Medical Research Archives

ESMED
European Society of Medicine

OPEN ACCESS

Published: October 31, 2022

Citation: Havas M and Symington MS, 2022. Pulsed Electromagnetic Field Therapy (Seqex, Theta) Promotes Well-being as assessed by Heart Rate Variability: A Pilot Study., Medical Research Archives, [online] 10(10). https://doi.org/10.18103/mra.v10i10.3208

DOI
https://doi.org/10.18103/mra.v10i10.3208

ISSN: 2375-1924

RESEARCH ARTICLE

Pulsed Electromagnetic Field Therapy (Seqex, Theta) Promotes Well-being as assessed by Heart Rate Variability: A Pilot Study

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ABSTRACT
Frequency therapy, in the form of pulsed electromagnetic fields, is becoming increasingly popular within the scientific/medical community as is heart rate variability for assessing wellness. These two techniques were combined to determine if a particular pulsed electromagnetic field treatment (Seqex, Theta) had any beneficial effects (based on Brain Tap HRV) on 20 volunteers ranging in age from 21-81. Treatment consisted of a 36-minute exposure to 4–8 Hz with a magnetic flux density between 12 to 68 mG and several proprietary waveforms. Treatment was conducted at a wellness clinic that had low levels of electromagnetic fields/radiation and heart rate variability was tested immediately before and immediately following treatment. Significant benefits were documented for 72% of the participants and these were associated with reduced stress and a lower biological age (vs. chronological age) as indicators on Brain Tap HRV. Indices for cardiovascular health; LF/HF balance, neurohormonal regulation and psychoemotional state all improved overall as did energy resources and energy balance (catabolic vs. anabolic). Individuals who believed they were sensitive to electromagnetic fields (i.e. had electrohypersensitivity) also improved. Some of the beneficial results persisted over a 24-hour period. Despite this positive outcome, 28% of the participants either showed no objective change or were worse (based on heart rate variability) immediately following treatment. We conclude that pulsed electromagnetic field treatments may be highly beneficial even among those who have electrohypersensitivity resulting in reduced stress and improved homeostasis. However, treatments should be provided in an electromagnetic clean environment for optimal results and objective testing with heart rate variability, or some other assessment tool, should be used to ensure that the patient is receiving a treatment that is beneficial.

Keywords: pulsed electromagnetic field therapy; PEMF; heart rate variability; (HRV); autonomic nervous system; Seqex; Brain Tap HRV; ion cyclotron resonance, theta

1. Introduction

Pulsed electromagnetic field (PEMF) therapy, initially used to heal non-union bone fractures in the 1970s[1], is increasingly being used to accelerate soft tissue healing, to reduce pain, and to promote wellness in both humans and animals[2–7]. The number and type of PEMF devices are increasing as are the health claims made by the manufacturers. Features of PEMF technology vary enormously. They differ in intensity, frequency, wave shape, pulse rate, duration of exposure etc. Some have preset programs and others can be adjusted and while some are intended to be used in hospitals and wellness clinics, others are designed for home use to minimize minor pain and to maintain optimal health. Pulsed electromagnetic field technology used to heal soft-tissue injury or bone fractures often takes days to months before benefits can be observed. When this technology is used to reduce pain, the patient often notices immediate changes that may last from hours to weeks and, in some cases, may be permanent.

Several years ago, we tested *Rhumart*, a PEMF device for treating rheumatism and arthritis in a Bioenergy Medical Clinic. The doctor assessed his patient using an Electro-interstitial Scan that indicated which vertebra were inflamed. The patient was scanned immediately before and after a 10-minute treatment. The follow-up scan, which provided an objective assessment, showed that much of the inflammation had disappeared immediately after treatment. The patient's subjective assessment was that 80% of the pain dissipated and a follow-up two weeks later confirmed the pain had not returned (Fig.1).

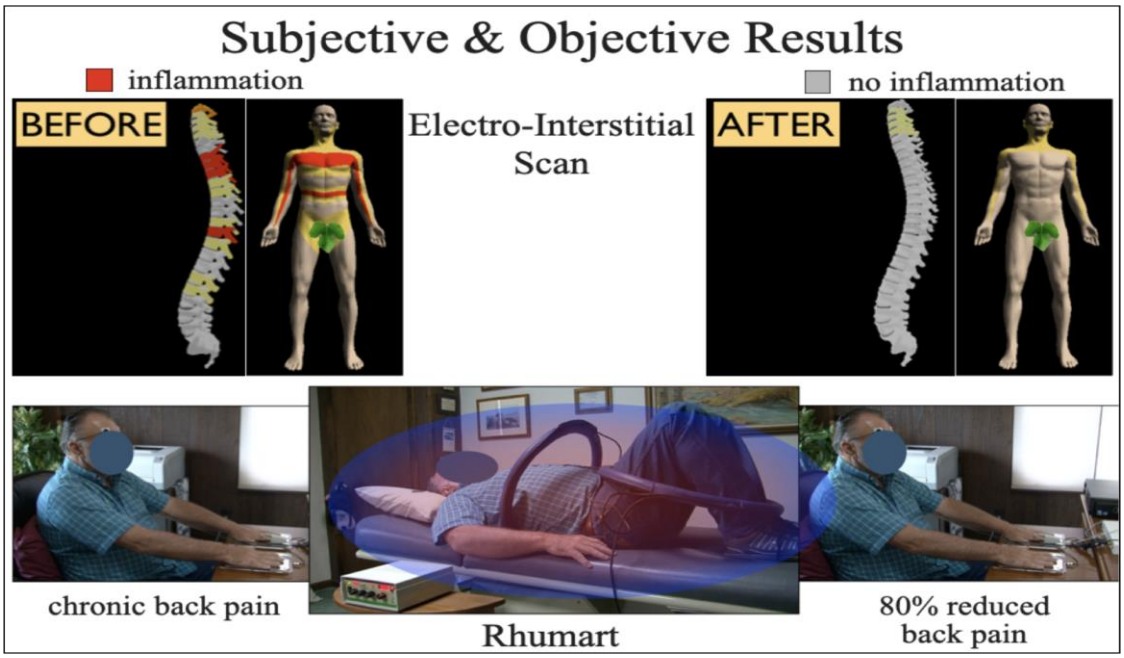

Figure 1. Patient experienced chronic back pain and was treated using PEMF therapy (Rhumart). Immediately after treatment he stated that 80% of the pain had subsided. The pain had not returned after a two-week follow-up. The Electro-Interstial Scan (EIS) administered immediately before and after the PEMF treatment indicates that the vertebrate were no longer inflamed after a 10-minute treatment. Data courtesy of Dr. Jeffrey Marrongelle, BioEnergiMed Metabolic Institute.

Testing the effectiveness of a treatment is important information that tells both doctor and patient if an intervention is working. However, this is seldom done on a routine basis especially in wellness clinics. When there are no subjective changes and no objective measures, how is one to know if the treatment was effective?

One technology that shows great promise in providing immediate feedback is heart rate variability (HRV) testing. HRV, to access health status, is becoming increasingly popular as the power of the technology continues to improve providing information about the functioning of the autonomic nervous system (ANS) and related neurohormonal regulation[8–10]. Heart rate variaiblity is a non-invasive tool that provides physiological information rapidly about the functioning of the autonomic nervous system (ANS) without the need for laboratory assessment of blood or urine chemistry and without expensive MRI or CT scans.

According to PubMed the number of publications for both PEMF therapies and HRV as an assessment tool are increasing (Fig. 2A, 2B). However, they are seldom used together.

