribution.

Photon Counting Statistics of Biophotons from Hands

Because of the low intensity of biophoton signals, the question is asked whether the biophoton signal is a result of random or of coherent processes. Photon counting statistics on the distribution of photons in a biophoton signal should provide an answer to this question. In this respect, photon count distribution has been studied by two procedures.

The first procedure makes use of first and second moments. The first moment gives n, the average rate of photon emission, while the second moment gives σ^2, the square of standard deviation. These moments are combined to define the parameter $\delta = (\sigma^2 - n) / n$ for testing randomness or coherence of the signal. The value of δ is zero for Poisson distribution and positive for thermal distribution. In addition, higher probability moments of photon emission are sometimes calculated. This procedure was used for the analysis of the spontaneous photon emission of several body locations [18] as well as for biophoton signals emitted from the hands of 20 healthy subjects and a few paralytic patients [31]. It was observed that the higher probability moments of biophotons from healthy subjects corresponded to Poisson distribution while those of paralytic persons revealed deviations from Poisson distribution and seemed to approach geometrical distribution. The authors explained these findings in terms of interrelations of the underlying metabolic processes.

The second procedure makes use of the Fano factor F(T) that quantifies the deviation from Poisson statistics as a function of observation time T. F(T) as used by Vekaria [30] and Kobayashi et al. [32] is defined as the variance of the number of photons divided by the mean number of photons for a given time window of length T. For a periodic (rhythmic) process, the variance decreases and F approaches zero as the window size is increased. In contrast, for a fractal process, F increases as a power of the window size and may reach values >1.0. This reflects the greater variance in photon counts with increasing window size. The increase in variance occurs because rare clusters of high and low photon counts are more apt to be found the more data are collected. Such clustering has been considered as characteristic of a fractal process [33, 34]. Without discussing it in detail, the authors concluded that photon count statistics had a potential to be used as an indicator of the healthy state, but that additional case studies were required to determine statistically significant diagnostic criteria. Recently, Van Wijk et al. characterised photon emission from the hands in the pre- and post-meditation phases by the Fano factor [4]. Data indicated that the Fano factor time curve is useful to quantify the effect of meditation on human photon emission.

Application for Evaluation of Skin Oxidative Status and Antioxidant Capacity

Sauermann et al. [6] reviewed applications of photon emission recording since the 1980's in studies on human skin that was treated with UV, ultrasound, topical applications of peroxides, and antioxidants. Most of the existing methods for evaluation of skin oxidative status and antioxidant capacity are invasive and require removal of the skin, its separation into its various layers, homogenisation, and analysis of its antioxidants or its oxidation products. It is obvious that such measurements cannot be done on a large scale in humans. Instead, monitoring of UPE directly on the skin has provided a unique technique for routine non-invasive detection of peroxidative processes and the effectiveness of antioxidants for human skin in vivo.

Experimental Setup and Future Questions

Protocol

The handling of subjects requires careful attention by the researcher. It has been reported that illumination with (artificial) sunlight leads to a delayed luminescence, its kinetics, however, is essentially unknown. It may last long, and has to be carefully controlled. Other conditions that need to be controlled are temperature, humidity, skin condition (creams and lotions) and clothing of the subjects (e.g. photosensitisers in laundry powder). Also, static electricity that may be caused by friction may lead to spurious luminescence effects. Another aspect is the recording time necessary to obtain reliable average values of the intensity. Only few studies [22] show primary data on fluctuations in photon count time series. The origin of such fluctuations has not been carefully analysed and needs further characterisation.

Multi-Site Recording of Human Emission

Data shows that photon emission differs between subjects, between body locations, and in time. A more systematic approach is required to describe time-spatial aspects of human biophoton emission. Also, the aspect of symmetry in emission deserves special attention. Furthermore, a combination of the techniques of 1- and 2-dimensional recording must be stimulated to collect optimal information about biophoton emission in time and space.

Recording of Colour Spectrum

The analysis of the spectral distribution of very weak intensities has limitations relative to equipment specifications [35]. Mostly, cut-off glass filters with high transmittances are utilised to prevent loss of photons when recording very weak emission. However, the comparison of colour spectrum over the body remains difficult due to the low emission at certain sites and the large differences between body sites. To find the pitfalls in such studies, careful stepwise analysis of the spectra of human body sites is required.

Body Position and Mental State

The tourniquet experiment has shown the importance of blood flow and thus the positioning of the subject during long-term recordings. Moreover, the present review suggests that the subject's state of consciousness must be taken into account. On both aspects – fixed positioning and mental state – more data must be collected, in particular during long-term recordings.

Photon Count Statistics in Human Biophoton Emission

Several procedures for statistical analyses of photon counts have been applied on human biophoton emission data. In the light of the coherency theory of photon emission [36–38], the application of photon count statistics must be further promoted. In summary, we believe that work on human biophoton emission deserves to be continued in order to better understand the physiological implications of the present data, particularly regarding stress and disease [9, 39].

Conclusion

While weak photon emission from a variety of mammal tissues has been previously reviewed [8–12], photon emission from the intact human body has not been reviewed before. Data are scarce and spread through the literature of the last 30 years. The limited number of studies observed does not allow hard conclusions about the implications and significance of biophotons in relation to health and disease, mental state, or acupuncture. Still, the presented experimental data, make clear that these aspects need attention in future research. Among others our group will focus on some of these problems, the results are presented in separate publications [4, 22].

Acknowledgements

The authors wish to thank the Samueli Institute for Information Biology, the Rockefeller-Samueli Center for Research in Mind-Body Energy, the Fred Foundation, and the Foundation for Bioregulation Research for financial support.

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