Emotional Stress, Heart Rate Variability, Grounding, and Improved Autonomic Tone: Clinical Applications
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Abstract
Over the last few years, the utilization of integrative biophysics for medical application has been increasing in popularity. Grounding or earthing is the oldest and most basic form of natural bioelectric potential that supports physiological and electrophysiological changes in the body. Since previous investigations have shown that grounding profoundly affects skin conductance within seconds, we hypothesized that grounding may also improve heart rate variability (HRV). In this study of 27 final participants, grounded subjects had improvements in HRV that go beyond basic relaxation (P<.01). Since improved HRV has such a positive impact on cardiovascular status, it is suggested that simple grounding techniques be utilized as a basic integrative strategy in supporting the cardiovascular system, especially under situations of heightened autonomic tone (ie, when the sympathetic nervous system is more activated than the parasympathetic nervous system).

Grounding or earthing is defined as placing one’s bare feet on the ground (especially when humid or wet), whether it be dirt, grass, sand, or concrete. It is known that the earth maintains a negative electrical potential on its surface.1,2 When in direct contact with the ground (walking, sitting, or lying down on the earth’s surface), the earth’s electrons are conducted to the human body, bringing it to the same electrical potential as the earth.3,4 Living in direct contact with the earth grounds the body, inducing favorable physiological and electrophysiological changes that promote optimum health.5 Regulation of circadian rhythms and improved sleep and nighttime cortisol dynamics reflect a few changes associated with favorable autonomic nervous system (ANS) function that can come about with grounding.5,6

The many unpredictable sociological, economic, and political events of the 21st century have increased the stress of modern living as compared to earlier and simpler times. As a result, more and more people live day-to-day in unrelenting states of heightened physiological arousal. These physiological states involve chronic over-activation of the ANS.

Informed consent was obtained from all subjects prior to their participation. The Biomedical Research Institute of America provided Institutional Review Board supervision of the project (website: www.biomedirb.com).

Materials and Methods Subjects
The health status of subjects was determined using the Health History Inventory (HHI).10 The results presented in this paper are those of 28 relatively healthy subjects (48.11 ± 14.48; average age ± standard deviation [SD]). These subjects were equally divided among men and women: 14 men (45.43 ± 13.62, range 25-66), and 14 women (50.79 ± 15.32, range 26-78). Informed consent was obtained from all subjects prior to their participation. The Biomedical Research Institute of America provided Institutional Review Board supervision of the project (website: www.biomedirb.com).
Exclusion criteria were: 1) pregnancy; 2) age under 18 or over 80; 3) taking pain, anti-inflammatory, sedative, or prescription sleeping medications (less than 5 days prior to testing); 4) taking psychotropic drugs or being diagnosed with mental disorder; 5) recent surgery (less than 1 year); 6) documented life-threatening disease (such as cancer, AIDS [acquired immune deficiency syndrome], etc); 7) consumption of alcohol within 48 hours of participation; and 8) use of recreational drugs. Past pilot projects suggested that the resulting relatively healthy subjects may be more responsive to short-term grounding.

Grounding System

Four transcutaneous electrical nerve stimulation (TENS) type adhesive electrode patches were placed on subjects, 1 on the sole of each foot and 1 on each palm. Wires from a standard electrostatic discharge ground system were snap-attached to the electrode patches and connected to a box (see Figure 1). The grounding system itself consisted of a 100-foot long (30.48 m) ground cord connected to the box on 1 end and attached to a 12-inch (30.48 cm) stainless steel rod planted in the earth outdoors at the other end.

Figure 1. Grounding system showing patches, wires, and box connecting to a ground rod planted outside through a switch (not shown) and a fuse (not shown). Similar patches and wires from the hands were also connected to the box to ground the hands.

Experimental Procedure and Study Design

After the consent form was signed and the HHI showed compliance with respect to the exclusion criteria, the subject was asked to sit in a comfortable reclining chair in the experiment room.