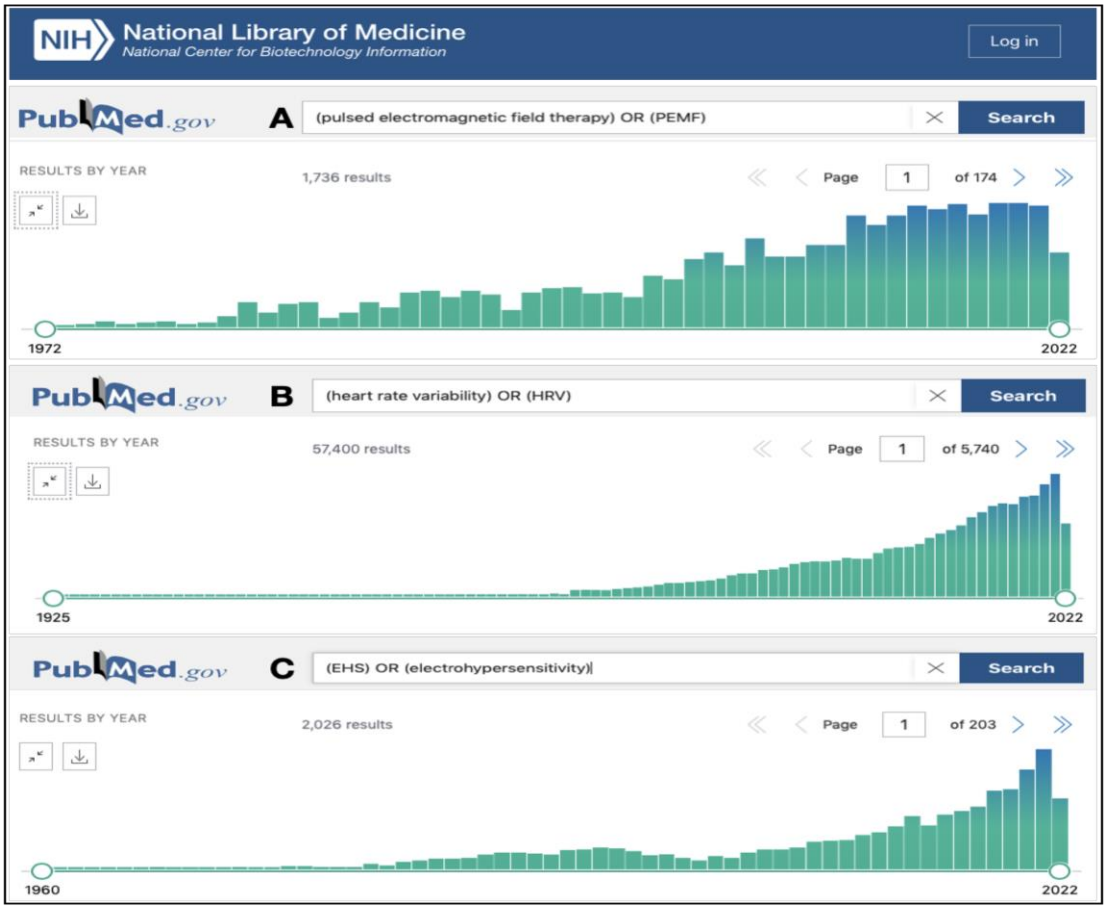

Figure 2. As of August 12, 2022, a PubMed search shows the number of publications using the terms: A. pulsed electromagnetic field therapy (PEMF); B. heart rate variability (HRV); and C. electrohypersensitivity (EHS). No filters were used.

One concern about PEMF therapy is whether individuals who are suffering from electrohypersensitivity (EHS) can benefit from this technology. Electrohypersensitivity refers to individuals who are unable to tolerate even low levels of electromagnetic fields that range from extremely low frequency (ELF) to radio frequency (RF) and microwave (MW) radiation.

Originally EHS was called *neurasthenia* or a weakening of the nervous system and was the focus of a Canadian Royal Commission report as far back as 1907, when telephone operators in Toronto working on switch boards became ill[11]. During World War II, it was called *microwave illness* or *radiowave sickness* as experienced by radar operators exposed to microwave radiation[12]. The World Health Organization (WHO) prefers to call this illness, *idiopathic environmental intolerance-attributed to electromagnetic fields* (IEI-EMFs)[13].

According to PubMed, the term *electrohypersensitivity* (EHS) was first used in the 1960s (Fig. 2C). Since that time a growing number of devices–including cell phones, WiFi, smart meters, among others–communicate using radio frequencies and consequently exposures are increasing. Some people are unable to tolerate these exposures and manifest symptoms of EHS.

The purpose of this research is to determine if a particular PEMF device, Seqex from Italy, has beneficial effects based on HRV testing and–to a lesser extent–whether those who suffer from EHS are able to tolerate the electromagnetic exposure generated by PEMFs. In this study we tested the technology as a *wellness promoter* rather than a device that accelerates the healing of an injury or a specific illness.

2. Materials and Method

2.1 Participants

A total of 20 people, consisting of 15 females and 5 males, volunteered to be tested. They ranged in age from 21 to 81 with an average of 49 years. Their overall health status based on a self assessment varied from average (for my age) to good with only two subjects complaining of poor health. Prior to testing, everyone completed a wellness questionnaire that enquired about their perceived sensitivity to electromagnetic fields/radiation. Of the 20 volunteers, 25% stated they were sensitive, 5% probably sensitive, 15%

possibly sensitive, 35% were not sensitive and 20% didn't know.

2.2 Testing Protocol

Participants were asked to be well hydrated (i.e. to drink water prior to testing), not to eat or drink caffeinated beverages at least two hours prior to testing and to avoid vigorous exercise at least 4 hours prior to testing. Testing was done at a wellness clinic in Collingwood, Ontario, Canada that had low levels of electromagnetic fields and electromagnetic radiation (i.e. levels orders of magnitude below international guidelines). Upon entering the clinic for their appointment, participants were asked to complete a consent form (requirement for ethics) and a wellness questionnaire that enquired about their perceived state of health and their perceived electrohypersensitivity.

After completion of the paper work, volunteers were hooked up to a heart rate variability monitor, as described below, and their readings were recorded. Normal time for this depends on heart rate and ranges from 3 to 5 minutes. They were then taken to the treatment room where they laid down on a Seqex PEMF mat set to Theta setting for 36 minutes. As soon as the program ended, their heart rate variability was retested and recorded.

2.3 Heart Rate Variability

Heart rate variability (HRV) was measured using Brain Tap HRV. The software and hardware (Dinamika, www.dyn.ru) meet the standards of measurement, physiological interpretation and clinical use of cardiac intervalometry indices, adopted by the European Society of Cardiology and North American Association for Electrophysiology. Heart rate variability relies on the Fast Fournier Transformation (FFT), which is a digital tool that analyses the heart rate signal using time and frequency algorithms, measuring frequency and amplitude oscillations of the heart. The FFT converts the ECG into frequency-component bandwidths that correspond to specific parts of the nervous system involved in regulation of the body. The low frequency (LF) corresponds primarily to the sympathetic nervous system (SNS) that regulates the stress response (fight/flight or freeze). The high frequency (HF) component corresponds to the parasympathetic nervous system (PNS) that regulates the rest/digest/heal/detoxify mode. The very low frequency (VLF) has some sympathetic properties but primarily reflects hormonal regulation through the hypothalamic-pituitary-adrenal (HPA) axis and indicates "burn out" or adrenal exhaustion. Brain Tap HRV provides a stress index, brain coherence, hormonal vs. nervous system response, biological age, spinal cord blockages, chakra energy associated with various organs and endocrine glands as well as meridian blockages according to Chinese medicine[14,15].

