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The effect of earthing (grounding) on human physiology

Gaétan Chevalier¹, Kazuhito Mori², and James L. Oschman³

¹ California Institute for Human Science, Graduate School & Research Center, Encinitas, CA

² California Institute for Human Science, Graduate School & Research Center, Encinitas, CA

³ Nature’s Own Research Association, Dover, NH

Corresponding Author: Gaétan Chevalier

Abstract

Previous research (12) showed that connecting the human body to the earth during sleep normalizes circadian cortisol profiles and reduces or eliminates various subjectively reported symptoms, including sleep dysfunction, pain and stress. We therefore hypothesized that earthing might also influence other aspects of physiology. Fifty-eight healthy adult subjects (30 controls) participated in a double blind pilot study. Earthing was accomplished with a conductive adhesive patch placed on the sole of each foot. An earthing cord led outdoors to a rod driven into the earth. A biofeedback system recorded electrophysiological and physiological parameters. Upon earthing, about half the experimental subjects showed an abrupt, almost instantaneous change in root mean square (rms) values of electroencephalograms (EEG) from the left hemisphere (but not the right hemisphere) and all of them presented an abrupt change in rms values of surface electromyograms (SEMGs) from right and left upper trapezius muscles. Signal variance in rms muscle potentials also increased significantly. Earthing decreased blood volume pulse (BVP) in 19 of 22 experimental subjects ($p < 0.001$) and in 8 of 30 controls ($p \cong 0.1$, not significant); heart rate (HR) was not affected. From these results, it appears that earthing the human body has significant effects on electrophysiological properties of the brain and musculature, on the blood volume pulse, and on the noise and stability of electrophysiological recordings. Taken together, the changes in EEG, EMG, and BVP suggest reductions in overall stress levels and tensions, and a shift in autonomic balance upon earthing. The results therefore extend the conclusions of the previous study (12).

Keywords: sleep; stress; electroencephalogram; surface electromyogram; blood volume pulse; autonomic balance

Introduction

Until a few generations ago, most humans walked and slept in direct contact with the surface of the earth. Our modern life style involves wearing insulating shoes and sleeping in buildings that electrically isolate the body from the ground plane. While some people intuitively sense that they feel better when they walk or even sleep directly on the earth (as on a camping trip), most of the population is more or less permanently isolated from the earth's electrical influences.

The earth's surface is electrically conductive and is maintained at a negative potential by a global electrical circuit. This circuit has three main generators: the solar wind entering the magnetosphere; the ionospheric wind; and thunderstorms (35). An estimated 1000 to 2000 thunderstorms are continually active around the globe, emitting thousands of lightning strikes per minute. This creates a constant current of thousands of amperes transferring positive charge to the upper atmosphere and negative charge to the surface of the earth. The earth's surface is therefore an abundant source of free electrons (11).

When humans are in direct contact with the earth (barefoot), free electrons are conducted onto the skin surface and into the body via the mucus membranes of the digestive and respiratory systems. The body is thereby maintained at the same electrical potential as the earth (6,9). This has been the natural bioelectrical environment of the human body and of other organisms throughout most of evolutionary history. We refer to this condition as "earthing" to distinguish it from the equipment "grounding" commonly used to protect consumers from electrical shock when appliances have a short circuit.

When standing outdoors, the unearthed body (wearing shoes with insulating soles) equilibrates with the potential of the atmosphere, which is electrically positive in normal weather conditions. When one is standing or sleeping inside a building, the unearthed body becomes electrified by ambient electric and electromagnetic fields. Connecting such person to the earth immediately reduces this electrification. In the previous study (12), body voltages in 12 subjects decreased from an average of 3.27 volts (V) unearthed to an average of 0.007 V upon earthing. This is on average a 467-fold decrease in voltage, attendant with regularization of cortisol profiles and reduction in sleep dysfunction, pain and stress (12). In view of the electrical nature of the intervention used in that study (i.e., connecting the human body to a natural source of electrons during sleep) we hypothesized that earthing might also affect electrical and physiological properties of the body, and might also influence the electrophysiological measuring process itself.

The parameters chosen for this study included EEG, which records changes in the dynamics of large neuronal populations in the cortex (34). EEG is rapidly sensitive to environmental stimuli (32), and it will be seen that earthing caused virtually instantaneous changes in signals recorded from the left hemisphere.

We also studied SEMG, a sensitive measure of the activity of underlying muscles and resting muscle tension (4,20,28).

Finally, we studied HR and BVP. The latter parameter is a relative measure of peripheral blood flow, and has been related to sympathetic/parasympathetic balance (5).

Materials and Methods

The protocol and informed consent form were approved by an Institutional Review Board, the Biomedical Research Institute of America, San Diego, CA. Informed consent was obtained from all subjects in the study.

Subjects

Exclusion criteria were: below the age of 18 or above 75; pregnancy; taking pain, anti-inflammatory medication, sedatives or prescription sleeping medication (less than 5 days prior to testing); taking psychotropic drugs or diagnosed with mental disorder; recent surgery (less than 1 year); documented life threatening disease (such as cancer, AIDS, etc.); consumption of alcohol within 48 hours of participation; use of recreational drugs. The health status of prospective subjects was ascertained using the Past Medical Inventory (PMI) questionnaire. The PMI is designed to provide information not only on major medical issues but also on past surgeries, injuries or accidents, major mental problems and medication.

Of 65 subjects selected and tested, 58 (30 controls and 28 earthed subjects) had complete data sets. Twenty-two (22) earthed subjects had complete data sets suitable for statistical analysis. Basic information on subjects is summarized in Table 1.