Participants served as their own controls. Each subject’s data from a 2-hour session, of which 40 minutes were grounded, was compared with another 2-hour session when not grounded. For all sessions (grounded and nongrounded) and for all subjects, the switch was flipped on and off at the same time (40 minutes after the start of the session for the “on” position and 40 minutes later for the “off” position). The assistant in charge of replacing the fuse was the only person during the entire experiment to know which session was the control and which was the grounding session for each subject.

Subjects were not allowed to leave the laboratory premises for the entire 2-hour experiment and lunch or a snack was provided. Subjects received instructions to relax and rest. Falling asleep was permitted but meditation was not allowed.

Results

The HRV parameters calculated from electrocardiogram recordings during the study were as follows:

- the standard deviation of R-R intervals (SDRR, standard deviation of normal to normal intervals or SDNN);
- 3 spectral components of the power spectrum density (PSD, the square of the Fast Fourier Transform of the R-R intervals): low frequencies (LF), high frequencies (HF), and very low frequencies (VLF);
- the ratio LF/HF.

These parameters were automatically calculated according to the task force recommendations.11

Recordings of the average values and standard deviations for 27 subjects are shown in graphic representations in Figure 2 (1 subject could not be included because the grounded period lasted 55 minutes, 15 minutes longer than the other subjects). From this figure, it is clear that there is a change in slope at grounding and again at ungrounding for HF, LF, and SDRR average values (even though less pronounced for SDRR) that is not seen in the corresponding recordings when the subjects served as controls (nongrounded). This pattern is also seen for standard deviations, but these results are not shown in Figure 2 for clarity of presentation. At grounding, the slope changes from negative to positive and the opposite happens at ungrounding.

Since PNS activity is the major contributor to the HF component of HRV,11 a decrease in PNS function is seen in Figure 2 before grounding (HF-G, green line), which reverses and starts to increase after grounding. This increase continues for the entire 40 minutes of the grounding period and reverses back to pregrounding condition after ungrounding.

The nongrounded group HF average values recording presents a small increase after the 2200th second from the beginning of the session, stabilizing about 10 minutes after that (at 2800
seconds). This can be interpreted as an increase in relaxation, which remained relatively steady for the rest of the session. This increase in HF is small compared to that of the grounded group.

At the end of both 40-minute periods, HF increased by 33% for the nongrounded group compared to an increase by 63% for the grounded group—about double the increase of the non-grounded group. The increase in HF standard deviation during the grounding period (not shown, but which shows a similar pattern as HF) suggests an increase in vagal variability that started to reverse after ungrounding.

The meaning of LF is less clear. The general consensus is that both the sympathetic nervous system (SNS) and the PNS contribute to LF. However, according to Perini, LF could be used as a marker of SNS function while monitoring the change from supine position (predominantly dominated by PNS) to sitting position (predominantly dominated by SNS) for healthy people in normal conditions. Since our subjects were healthy and in supine position, we presume that LF in our case is also predominantly related to the PNS. This hypothesis is confirmed by the fact that the LF graph in Figure 2 (LF-G, the cornflower blue line) shows similar tendencies as HF (HF-G, green line). At the end of the 40-minute periods, LF increased by 28% for the nongrounded group (LF-NG, red line) and by 68% for the grounded group—a little more than double the nongrounded group increase.

SDRR is recognized as a parameter representing total power; ie, it includes contributions from all frequencies present in the recording. As such, it contains contributions from both SNS and PNS. However, because for short recordings HF and LF are the major components of SDRR (the other, smaller component being VLF) and the fact that they mainly represent the PNS for healthy subjects in supine position, a similar conclusion as for HF and LF can be drawn, namely that the most important contribution to SDRR comes from the PNS. At the end of the 40-minute periods, SDRR increased by 20% for the nongrounded group and by 50% for the grounded group.

The LF/HF ratio in Figure 2 reveals that the changes in LF and HF during grounding were virtually the same so that there was no change in their ratio. In fact that line for the grounded group is even more flat than it is for the nongrounded group. The fact that LF/HF is so perfectly flat during grounding is important because it suggests that the changes in these two components were in the same direction.