HRV was monitored immediately before and immediately after a Seqex theta treatment. Electrodes were placed on each moistened wrist and the seated subject was told not to move or talk during the test, which captured 300 heart beats. A total of 38 parameters were included in the results and these are as follows: total power, vegetative balance, stress index, vegetative index of heart, energy resources, energy balance, psychoemotional index, level of harmonization, biological age, adaptation level, vegetative index, neurohormonal index, psychoemotional state, 5 regions of the spine (cervical, thoracic, lumbar, sacrum, coccyx); 7 Chakras (crown, pineal, throat, heart, solar plexus, genitals, colon) plus overall response; 12 major meridians (lung, large intestine, stomach, heart, small intestine, bladder, kidney, pericardium, triple warmer, gallbladder, spleen, liver).

Brain Tap HRV indicates the reliability of each rhythmogram and for two subjects the reliability of the monitoring was low and, consequently, these results were discarded.

A two-tailed T-test was used to determine statistical significance before vs. after treatment for paired samples.

All subjects were tested immediately before and immediately after a PEMF treatment that lasted 36 minutes. Two subjects were retested for HRV the following day to determine stability of response during a 24-hour period.

2.4 PEMF Therapy

Seqex is a PEMF device made in Italy and approved by Health Canada as a medical device (Health Canada license # 99894, issued 2017/10/24). It is based on the concept of ion cyclotron resonance[16]. Seqex has multiple applicators including a mat for full body exposure, a pad for generalized treatment and a probe for localized treatment. Seqex has pre-set programs that either correspond to brain wave activity (delta, theta, alpha, beta, gamma) or that have specific functions (regeneration, wound fractures, micro-circulation, Fibonacci, sport-endurance, and muscle). All of the programs can be individualized with a biofeedback mechanism producing an individualized prescription card with the MED unit that can be used at home with a FAM unit. Participants were exposed for 36 minutes while lying on a Seqex mat set to program Theta.

***2.4.1Theta Protocol*:** The program tested in this study was theta and participants had individualized theta prescription cards. The basic theta program takes 36 minutes to complete and consists of 9 consecutive cycles (Table 1).

Table 1. Seqex Theta program indicating intensity, frequency, wave form and duration of exposure for each of 9 consecutive sequences. The wave form is proprietary information.

Sequence	Intensity (% of 0.2 Gauss)	Frequency (Hz)	Wave Form	Duration (min)
1	30	4	26	4
2	30.5	4	27	4
3	31.1	5	28	4
4	31.5	5	21	4
5	32	6	22	4
6	32.5	6	23	4
7	33	7	15	4
8	33.5	7	10	4
9	34	8	5	4

3. Results

3.1 Overall Response to Treatment

Brain Tap HRV indicates various states of health based on 62 numeric scores, some of which overlap and some of which are integrative. We based our data on 38 of these parameters to minimize overlap and ranked subjects according to their combined response with the subject ranked as number one experiencing the greatest improvement (Table 2). According to this table, there were no statistically significant differences before and after PEMF treatment except for heart rate, which decreased from an average of 70 (range 53–98) to 67 (range (48–82) bpm ($P \leq 0.5$). It is important to note that no significant difference (nsd) for HF, LF, and VLF should not be interpreted that the treatment had no effect since it is the relative ratio of these three parameters that determines the state of health and the functioning of the autonomic nervous system (ANS) and, in this regard, there were differences as discussed later.

Table 2. Basic HRV and health data before and after PEMF exposure to Seqex Theta for subjects ranked according to their combined response to 38 variables provided by Brain Tap HRV.

									Normal Range									
Rank	Gender	Age	Self Prroclaimed Health Status	EHS Status	Rhymogram Reliabiity		Heart Rate (pbm)		Total Power (2385-4545)		HF (15-20%)		LF (30-50%)		VLF (15-35%)		VLF vs. Age (age – VLF)	
					Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
1	M	41	poor	yes	100%	72%	72	75	6660	2055	34%	8%	26%	60%	40%	32%	1	9
2	F	37	average	no	83%	90%	98	82	677	3588	10%	9%	33%	31%	57%	60%	-20	-23
3	F	50	average	yes	95%	98%	79	69	286	1126	41%	56%	20%	31%	38%	13%	12	37
4	F	56	average	yes	79%	94%	76	74	859	1694	12%	13%	38%	38%	50%	49%	6	7
5	F	67	average	don't know	93%	80%	53	48	927	1899	13%	9%	15%	18%	72%	73%	-5	-6
6	F	53	average	yes	100%	100%	89	81	125	217	18%	42%	34%	24%	48%	34%	5	19
7	F	49	average	probably	100%	97%	62	69	1302	1429	55%	33%	17%	27%	28%	40%	21	9
8	F	43	poor	don't know	100%	85%	72	62	1018	1522	41%	46%	34%	28%	25%	25%	18	18
9	F	43	good	no	79%	88%	65	63	1513	1458	24%	23%	27%	33%	49%	44%	-6	-1
10	F	49	average	probably	95%	91%	75	71	1144	1174	25%	27%	15%	22%	60%	52%	-11	-3
11	M	37	average	no	100%	99%	68	67	299	362	24%	18%	33%	33%	43%	49%	-6	-12
12	M	21	average	no	96%	85%	59	66	5184	5095	19%	11%	65%	63%	16%	26%	5	-5
13	F	33	good	possibly	77%	90%	65	64	1956	2285	40%	26%	26%	36%	34%	38%	-1	-5
14	F	73	good	no	90%	97%	68	67	444	310	9%	18%	13%	19%	78%	63%	-5	10
15	F	52	average	yes	83%	80%	73	70	784	1100	16%	12%	30%	23%	54%	64%	-2	-12
16	M	35	good	don't know	76%	79%	63	59	1632	1162	15%	31%	54%	48%	31%	21%	4	14
17	F	61	average	don't know	87%	98%	63	65	650	380	15%	24%	26%	17%	59%	59%	2	2
18	F	62	good	no	81%	79%	63	59	1553	1257	33%	30%	21%	17%	46%	53%	16	9
	max	73			100%	100%	98	82	6660	5095	55%	56%	65%	63%	78%	73%	21	37
	mean	48			90%	89%	70	67	1501	1562	25%	24%	29%	32%	46%	44%	2	4
	min	21			76%	72%	53	48	125	217	9%	8%	13%	17%	16%	13%	-20	-23
				ttest	0.80		0.05		0.85		0.88		0.37		0.45		0.45	

The magnitude of the combined numeric scores (Fig. 2A) indicates that of the 18 participants–for which reliable rhythmograms were available–72% (13) improved, 11% (2) remained the same, and 17% (3) got worse following treatment resulting in a net improvement of 55% of the participants.

3.2 Biological vs. Chronological Age

Those who improved generally had a lower biological vs. chronological age, while those who got worse had a higher biological vs. chronological age indicating premature aging caused by illness/stress (Fig. 3B).

3.3 Stress Index

Similarly, the stress index after treatment was generally lower among those who improved and the reverse was the case for those who got worse (Fig. 3C).