Table 1: Basic information on subjects

Subjects:	Females	Males	Total	Mean Age	SD
Earthed	19	9	28	51.12	12.46
Not earthed	21	9	30	49.69	12.43
Total	40	18	58		
Mean Age	50.89	49.18			
SD	12.66	11.92			

Ratios of female to male subjects (F/M) = 2.22. The mean age and standard deviation for each gender were similar and were also similar between the earthed (experimental) and the not earthed (control) group.

Instrumentation

The I-410 biofeedback system from J & J Engineering, Inc., Poulsbo, Washington, was utilized for this study. Parameters measured were: EEG, 2 channels, left and right frontal lobes (locations F_{p1} and F_{p2}); surface EMG, 2 channels, left and right upper trapezius muscles; BVP (from a photoplethysmograph placed around a finger); and HR (from a photoplethysmograph placed around a finger).

The EEG and SEMG scales were monitored by the I-410 biofeedback system at a data acquisition speed of 1,024 data points per second and 12 bits resolution. The means and standard deviations of the

rms voltage values of these data points were then calculated for every 10-second period and presented in a report automatically generated by the system. HR and BVP were processed by the system from the photoplethysmograph raw waveform using the instrument's software proprietary algorithms. The recording system includes an impedance test that can be performed before an experiment to ensure electrode impedance is within accepted standards.

Earthing Intervention

Prior to measurement, subjects were seated in a comfortable reclining chair and a conductive adhesive patch was placed on the sole of each foot. Patches were connected to a ground cord that attached to a dedicated ground rod driven into the earth outdoors. A switch placed about 4 feet from the subject completed or interrupted the earthing connection for experimental and control subjects respectively. The ground cord also had a fuse that was replaced by a plastic object for control subjects. Experimental subjects were exposed to 28 minutes in the unearthed condition followed by 28 minutes with the earthing wire connected. Controls were unearthed for 56 minutes. Subject participation (experimental vs. control) was determined randomly by an assistant before subjects' arrival. This assistant was the only person knowing into which group (experimental vs. control) each subject was placed and he was in charge of secretly changing the fuse before the arrival of each subject. An experimenter (Mori) was in charge of flipping the switch at the appropriate time (after 28 minutes of relaxation) regardless of the subject's assigned group. Records of each subject's group assignment remained confidential until all data were recorded. Subjects were tested one at a time over a 14-day period. Each subject's participation, including time for electrode placement, lasted approximately 1 hour and 10 minutes. Subjects were asked to relax in the chair and to move their bodies as little as possible.

Measurement Protocol

PG-100 pre-gelled disposable electrodes (Stens Corporation, San Rafael, California) were used in the study. Prior to attaching the electrodes, the skin was thoroughly degreased with 95% alcohol. Two EEG electrodes were placed on the forehead, one above the left and one above the right frontal lobes at regions referred to as F_{p1} and F_{p2} in the international 10-20 system of electrode placement (8). Ground and reference electrodes were placed according to the same standard protocol. To measure surface EMG, two electrodes were placed laterally 2 centimeters (cm) apart on the skin above the left upper trapezius muscle, the medial electrode being placed 2.5 cm lateral from the middle point (C7). Two other electrodes were placed on the skin above the right upper trapezius muscle in a manner mirroring the placement on the left upper trapezius muscle. BVP and HR were measured via a photoplethysmograph placed around the middle finger of the left hand (secured via a Velcro strap).

Earthing wire effects

There was concern that the earthing patch and the wire attached to it could act as an antenna for stray electrical fields, particularly when the lead was disconnected from the earth during the control periods in the study. There was also concern that the electric wiring of the room could induce body voltages. To avoid these problems, care was taken to choose a room with modern well-grounded electrical outlets (all wiring was clad in grounded electrical conduit). Absence of induced body voltages, such as from the 60 Hz wiring, was confirmed by using a voltmeter with a separate dedicated grounding system (a rod driven into the earth, identical to the body earthing system). The voltmeter had a large

(approximately ½ inch diameter) metal contact attached to the ungrounded terminal. Subjects were asked to place their thumb on this contact to measure induced body voltage with respect to the earth. The meter had an accuracy of about 0.3 %, and readings on the body were typically less than 5 millivolts (mV). Thus the subjects, patches, and wires did not have appreciable induced body voltages that could interfere with the electrophysiological measurements.

Data Analysis

Subjects were recorded for a total of 56 minutes; the data sets for statistical analyses of pre- and post-earthing EEG recordings were taken from the last 14-minute period before earthing and the first 14-minute period after earthing, respectively. Hence there was a 14-minute period for the EEG signals to stabilize prior to the period that was analyzed. The I-410 system automatically separated the EEG signal into 6 scales: Beta, Alpha, Theta, Delta, Theta/Beta ratio, and Delta/Beta ratio. The statistical methods used in this study were Student's t-test, F-test of differences between variances, Chi Square and Pearson Product Moment Correlation.

Results

EEG

As mentioned earlier, EEG recordings were taken for both left and right hemispheres at points F_{p1} (left hemisphere) and F_{p2} (right hemisphere) in the international 10-20 system of electrode placement. Inspection of rms EEG recordings showed an abrupt change (decrease or increase) at earthing time in the left hemisphere for a number of subjects but no change was visible in any recording of the right hemisphere (see Figure 1 for examples of recording displays). Consequently, it was decided to test if the changes observed in left hemisphere recordings were statistically significant. The results for 22 earthed subjects are presented in Table 2. Only the data of 22 experimental subjects were used because the data of the 6 others were not complete enough due to instrumental error.