![Graph showing LF, HF, LF/HF, and SDRR (n=27)](image)

**Figure 2.** Grounded and non-grounded group results (n=27 subjects). Average amplitudes and standard deviations of LF, HF, LF/HF, and SDRR for a 1-hour window of the 2-hour session, starting 30 minutes (1800 s) after the beginning of the session, ending 1 hour later (at 5400 s). Grounding (or sham-grounding for the control group) occurred 40 minutes (2400 s) and ungrounding (or sham ungrounding for the control session) 80 minutes (4800 s) after the start of the session.
grounding supports our presumption that the change in LF was due to the same cause as for HF, namely dominance of the PNS over the SNS.

Statistical tests were performed to determine differences in means and in variances before and after grounding (or sham-grounding for control sessions) and between the grounded and nongrounded sessions. In order to retain the normality of our data, periods selected for statistical tests were:

- the last 10 seconds before grounding (or sham-grounding for control sessions)
- the last 10 seconds at the end of the 40-minute grounding period (or sham-grounding period for control sessions).

To compare difference in means, t-tests were used, while F-tests were used to compare difference in variances. Since there were statistically significant differences before grounding between the groups we repeated the statistical tests after normalizing the data so that the means before grounding were the same for both groups. Sixteen means and their standard deviations were computed (4 parameters: SSDR, LF, HF, and LF/HF, before and after grounding for the grounded and sham-grounded groups) and used to perform a total of 40 t-tests (5 t-tests per parameter repeated for normalized groups) and 40 F-tests. All t-tests comparisons were significant at P < .01 or better.

These results mean, for example, that the mean amplitude for the last 10 seconds of grounding was statistically larger compared to the last 10 seconds of sham-grounding. This difference was true also for F-tests and for all parameters tested (LF, HF, SDRR, and LF/HF). The only exception was the F-test comparing LF/HF variances before and during grounding for the grounded session, which was not significant, meaning the variance of LF/HF did not change during grounding.

The conclusion of these statistical tests is that for LF, HF, SDRR, and LF/HF, the means and variances before and during grounding (or sham-grounding for control sessions) were significantly different (with 1 exception) and that was also true for comparisons between sessions. We conclude that there were real effects changing both the means and variances over time. For the sham-grounded group, this effect was primary relaxation, while for the grounded group, an additional effect on the PNS due to grounding was observed. It is worth noting that this additional effect due to grounding was at least as important as the effect due to relaxation alone.

In summary, the PNS function increased about twice as much in the grounded group as compared to the nongrounded group at the end of the 40-minute grounding or sham-grounding periods. Also, there was a continuous increase in their SDs that was not present (or small) for the nongrounded group, which points to an increase in the vagal nerve variability. Combined, these results indicate that grounding produced an improvement in HRV that is beyond simple relaxation.

**Discussion**

**Heart Rate Variability**

The characteristics of a healthy ANS include intact HRV as well as normal baroreflex sensitivity (reflex-mediated changes in heart rate that respond to fluctuations in venous return such as those noted upon supine and standing conditions). Altered cardiac autonomic tone determined by HRV represents one of the most interesting explanations of sympathico-vagal imbalance due to an excessive cardiac sympathetic situation and/or inadequate cardiac parasympathetic tone.

Excessive sympathetic stimulation and/or diminished vagal tone are markers of a stressed cardiovascular system. There are multiple situations that contribute to sympathetic activities including physical, emotional, behavioral, and pharmaceutical factors (see Table 1). Chronic sympathetic hyperactivity increases cardiovascular hemodynamics and predisposes to endothelial dysfunction, coronary spasm, left ventricular hypertrophy, and cardiac arrhythmia.