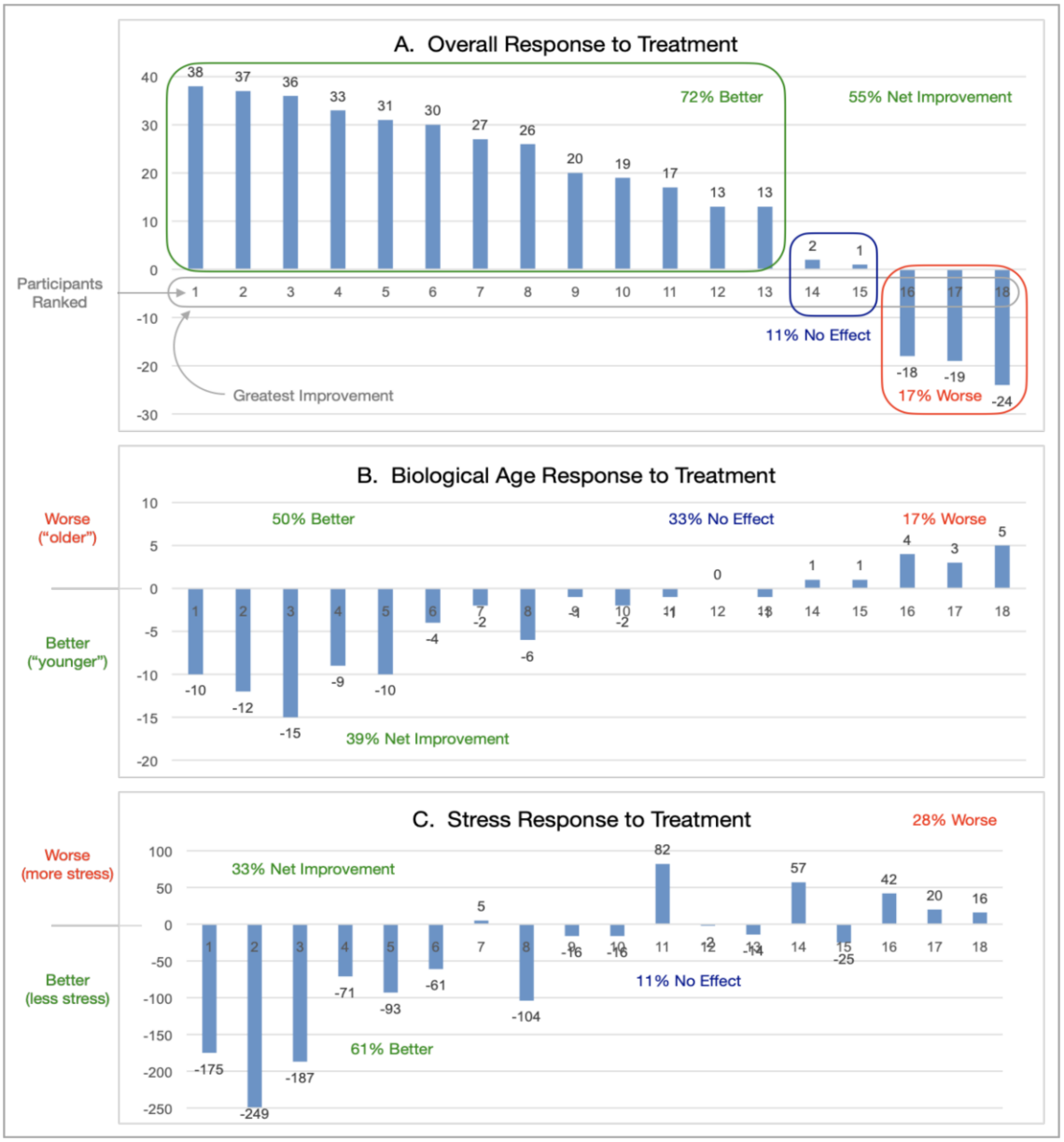

Figure 3. Participants ranked according to their (A) overall response to Seqex PEMF Theta treatment (38 markers); (B) biological age as opposed to their chronological age in years; and (C) their stress index (n=18). Based on Brain Tap HRV.

3.4 Statistical Relationships

Correlations between the overall response vs. biological age (Fig. 4A); overall response vs. stress response (Fig. 4B); and stress vs. biological age (Fig. 4C) were highly significant, accounting for more than 70% of the variance ($R^2 > 0.7$).

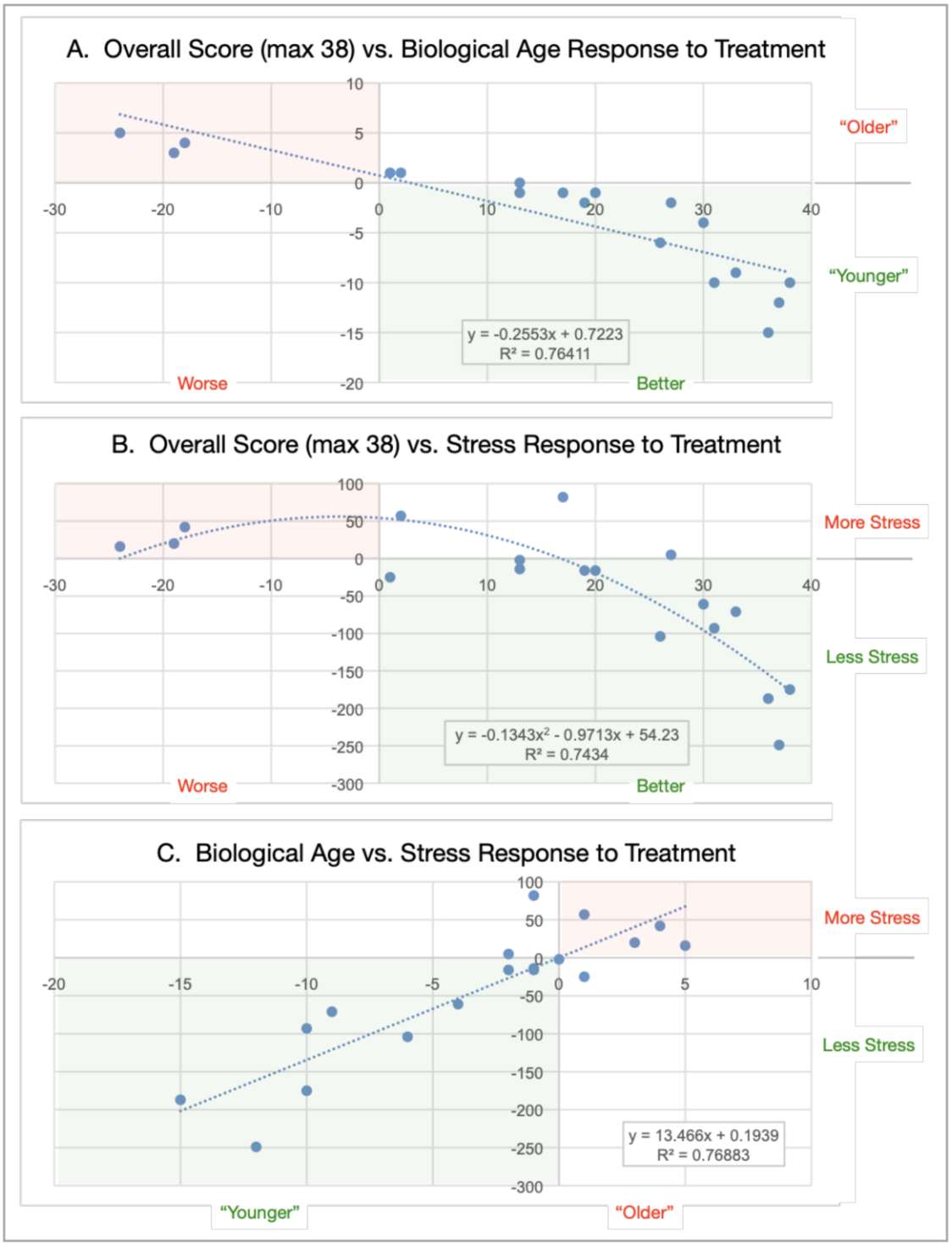

Figure 4. Regression equations for (A) overall response vs. biological age; (B) overall response vs. stress response; and (C) biological age vs. stress response to PEMF Treatment (Seqex, Theta) (n=18). Based on Brain Tap HRV.