Table 2: t-tests results for rms EEG recordings of 22 earthed subjects (left hemisphere)

Parameter	pre-test		post-test		change	t-test df* = 20	probability (two tails)
	M	SD	M	SD			
Beta left	1.98	1.77	0.61	0.50	-1.37	1.86	0.10
Alpha left	3.44	1.54	3.00	1.32	-0.44	1.09	ns**
Theta left	3.24	8.7	3.03	0.94	-0.21	0.89	ns
Delta left	3.98	1.74	3.54	1.95	-0.44	1.01	ns
T/B left	2.07	0.56	2.04	0.78	-0.03	0.13	ns
D/B left	2.45	1.32	2.35	1.39	-0.10	0.39	ns

* df = degrees of freedom

** ns = not significant

As shown in Table 2, on all scales the earthed subjects tended to show a decrease in mean rms values pre- and post-earthing, although no statistical significance was reached (Beta left just failed to reach significance with $p < 0.10$). However, inspection of rms data recordings of experimental subjects clearly shows an abrupt change for many of these subjects at the time of earthing, and this change continued throughout the earthing period. However the changes were increases or decreases and it

seemed as though there was a wash-out or cancelling effect in the results shown in Table 2 when both increases and decreases were pooled in the same statistical analysis. To see if this was correct, pre- and post-earthing data were compared using a t-test for correlated samples of the absolute rms values of the changes. Statistical significance was found at the 0.001 level of confidence for Beta left, Alpha left, Theta left and Delta/Beta (D/B) left and at the 0.004 level of confidence for Delta left and Theta/Beta (T/B) left (see Table 3).

Table 3: t-test results of absolute changes for rms EEG recordings of 22 earthed subjects (left hemisphere)

Parameter	pre-test		post-test		change	t-test df = 20	probability (two tails)
	M	SD	M	SD			
Beta left	2.07	0.57	1.73	0.43	-0.34	5.07	0.001
Alpha left	3.87	1.62	2.77	1.07	-1.10	4.89	0.001
Theta left	3.49	1.01	2.78	0.61	-0.71	4.17	0.001
Delta left	4.23	1.95	3.09	1.55	-1.14	3.61	0.004
T/B left	2.27	0.70	1.83	0.57	-0.44	3.52	0.004
D/B left	2.75	1.35	2.06	1.26	-0.69	4.10	0.001

As mentioned earlier the abrupt changes pre- and post-earthing occurred only in the left hemisphere rms signals. Figure 1 shows examples of two subjects from the experimental group (subjects 4 and 6). Each scale (Beta, Alpha, Theta, Delta) represents 56 minutes of recording: the first half of the scales are pre-earthing and the second half after earthing. Right hemisphere rms recordings are shown in blue; left hemisphere rms recordings are shown in red. The abrupt shift in the left hemisphere (red) is clearly seen exactly at the midpoint of these graphs, when the subjects were earthed (arrow). This shift continues throughout the intervention period. Little if any change occurs in the right hemisphere (blue). Similar graphs for control subjects showed no observable change in left or right hemisphere rms recordings.

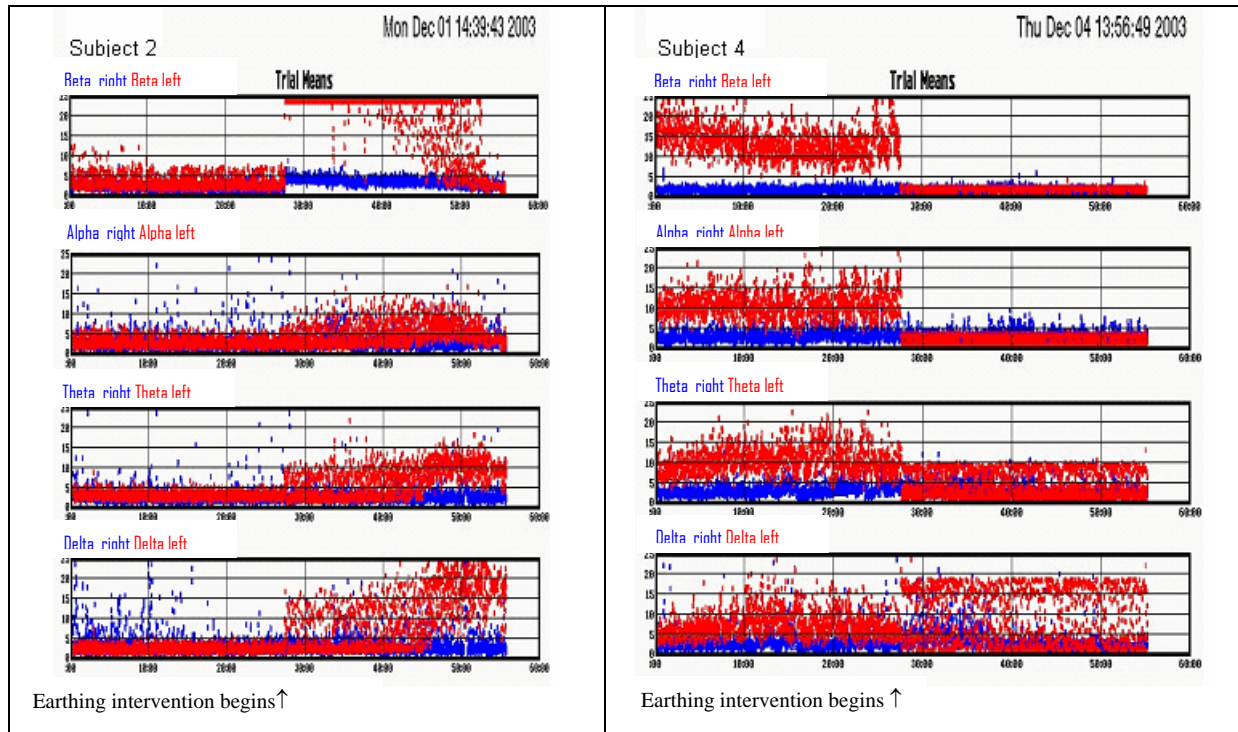


Figure 1. EEG changes in left hemisphere rms recordings. First 28 minutes pre-earthing; second 28-minutes after earthing (arrow shows when earthing intervention begins). An immediate and abrupt shift occurs in the left hemisphere (red) in one or more of the EEG scales (Beta, Alpha, Theta, Delta) when subjects are earthed; changes are maintained throughout the earthing period. The right hemisphere (blue) did not change.