**Table 1. Factors Contributing to Chronic Sympathetic Activation**

<table>
<thead>
<tr>
<th>Environmental conditions</th>
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<td>Air pollution: Ambient particulate matter &lt;10 micron (PM (10))</td>
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<tr>
<th>Health conditions</th>
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<tbody>
<tr>
<td>Obesity</td>
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<td>Insulin resistance, diabetes, or metabolic syndrome</td>
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<td>Hypertension</td>
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<tr>
<td>Depression, anxiety</td>
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<tr>
<td>Congestive heart failure</td>
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<td>Sleep apnea</td>
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<table>
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<tr>
<th>Psychosocial and behavioral conditions</th>
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<tr>
<td>Chronic stress</td>
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<td>Social isolation and loneliness</td>
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<tr>
<td>Hostility, anger, or rage</td>
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<tr>
<td>Smoking</td>
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<tr>
<td>Sleep deprivation</td>
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<tr>
<td>Sugar-laden diet</td>
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<tr>
<td>Sedentary lifestyle</td>
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<td>Abuse of stimulants</td>
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**Pharmaceutical drugs**

- Short-acting calcium channel blockers
- B-agonist bronchodilators
- Peripheral alpha blockers

Increased vagal tone exerts a protective effect in a setting of ischemia and arrhythmia. Predictive associations between reduced HRV and increased mortality after an acute myocardial infarction have been documented. HRV represents one of the most promising evaluation tools for risk stratification of cardiac patients. Reduced HRV and an increase in the incidence of coronary heart disease and subsequent cardiovascular events have often been determined in community-based populations. HRV imbalance reflecting autonomic dysfunction and the severity of progression of coronary artery disease has been repeatedly demonstrated in clinical investigations.

For decades, the relationship between ANS dysfunction and sudden cardiac death (SCD) resulting from lethal cardiac arrhythmias has spurred considerable interest in terms of determining the degree of parasympathetic tone and/or reduced...
vagal activity. Thus, HRV has become a reliable clinical tool in investigating not only survival after myocardial infarction but also in predicting sudden death in patients with myocardial infarction independent of other prognostic indicators such as left ventricular dysfunction.

A recent statement by the American College of Cardiology on risk-stratification techniques for identifying patients at risk for SCD acknowledges that limited data exists to link diminished short-term HRV to SCD and is less reproducible in patients with congestive heart failure. Nonetheless, short-term HRV has reproducibility in normal subjects and therefore has important clinical applications. HRV studies will improve our understanding of physiological situations involving the actions of medications and disease mechanisms as well as yield valuable information in population studies.

Since reduced HRV appears to be a marker of cardiovascular disease, it makes sense not only to understand its clinical applications but also to utilize interventions to support or improve HRV, which will help reduce the likelihood of cardiac events. An outstanding review of autonomic tone as a cardiovascular risk factor was reported by Curtis and O’Keefe, Jr. in the Mayo Proceedings. In their conclusion, they urged clinicians to develop an increased awareness of the effect of various therapies on autonomic function and to carefully consider the risks involved before prescribing medications with sympathomimetic effects such as short-acting calcium channel blockers and beta-agonist bronchodilators.

They suggest placing greater emphasis on interventions that support autonomic function such as regular, moderate-intensity exercise, beta blockers, and ACE inhibitors, all of which have been shown to improve autonomic function and outcomes in patients with cardiovascular disease.

Omega-3 fatty acids also demonstrate a reduction in the risk of SDC and improved clinical outcomes for the same patients with higher intake either from their diet or supplements.

Among the host of interventions to improve autonomic function (see Table 2), we would like to add grounding as a simple, cost-effective, and noninvasive intervention.

### Table 2. Interventions to Improve Autonomic Function

<table>
<thead>
<tr>
<th>Modalities</th>
<th>Lifestyle modifications</th>
<th>Medications</th>
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<tbody>
<tr>
<td>Grounding to the earth</td>
<td>Exercise</td>
<td>Beta-blockers</td>
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<td>Social support</td>
<td>Angiotensin-converting enzyme inhibitors</td>
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<td>Religiosity or faith</td>
<td>Omega-3 fatty acids</td>
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<td>Meditation, yoga, tai chi, and/or qi gong</td>
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<td>Smoking cessation</td>
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<td>Stress reduction, biofeedback</td>
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### References