3.5 Basic Responses to Nervous System Regulation

Brain Tap HRV distinguishes between heart health (Adaptation Index); response of the autonomic nervous system (ANS) based primarily on LF vs. HF (Vegetative Index); involvement of the central nervous system (CNS) based primarily on VLF (neurohormonal index); and involvement of the brain (psychoemotional index). Figure 5 shows participants' status for these four parameters before and immediately after PEMF treatment. A considerable number show improvements in all four indices.

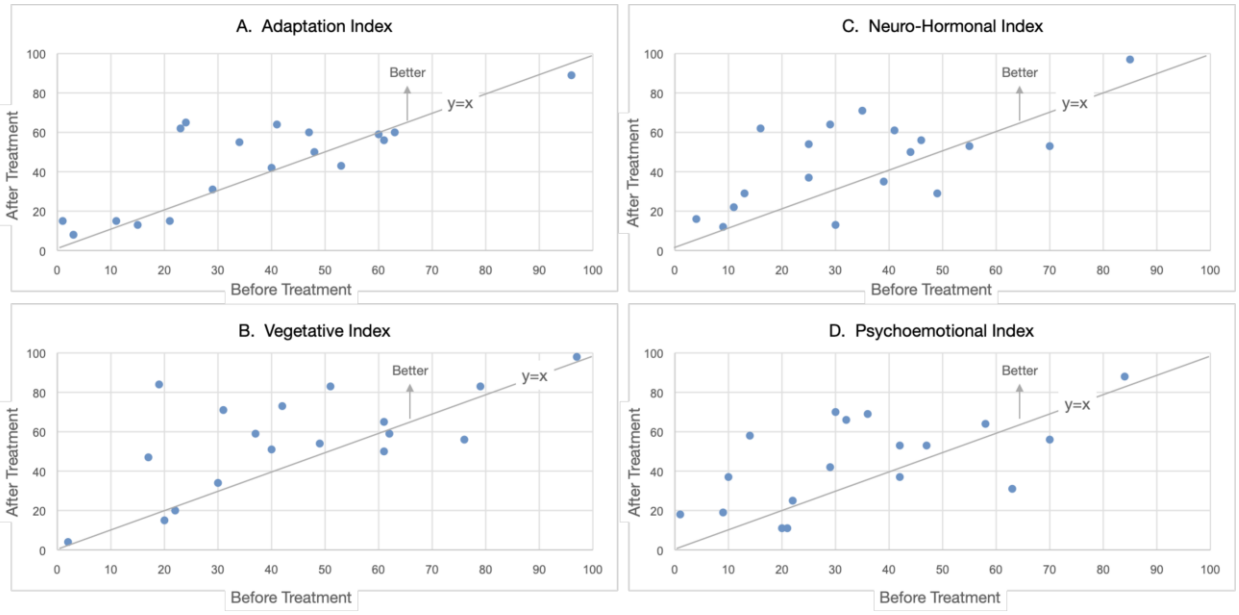

Figure 5. Before vs. After response to PEMF (Seqex Theta) treatment for (A) Adaptation Index; (B) Vegetative Index; (C) Neuro-Hormonal index; and (D) Psychoemotional Index according to Brain Tap HRV (n=18).

3.6 Energy Resources and Energy Balance

Whether the body is storing or consuming energy is based on the relative ratio of HF/LF/VLF. Greater stress results in more energy consumption. Energy resources generally improved immediately after PEMF treatment (Fig. 6A). Energy balance is based on the relative amount of energy stored vs. the amount used and ideally this should be close to 1, although this varies with activity. The normal range is 1 to 2.5 (energy storage vs. energy use) with higher ratios for athletes. Values less than 1 indicate that the body is storing energy and this information is useful in weight loss programs. The basic difference before vs. after treatment is that the spread is reduced after treatment bordering close to the balanced state (Fig. 6B, 6C). This may be due, in part, to the fact that participants spent the previous 36 minutes lying down. Some fell asleep during treatment. Prior to treatment, subjects spent about 30 minutes sitting while they completed a consent form (required for ethical approval) and a health status questionnaire so their level of physical activity was similar although their mental energy may have differed while completing the wellness survey.

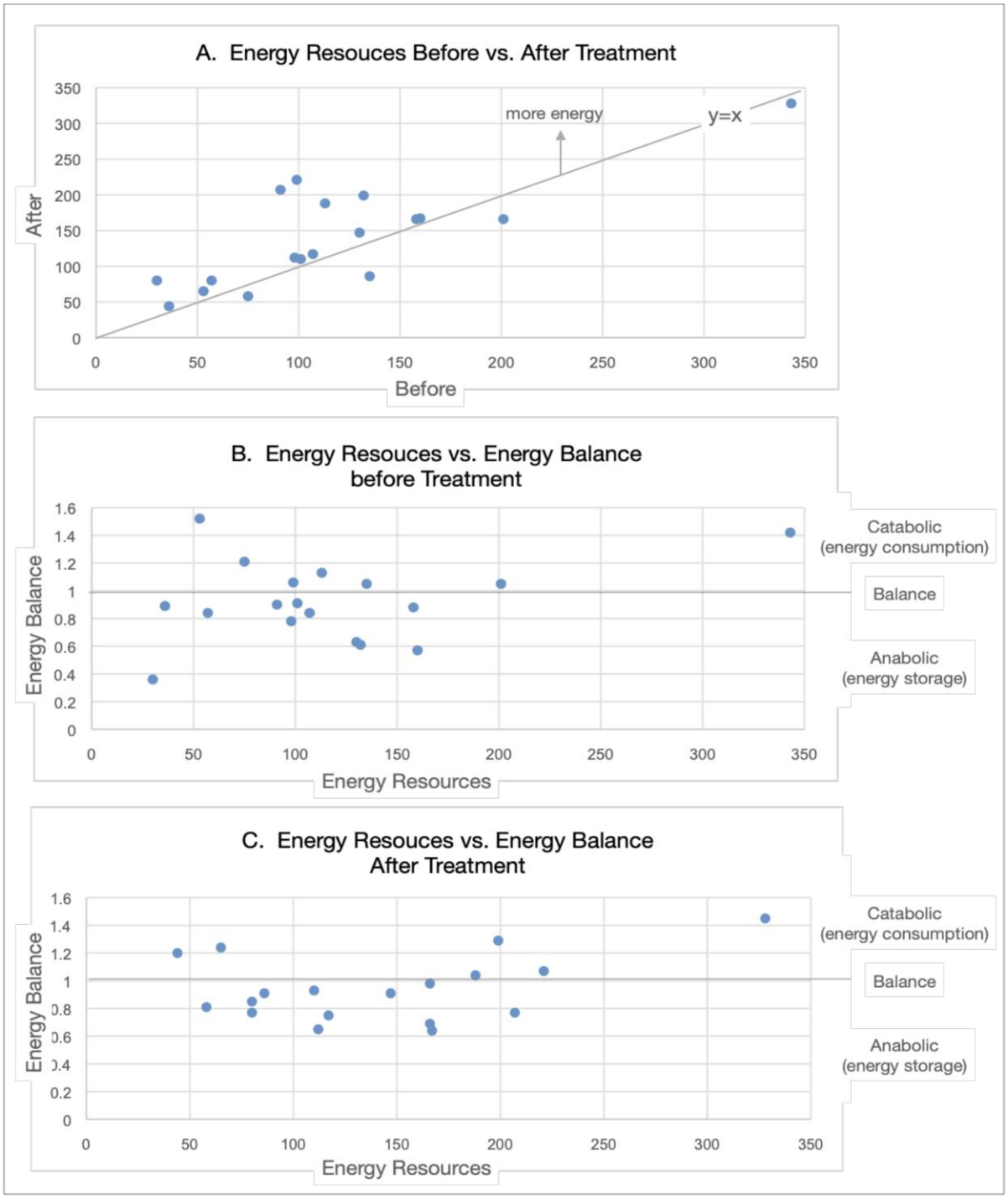

Figure 6. Energy resources before vs. after PEMF (Seqex Theta) treatment according to Brain Tap HRV (n=18).