During earthing, 12 out of 24 graphically analyzed earthed subjects showed a significant increase or decrease in one or more of the 4 EEG scales for the left hemisphere (Beta, Alpha, Theta, Delta). There is a relatively equal distribution of increases versus decreases in all scales, for the subjects in which change occurred (Table 4). For example, in 4 subjects both Beta left and Alpha left increased and in 5 subjects both Beta left and Alpha left decreased. In general changes were more dramatic and obvious for Beta left and Alpha left than Theta left and Delta left.

Table 4: Analysis of the abrupt changes in left hemisphere rms EEG recordings seen at earthing time in 4 scales (Beta, Alpha, Theta, and Delta) for 12 experimental subjects.

Subject ID:	23	2	24	1	4	25	18	5	3	6	7	8	Total
Beta Up			√	√	√	√		√			√		6
Beta Down	√	√					√		√	√		√	6
Alpha Up	√			√	√	√					√		5
Alpha Down		√	√				√	√	√	√		√	7
Theta Up				√	√	√						√	4
Theta Down			√				√	√	√	√	√		6
Delta Up		√		√	√	√						√	5
Delta Down							√	√			√		3

SEMG

T-test analyses of rms data (Table 5) revealed no significant difference for right or left SEMG pre- and post-earthing. However there was a significant change ($p < 0.025$) for right rms SEMG when comparing after earthing results between experimental and control groups.

Table 5: t-tests for right and left rms SEMG data

Subjects	Earthed				Earthed		Control				Earthed vs. Control	
	Before		After		Before vs. After		Before		After		After	
Measured	Mean	SD	Mean	SD	t-test*	p-level	Mean	SD	Mean	SD	t-test**	p-level
Right SEMG	32.2	44.4	43.4	64.9	1.7	ns	28.1	32.5	28.1	32.5	2.4	0.025
Left SEMG	34.9	61.7	36.5	48.6	0.3	ns	17.6	15.7	17.6	15.7	0.8	ns

*df = 20; **df = 48

To understand the lack of significance for the pre- and post-earthing rms SEMG data, examine Figures 2a, 2b and 2c. These are composite graphs of rms data from 22 experimental subjects. Just as is the case with EEG data, only 22 experimental subjects were used because the data of the 6 others were not complete enough due to machine error. Also, in similarity with EEG data, visual inspection of rms recordings reveals abrupt and distinct changes when subjects are earthed; these changes continue throughout the earthing period; they were seen for every subject in the experimental group and were not observed in the control group. Again the changes are either dramatic increases or dramatic decreases. The increases and decreases cancel each other out in the statistical analysis.

As seen in Figure 2c, the amplitude of left rms SEMG for one subject (subject 5) was about 300 micro volts rms (μV), dropping to 175 μV rms after earthing, while all other subjects were in the approximately 0-70 μV rms range during the pre-earthing and intervention periods. This “outlier” contributed to the cancellation effect in the statistical analysis of the left rms SEMG data. After testing was completed, subject 5 (who also had high right rms SEMG values of about 100 μV rms before earthing and about 50 μV rms after earthing) reported experiencing discomfort while seated in the recliner due to an old injury. This discomfort was the likely cause of this extreme amplitude range (and the “outlier” effect).

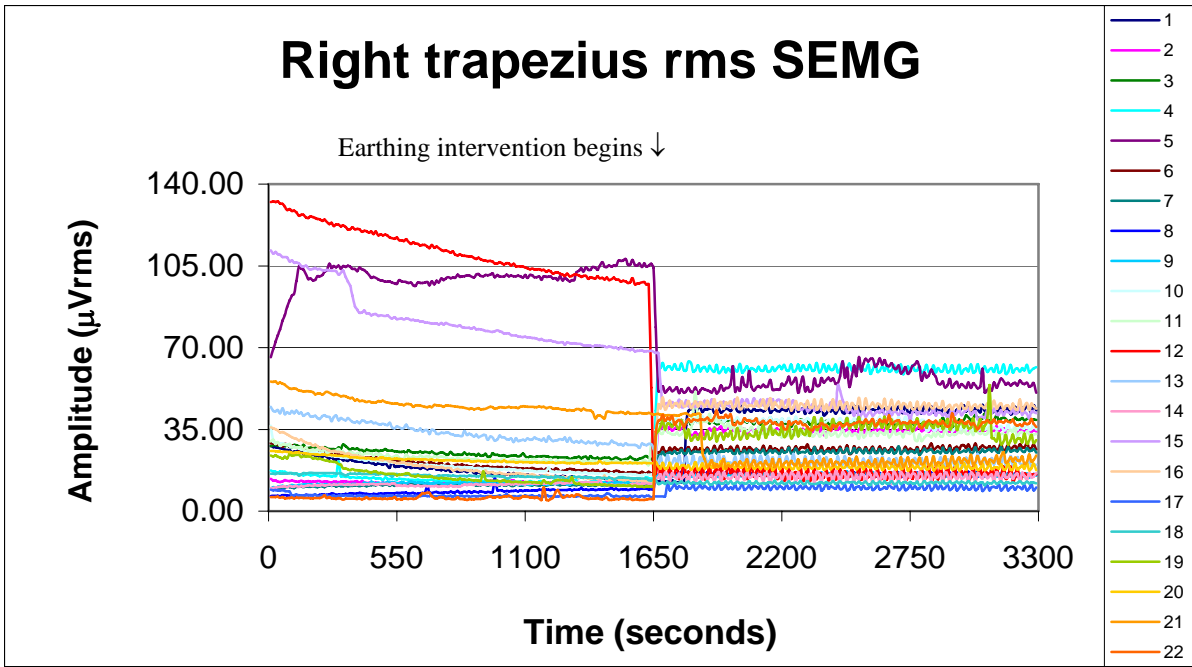


Figure 2a. Graph of right rms SEMG recordings of 22 experimental subjects. Note the abrupt change when earthing intervention begins for all the subjects (arrow).