3.6 Energy (spinal cord, meridians, Chakras)

All parts of the body work together to maintain homeostasis (nervous system, hormonal system, cardiovascular system). Different parts of the body (organs, nerves) are connected by various vertebra which can produce a relative energy diagram of the spinal cord. Flow of this energy through the body is essential for good health and blockages of the spinal cord, endocrine glands (Chakras) and/or meridians (Chinese medicine) often results in deteriorating health. The relative degree of energy flow (Fig. 7) indicates that there are fewer blockages after treatment which should have a beneficial effect on health.

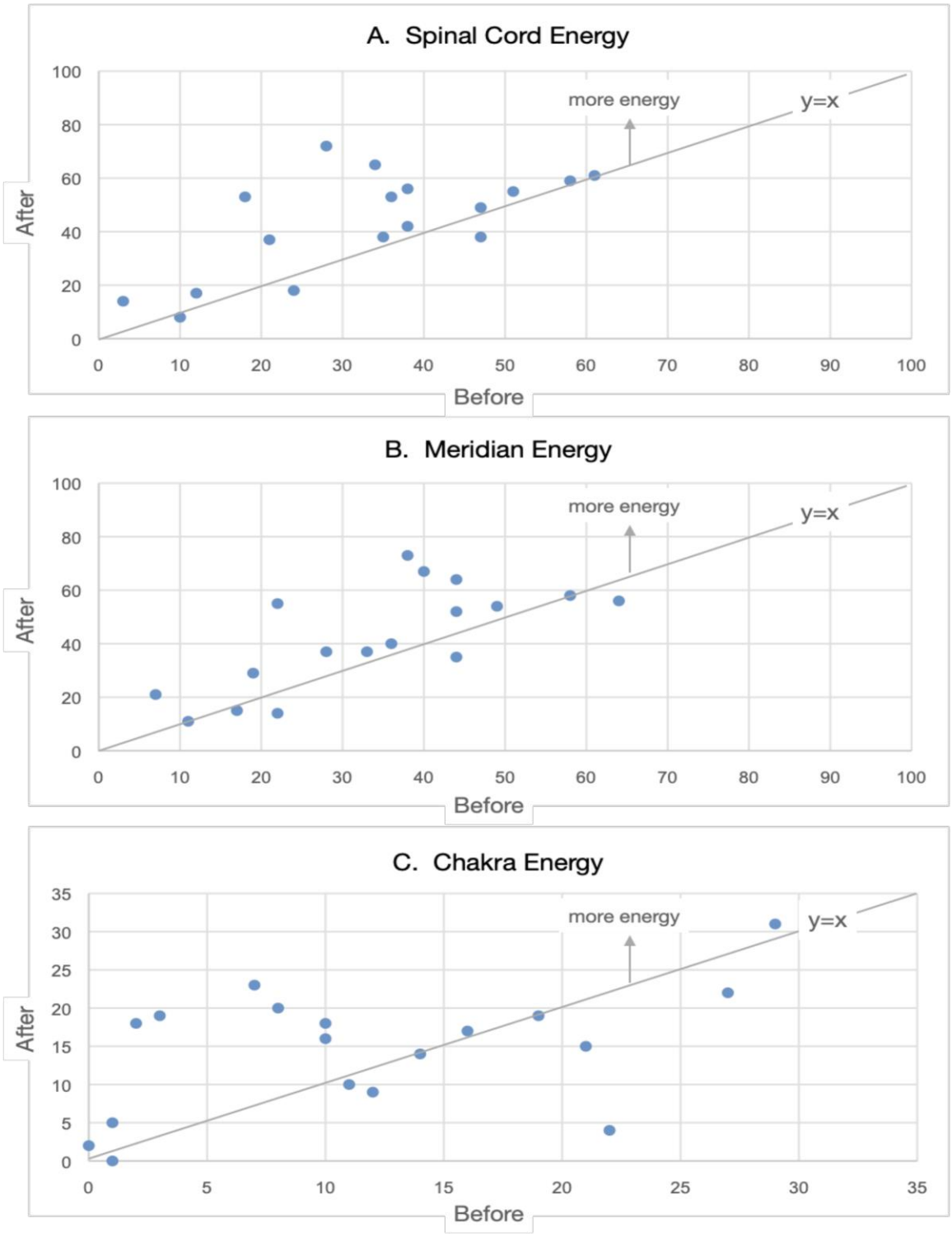

Figure 7. Energy of the spinal cord (A); meridians (B); and Chakras (C) before vs. after PEMF (Seqex Theta) treatment according to Brain Tap HRV (n=18).

3.7 Descriptive Statistics and T-Test

Descriptive statistics and the results of two-tailed, paired t-tests for before and after PEMF treatment are provided in Table 3. Many of the parameters changed after treatment. Both the stress response and biological age decreased (younger) following treatment. Energy resources, energies associated with the spinal cord and meridians, level of harmonization, as well as the four key indices (adaptation, vegetative, neurohormonal and psychoemotional) were all significantly higher after treatment. All of these indicate improved regulation.

Table 3. Descriptive statistics for HRV results before and after PEMF treatment. T-test based on 2-tailed, paired samples (n=18).

	Biological age		Biological vs. Chronological Age		Stress Index		Energy Resources		Energy Balance		Level of Harmonization	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
max	77	78	14	13	780	719	343	328	1.52	1.45	96	89
mean	50	46	3	-1	216	172	118	141	0.9	0.9	37	46
min	16	16	-11	-17	40	38	30	44	0.4	0.6	1	8
ttest	0.02	*	0.01	**	0.05	*	0.05	*	0.80		0.03	*

	Adaptation Index		Vegetative Index		Neurohormonal Index		Psychoemotional Index		Chakra Energy		Meridian Energy		Spinal Cord Energy	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
max	96	89	97	98	85	97	84	88	29	31	87	90	89	90
mean	37	45	44	56	35	45	35	45	12	15	37	45	36	46
min	1	8	2	4	4	12	1	11	0	0	7	11	3	8
ttest	0.05	*	0.03	*	0.03	*	0.05	*	0.20		0.02	*	0.01	**

Significant difference represented by * ($P \leq 0.05$) and ** ($P \leq 0.01$)

3.8 24-hour Response Two participants (ranked 3rd and 6th) were available to be re-assessed for HRV the following day to determine relative changes after a 24-hour period. Subject 3 had an immediate net beneficial response for 36 parameters, which dropped to 34 after 24 hours. Subject 6 was not as healthy and her net beneficial markers dropped from 30 to 9 after 24 hours so elements of improvement were still active. Clearly there is a lasting effect, although this may depend on the program used and the person tested.

3.9 HF/LF/VLF Ratio

As mentioned earlier the ratio of HF/LF/VLF determines the degree of involvement of the nervous system, endocrine system, heart, and brain. These ratios changed but there was no consistent pattern that could be detected. Some of the types of changes in the ratio before and after treatment are provided in Fig. 8. Participant 1 up regulated LF and down regulation of HF. Participant 3 up regulated both HF and LF at the expense of VLF. This is a healthy response with less involvement of neurohormonal regulation, which is less efficient than HF/LF regulation. The opposite was the case for participant 18. Very low frequency (VLF) was up regulated at the expense of both HF and LF.

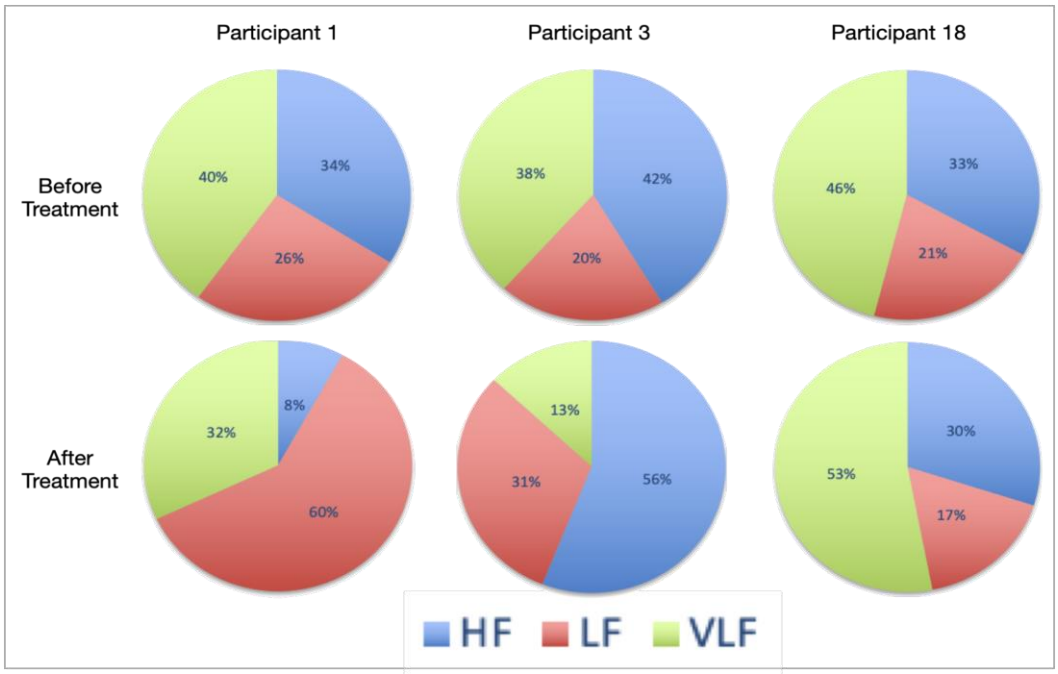

Figure 8. Ratio of HF (parasympathetic), LF (sympathetic) and VLF (neurohormonal) based on Brain Tap HRV for three participants before and after PEMF (Seqex, Theta) treatment.

4. Discussion

Heart rate variability (HRV) promises to be a useful tool for health care providers in assessing overall patient health. It is a non-invasive tool that provides physiological information about nervous system function, energy regulation, and cardiovascular health[8–10,17]. Heart rate variability is gaining popularity as an analytical tool in the scientific/medical literature (Fig.2B).

We used HRV previously, in a double-blind provocation study, showing that exposure to microwave radiation from a cordless phone, at exposures well below international guidelines, disturbs the autonomic nervous system (ANS), generates a stress response and indicates sensitivity to radio frequency radiation[18].

Just as the number of HRV publications are increasing so are the studies using PEMF (Fig. 2A). Our research shows that PEMFs reduce rouleau formation and promote blood circulation (MRS 2000); that it relieves pain and improves mobility among those with arthritis (Centurion); and that two 20-minute treatments using PEMFs (Ondamed) significantly reduced pleural effusion following open heart surgery[3,5,19].

Heart rate variability can also be used to assess the beneficial effects (if any) of various interventions including pulsed electromagnetic field (PEMF) therapy. When the two (HRV and PEMF) are paired, immediate and lasting beneficial effects can be documented. Heart rate variability also alerts the health care provider when a particular treatment is inappropriate, ineffective or possibly deleterious. Many PEMF devices are now available and the degree to which these treatments help patients can be easily and quickly assessed using HRV.

In this study, we tested a PEMF device (Seqex) from Italy that has Health Canada approval as a medical device. It provides various preset programs that can all be adjusted using biofeedback with personalized prescription cards. We used the theta program that has nine sequential exposures lasting four minutes each for a treatment lasting 36 minutes. Exposures range from 4 to 8 Hz and have an intensity between 12 to 68 mG. Different proprietary wave forms are used for each sequence. Seqex is based on the concept of ion cyclotron resonance as described by Liboff[16].

Brain Tap was used to assess HRV. The benefits of this particular program are that it translates the response to various functions within the body and provides information about the nervous system, the cardiovascular system, energy regulation, stress response and biological age (which is particularly useful for patients).

Following a 36-minute Seqex theta treatment, 72% of the participants benefited, 11% showed no effect and 17% got slightly worse based on HRV (Fig. 3A). Many of those who benefitted had a lower stress index following treatment (Fig. 3C) and those same individuals had a lower biological age (i.e. were "younger" compared with their chronological age) (Fig. 3B). Stress and biological age are positively correlated (Fig. 4C) and both are associated with the overall score (Fig. 4A, 4B).

Stress, as a cause of chronic illness[20,21], is a serious concern. Those who have a life style that includes moderate physical activity, nutritious meals, clean water, quality sleep, minimal stress and live in a health-promoting environment often feel younger than their chronological age. With an aging global population, chronic illness is rampant and anything that promotes wellness and reduces stress and helps regulate energy is likely to benefit patient health and to reduce the strain on the health care system.

Brain Tap HRV converts the rhythmogram, based on proprietary algorithms, into an index of cardiovascular regulation (Adaptation Index); balance between LF vs. HF (Vegetative Index); role of VLF (Neuro-hormonal Index) and role of the brain (Psychoemotional Index). The overall response within all of these categories was positive (i.e. showing improvement among most of the participants) (Fig. 5).

The body uses more energy when LF and VLF are up regulated (increased stress). On average, the balance between energy storage and energy use should be close to one, although this depends on the level of physical/emotional/mental activity. Generally, energy resources increased after PEMF treatment (similar to charging a battery) and energy balance (storage/use) was closer to a balanced state (Fig 6).

Heart rate variability measures more than just the response of the autonomic nervous system. The brain and heart work together along with the respiratory, nervous, immune and endocrine systems to maintain homeostasis under different circumstances. That relationship, as it relates to the flow of energy along the spinal cord, along meridians and within various organs/endocrine organs can be estimated. Blockages in any of these systems often leads to impaired health.

Energy flow was significantly enhanced ($P \leq 0.05$) following PEMF treatment within the spinal cord and along the meridians (Fig. 7, Table 3). Treatments that reduce blockages and enhances energy flow should promote health. Common techniques to reduce blockages include certain medications/minerals (aspirin, magnesium, beta blockers, nitro-glycerine) and physical manipulation of the body (exercise, massage, lymphatic

drainage, craniosacral manipulations, reiki, reflexology, acupuncture) and techniques to regulation the mind/emotions (meditation, hypnosis, music therapy). Increasingly, the use of frequency therapy such as PEMF, photobiomodulation, low level light therapy (LLLT) and sound (physical vibration) is proving to be safe without adverse side effects that sometimes result from other therapies[22–25]. It is as though the electromagnetic pulses are massaging the body to assist with homeostasis.

Not everyone tolerates certain types of medication and not everyone tolerates exposure to even low levels of electromagnetic fields. A growing population is developing electrohypersensitivity (EHS)[26] and the question remains, "Can individuals who are electromagnetic intolerant benefit from PEMF treatments"? According to this study, those who benefitted the most were self-classified as being EHS (n=7). This is just one program with a small sample size but clearly, having EHS does not necessarily prevent someone from receiving and benefiting from a PEMF treatment. Each individual and each treatment need to be tested.