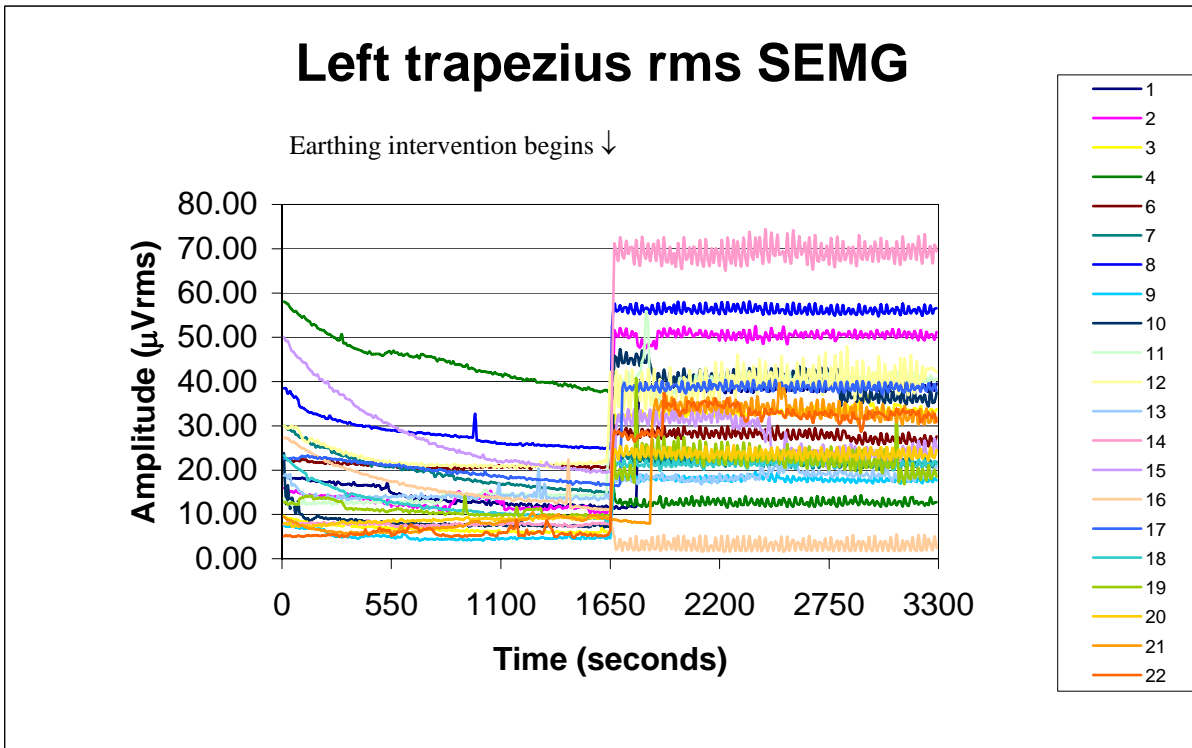


Figure 2b. Graph of left rms SEMG recordings of 21 experimental subjects. One experimental subject (5) has been omitted for clarity (see figure 2c). Note the abrupt change when earthing intervention begins for all the subjects (arrow).

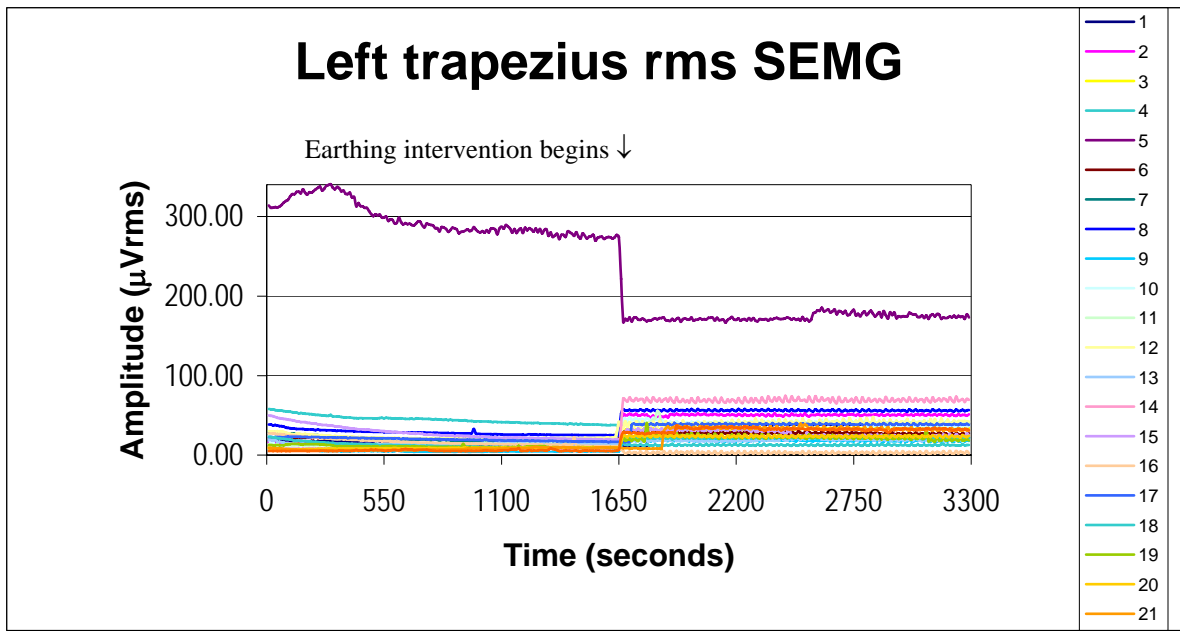


Figure 2c. Graph of left rms SEMG recordings of 22 experimental subjects. Note the abrupt change when earthing intervention begins for all the subjects (arrow). One subject (number 5) presents a drastic decrease while others show drastic increases. This situation canceled out in the statistical analysis, but the shift at the time of earthing is unmistakable.

When looking at absolute differences between pre- and post-earthing for the experimental group (Table 6), significant differences can be seen for right and left rms SEMG, with the most significant differences ($p < 0.004$) seen for the left rms SEMG. In the unearthed control group, rms SEMG recordings did not change.

Table 6: t-tests for right and left rms SEMG recordings based on absolute differences

Parameter Measured	t-test*	p-Level
Right SEMG	2.4	0.03
Left SEMG	3.6	0.004

*df = 20

Figure 3 shows the increase in rms SEMG variance when subjects are earthed. A close look at this figure (examples of 4 subjects' left rms SEMG charts) reveals that this increased variance is due to the presence of low frequency oscillations (between 0.025 and 0.05 Hz). When comparing variances before and after earthing for 22 subjects it was found that the increased variance is highly statistically significant ($p < 0.001$) for both right and left rms SEMG's.

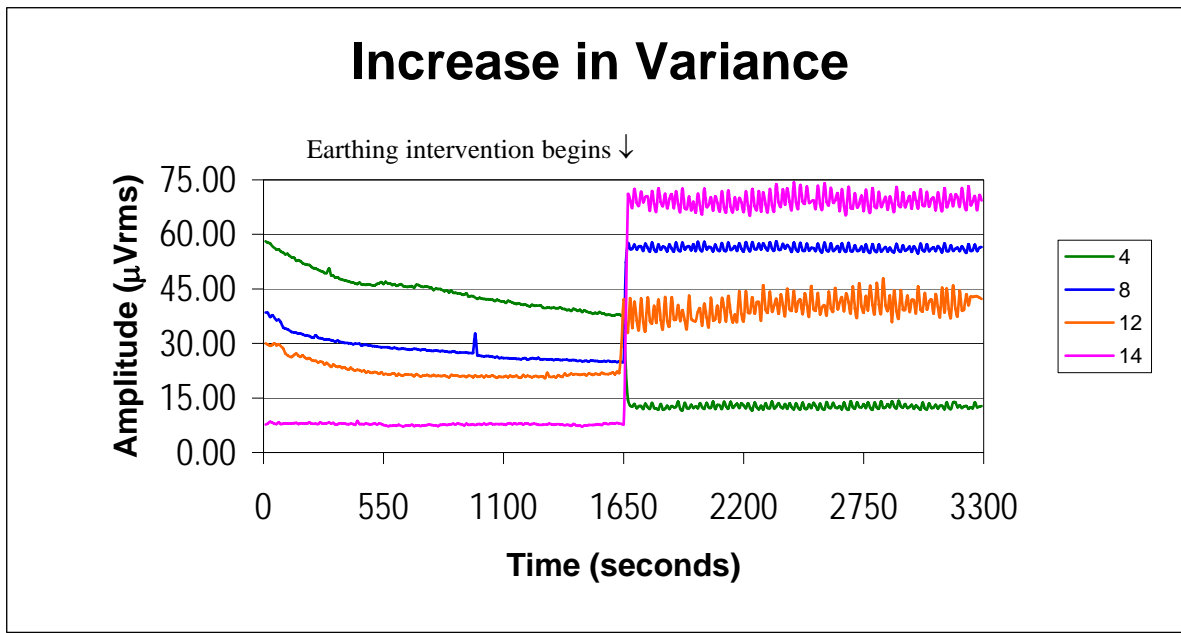


Figure 3. Details of left rms SEMG data for four experimental subjects shown in Figure 2. At the midway point subjects were earthed (arrow). Note the dramatic increase in rms voltage variances after earthing.

Heart Rate and BVP

Earthing had no detectable effect on heart rate.

With regard to BVP, statistical analysis using t-tests on raw scores before and after earthing did not show any change. However, careful inspection of recordings showed that earthing decreased BVP in 86.4 % (19) of the 22 experimental subjects, and only in 32.0% (8) of the 25 control subjects with adequate data for analysis. As can be seen from Table 7, the number of earthed subjects for which the reading went up has a very low probability to be due to chance ($p < 0.001$) while the result obtained for the controls is within chance limits (and shows an opposite tendency compared to the earthed subjects).

Table 7: Summary of observations on BVP

	Controls	%	Earthed	%
Down:	8	32.0%	19	86.4%
Up:	16	64.0%	3	13.6%
Stable:	1	4.0%	0	0.0%
Total:	25	100.0%	22	100.0%
Expected down:	12	50.0%	11	50.0%
Expected up:	12	50.0%	11	50.0%
Chi Square p =	0.1025	n.s.	0.0006	

n.s. = not significant

DISCUSSION

The principal discovery reported here is that electrically coupling the human body to the earth produces immediate and lasting changes in electrophysiological measures: the left hemisphere EEG and right and left trapezius EMG. These changes appear to take place in less than one second after earthing. At the same time, BVP, which is a direct physiological measure and not an electrophysiological measure, decreases steadily and significantly after earthing. Taken with the results of the previous study (12), which showed that earthing changes cortisol profiles and affects subjective reports of quality of sleep, pain, and stress, we begin to see a picture of systemic effects of earthing.

The validity of the results presented here depends on a number of methodological considerations. Care must always be taken to insure that the electrodes on the skin have low impedance and are not, themselves, generating signals. Ideally, the measuring equipment does not produce any voltage or current, and the system records only signals generated by the body. In this study a variety of precautions, mentioned in the Methods section, insured that the changes in the electrophysiological measures after earthing resulted from connecting the earth to the body, which was the purpose of the study. Importantly, the subjects were relaxed and were asked to avoid moving during the measurement period. The electrodes used in the study adhered firmly to the skin and in no case were electrodes loose at the end of the recording period.

The fact that BVP, which is not an electrophysiological measurement, changed at earthing time, just like EEG and SEMG, supports the validity of the electrophysiological measurements; they were not due to faulty electrode placements, changes in electrode impedance, noise, or other artifacts. The fact that there was an effect only on the left hemisphere EEG of earthed subjects rules out the possibility that this could be an SEMG artifact due to faulty electrode placement (e.g. the frontalis muscle SEMG activity being picked up by the electrode) because there would be no reason why the electrode placement would be wrong always on the left side of earthed subjects and never on controls (all electrodes were put in place by the same experimenter regardless of which group the subject was in, experimental or control). Chance occurrence would require that any SEMG artifact would happen on average 50% on the left side and 50% on the right side of the forehead and with equal frequency in each subject's group. Hence the conclusion that the measured changes on the left EEG resulted from the effects of earthing on the electrical activity taking place within the left frontal lobe of the brain, with some of the primary rhythms increasing and others decreasing in amplitude, depending on the subject.

EEG is sensitive to a continuum of states ranging from alertness to relaxation, hypnosis, and sleep (32). It is intriguing that the abrupt and clear-cut changes (both increases and decreases) in EEG parameters were seen only in the left hemisphere of the brain. The frontal lobes (the area of EEG electrode placement in this study) are thought to be responsible for abstract thinking, judgment, tactfulness and foresight (8). The left hemisphere is thought to be involved with ratiocinative processes, with thinking that is analytical, rational, logical, and discursive; the right hemisphere with intuitive processes, with synthesis and gestalts, with perceiving the whole, with music, art, and poetry (13). Previous research has indicated that the left hemisphere predominantly influences parasympathetic activities, while the right hemisphere regulates sympathetic activities (3,16). Hence the significant change we observed in absolute values of the EEG recordings for the left hemisphere

(and not the right hemisphere) suggests that earthing may have influenced rational and parasympathetic aspects of brain functioning. The BVP results also support a shift in the direction of parasympathetic activation.

Abrupt and clear-cut changes occurred in the signals recorded with SEMG of the trapezius muscle for all 28 subjects who were earthed. Unlike the EEG findings, changes occurred in both sides (left and right trapezius). At the moment of earthing, we observed abrupt increases SEMG recordings in some subjects and abrupt decreases in others. Individuals with initially high SEMG readings (above 40 μV rms) generally decreased to the 20-50 μV rms range when they were earthed. Those with low SEMG readings (below 30 μV rms) generally increased to the 10-60 μV rms range.

When considering these results it is important to realize that any randomly selected group of people will show variations in their stress levels and consequently will have different “set points” in the spectrum of sympathetic/parasympathetic balance, muscle tension, and related stress parameters. This was the case in the previous study of cortisol levels (12). Some subjects had elevated cortisol; others had depressed levels. Earthing “normalized” the study population by bringing the elevated cortisol levels down and the depressed levels up. The results of the present study also indicate a normalization or balancing process upon earthing.

SEMG measurements of the trapezius muscles are known to correlate with overall stress (30). In essence, SEMG evaluates the overall “tone” of the musculature, which is set by the gamma motor system (e.g. 24) and also by the hemispheric balance, as mentioned above. A subject’s position in the “stress spectrum” will affect the way they respond to an intervention that normalizes physiological processes. The stressed or sympathetically “charged” individual will tend to relax; the person who tends toward excessive parasympathetic activation might be stimulated, and therefore display increased tension in their musculature.

We found empirically that the subject’s body position is crucial to obtaining the results of this pilot research. When subjects are in a normal sitting position, the variance in SEMG signals does not occur. It seems therefore important that subjects are put in a relaxing position where they feel they can fall asleep without fearing injury. In fact we found that many of our subjects slept during this experiment.

It is logical that directly connecting the body to the earth through a dedicated ground rod would reduce the noise (non-biological signals) in electrophysiological recordings (2). Noise comes from both natural and man-made electromagnetic sources (26). Common sources of noise include wiring, appliances, cellular telephones, radio and TV stations, and so on.

Generally speaking, if a subject is not conductively connected to an AC voltage source (such as a power outlet) any AC voltage induced on the body occurs because of capacitive coupling between the source and the body. Capacitive coupling is the mechanism by which an electric field on one conductor acts across a poorly conducting medium (or dielectric), such as air, to influence charges on a nearby conductor. In essence, a wire carrying an AC voltage acts as one plate of a capacitor, with the conductive tissues and fluids of the human body acting as another plate. The human body is composed of a number of tissues and fluid spaces with finite electrical conductivity. The term, “cable properties,” is used to describe the conductive aspects of elongated cells such as nerves and muscles (29), and sheets of cells called epithelia (25). AC fields induce voltages in body tissues even when no current is flowing in the AC circuit. The amount of this induced voltage depends on the source

voltage, the magnitude of the capacitive link between source and body and on the capacitive link between the body and the source's voltage reference, normally the potential of the earth. The degree of capacitive coupling is highly dependent on the geometry of a particular situation (2).

Electrification of the body from more distant and higher frequency sources of electromagnetic radiation takes place because the conductive tissues in the body act as antennas. As long as a person is in conductive contact with the earth, however, electrons can flow rapidly back and forth between the body and the earth with each AC cycle, as long as the spectral content is not of too high a frequency. The earth is a vast and stable source of electrons and is therefore a "source" and a "sink" that can essentially "swallow" noise-producing fields (17). Hence the earthed body is maintained at the same potential as the ground plane, and any voltages (or noise) that might be induced from external sources are effectively cancelled. Using the earthing system described in the present study, Applewhite (2) has documented this alternating flow between the body and the earth and *vice versa*.

The system used for earthing the human body must be distinguished from the grounding systems used in electrical wiring. Hence our use of the terms, "earthing" and "earthed" in this article refer to dedicated conductive systems between the body surface and an earthing rod that has been inserted directly into the earth. This connection is entirely separate from the so-called appliance or equipment-grounding conductor in the mains, connected to the 3rd prong of a power outlet. The reason for this is that equipment-grounding conductors are seldom, if ever, true grounds. For example, there is considerable variation in wiring configurations where power lines enter buildings (the service entrance). Different countries specify different earthing configurations. A list of standards around the world has been published (22). In the US, older buildings, constructed prior to modern wiring codes, are notorious for having poorly configured or faulty equipment grounds; before 1972 there were no grounding terminals in electrical outlets. Moreover, grounding electrodes and connections can corrode over time, increasing the resistance between grounding conductors and the earth. Finally, grounding conductors commonly run parallel to electrified conductors, and measurable electrical fields are therefore coupled or induced into the grounding conductors. The third "grounding" terminal in electrical outlets may therefore measure several volts or more with respect to the earth. In the interest of safety, most electrical codes do not allow connection of human subjects to the equipment ground conductor in the mains.

Bioelectrical measuring devices commonly have a "floating" ground that is required to be separate from the chassis or instrument ground. Voltages detected on the surface of the body are therefore recorded with respect to this floating ground, and never with respect to the grounding conductor in the mains. This floating ground itself is normally connected to the human body (to a bony structure or an ear lobe—a region of the body where no bioelectrical potentials can be generated). Special amplification circuitry reduces the influence of noise by a process known as *Common Mode Rejection*. This is the property of a differential amplifier to reject the part of an incoming signal that has the same amplitude and phase on both electrodes, referenced to the floating ground. While this technique improves the quality of the recordings (common mode rejection is never perfect), it does not eliminate the actual electrical noise experienced by the body. Moreover, few electrophysiologists check whether their equipment ground is well connected to the earth. Even if there is a good equipment ground, the conductive tissues in the body still act as antennas, picking up AC fields (noise) from the environment.

We have noted above that living systems evolved in close relationship with the earth's surface, which serves as a virtually unlimited source of electrons. Direct contact with the surface of the earth and its

abundant electrons is rare in modern life. The extent to which contact with a natural source of electrons is essential to normal physiological functioning and health is a new area for research.

Every physiological process in the human body has an electrical aspect, whether at the molecular, cellular, tissue or organ level (23). Our modern understandings of sensation, nerve conduction, muscle contraction, secretion, brain function and so on, have been derived in part from careful study of the bioelectrical and biomagnetic correlates of physiological processes. With few if any exceptions, these studies have been done on unearthened humans or animals. Hence the degree of earthing is a “hidden variable” in most electrophysiological studies. The extent to which the findings from electrophysiological research may have been influenced by the lack of earthing of the experimental subjects is unknown. Since living systems have been in contact with the earth for most of their evolutionary history, the question arises as to whether or not modern electrophysiologists have actually been studying “normal” organisms. Our modern concepts of physiology as derived from electrophysiological measurements may therefore require some reevaluation.

The possible effects of electromagnetic noise or interference on living systems is of interest to researchers who are exploring the controversial subject of whether the voltages induced into the body influence health (e.g. 7,10,19,21,27,31,33). This new topic of research has been given a name “bioelectromagnetism” and there is increased interest in the topic in light of the popular use of cell phones (18). Again, the degree of earthing is a hidden variable that could influence the conclusions in many studies of electromagnetic field bioeffects.

We have not directly studied the health effects of voltages induced into the unearthened body. However, this and the previous study (12) have indicated that induced voltages can be mitigated by means of a simple earthing technique. When this is done, there are improvements in various subjectively reported symptoms, including sleep dysfunction, pain and stress; and there is a shift in autonomic balance and an adjustment in muscle tension toward an optimal level. This is a different approach to the subject of health effects of environmental fields, since we are not looking for harmful conditions but are instead looking at improvements in health taking place when the environmental influences are mitigated.

SUMMARY AND CONCLUSIONS

Highly significant EEG, EMG and BVP results demonstrate that restoring the natural electrical potential of the earth to the human body (earthing) rapidly affects human electrophysiological and physiological parameters. The extreme rapidity of these changes indicates a physical/bioelectrical mechanism rather than a biochemical change. While more research is needed, it appears that the changes are in the direction of normalization or balancing of the electrical parameters affecting physiological systems. Taken together, the changes in EEG, EMG, and BVP reported here suggest reductions in overall stress levels, tensions and autonomic balance in the organism upon earthing. The results therefore correlate with the effects reported in the previous study (Ghaly, & Teplitz 2004), which showed changes in cortisol profiles associated with decreases in subjectively reported symptoms, including sleep dysfunction, pain and stress. Earthing appears to reduce the noise coupled into the body from various sources. Hence the degree of earthing may have been a “hidden variable” in many electrophysiological studies.

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