One major drawback of this study is the small sample size (n=18). We conceived of this as a pilot study to see if we could indeed detect any changes following a short (36-minutes) PEMF session. In that regard, the pilot study was successful, but more work needs to be done. We tested just one of the many Seqex programs, each of which is purported to elicit different responses (some stimulating and some relaxing). PEMF devices are now available with their own (sometimes proprietary) wave forms, frequencies and intensities. As we better understand how electromagnetic frequencies interact with the body, the more successful we will be in using the appropriate program for each specific function to optimize homeostasis and promote wellness.

We offer two recommendations for those using PEMFs with their patients or clients. (1) It is important that treatments be conducted in an electromagnetically clean environment as electromagnetic pollution is chaotic energy that can harm the body even at low exposures[27,28]; (2) Ideally, the outcome of each treatment should be measured objectively and subjectively. An objective marker that the body is improving encourages patient compliance. If there is no subjective or objective feedback, how does the doctor/patient know if the intervention was successful? Heart rate variability is one tool that can provide much needed objective feedback in assessing patient well-being and PEMFs are another tool to be included in a doctors' tool kit.

5. Conclusions

In this study, 13 of the18 participants (72%) benefited significantly from a 36-minute PEMF treatment (Seqex, Theta) resulting in reduced stress, improved energy regulation, improved cardiovascular adaptation, improved neurohormonal regulation and improved psychoemotional health based on heart rate variably (HRV) using Brain Tap HRV. These beneficial effects were associated with reduced stress and a lower biological age as opposed to chronological age. Many of these beneficial effects were still in evidence 24 hours after treatment. Participants who self-assessed as being sensitive to electromagnetic fields (EHS) also benefited from the therapy without any obvious ill effects. Pulsed electromagnetic field therapy combined with HRV analysis provides valuable feedback to patients encouraging compliance and enables health care providers to optimize treatment conditions for the long-term health of their patients. With health care costs increasing and with an aging population, use of PEMF in wellness clinics and at home to maintain optimal health may reduce the increasing pressure on our health care system.

Acknowledgments

We thank our volunteers, Health Energies for providing the space for testing, and the anonymous reviewers.

Ethics

Research approved by the Research Ethics Board (REB) at Trent University.

Funding

No funding received for this research.

Competing Interests

None

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Appendix A: Brain Tap HRV

Information Provided below is from:

DIMAMIKA Medicine, User's Manual, System of Complex Computer-Aided Inspection of the Functional Condition of the Human Organism, DIAMKIA Medicine, Saint-Petersburg, Russia, 2011, www.dyn.ru

https://dyn.ru/oldomega/Dinamika.Medicine.User.Guide.EN.pdf

Brain Tap HRV: HRV is a measure of heart rate variability and is based on the time between P-P intervals in an ECG measured in ms. The greater the variability the healthier the person. HRV decreases with age naturally and becomes worse with illness and long-term stress and can be affected temporarily by insufficient sleep. Low levels of HRV indicate that a person is at risk of developing serious illness (especially cardiovascular illness) or is aging prematurely.

Since not all HRV programs provide the same information, a brief description of the software is provided to help interpret the results.

Brain Tap HRV provides "screens" that indicate various states of health based on 62 numeric scores, some of which overlap and some of which are integrative. The results in this paper include the rhythmogram and its relative reliability; adaptation; vegetative regulation; neurohumoral regulation; psychoemotional state; and complex state index (which is a combination of the previous indices). It also provides a stress index; biological age, energy status; spinal cord energy flow; chakra energy and median energy/blockages based on Chinese medicine.

Rhythmogram: provides a time line on the P-P intervals measured in ms. Reliability of the monitoring is provided as a percentage and classified as good, satisfactory or poor during a capture of 300 heart beats.

Adaptation: Adaption indicates how quickly the cardiovascular system (CVS) can adapt to change based on the functioning of the autonomic nervous system (ANS). Standing up from a sitting position increases the sympathetic nervous system (SNS) and decreases the parasympathetic nervous system (PNS) resulting in a slight increase in heart beat. If no other actions are taken, the SNS should decrease slightly. The more quickly this happens the greater the adaptation.

Vegetative Regulation: Vegetative Balance Index is based on the proportion of LF (sympathetic), HF (parasympathetic), and VLF (primarily neurohormonal). When VLF is more than 50% the brain is more involved in regulation and the body has limited stress management. When VLF is predominant the body is regulated by chemical messages such as catecholamines. VLF is slower and not as efficient as the ANS is regulating response. The normal range for VLF is between 25-35% and this increases with age. Ideally the VLF should be lower than chronological age. Brain Tap HRV provides a *vegetative balance index* with six categories: optimal balance, stable balance, normal regulation, unstable regulation, disrupted balance, and disrupted regulation.

Neurohumoral Regulation: NH regulation comes from the complete spectral analysis of VF, VLF, HF and incorporates the relationship between different systems of the body. Brain Tap HRV classifies the response into six categories as follows: 83-100% maximum balance; 66-83% stable condition; 50-66% balanced state; 33-50% accumulated tiredness; 17-33% nervous overstrain; and 0-17% high stress level. A range of 50-100 is considered normal. A low number indicates decreased immune function.

Psychoemotional State: Brain activity depends on the other three systems (sympathetic, parasympathetic, neurohumoral) and also determines the function of all three systems. Brain Tap HRV classifies the response into six categories: 83-100% maximum balance; 66-83% stable condition; 50-66% balanced state; 33-50% accumulated tiredness; 17-33% nervous overstrain; and 0-17% high stress level.

Complex Analysis (Tension): This provides a percentage of previous analyses, namely adaptation level, vegetative index, neurohumoral regulation index and psychoemotional state. Ideally values should be close to one another. If one is much lower than the others it gives a sense of where to start examining illness. For example, if neurohumoral is low, adrenal problems are suspected. Lower values indicate physical or emotional stress. Six categories are provided: 80-100% optimal regulation; 60-80% balanced regulation; 40-60% stable regulation; 20-40% unstable regulation; 10-20% expressed tension; 0-10% significant over tension.

Stress Index: The stress index indicates how the body is using energy. A high stress index shows that the body is using more energy to correct for changing stressful conditions. Normal values fall with 10-100. Values above 500 indicate that lifestyle changes are required.

Biological Age: The gerontological curve provides an assessment of biological age as compared to chronological age. This provides the most easily understood information for patients by integrating all the other parameters.

Energy Status (metabolic pyramid): Under periods of illness or stress the body consumes more energy than it produces. The LF is associated with catabolic

activity (energy production), while the HF is associated with anabolic activity (energy storage). Brain Tap HRV indicates the relative balance between the anabolic state and catabolic state. The normal balance is between 1 and 2.5 in young, healthy individuals and may be higher in athletes. This also indicates the rate of recovery and decreases with age. An energy balance less than 1 indicates the body is in fat storage mode.

Spinal Cord Functioning: The nerves in the spinal cord are associated with different body parts, organs and the activity of the ANS. Brain Tap HRV provides information on segments of the spine and their relative energy flow as it relates to the ANS. The information is provided as a percent energy flow in different spinal segments (cervical, thoracic, lumbar, sacrum, coccyx) and this is classified into 5 categories: excellent, good, satisfactory, unsatisfactory and bad. The vertebrae and their associated body parts (organs) are also provided.

Chakra Energy: The chakras in Ayurvadic medicine are associated with different organs/endocrine glands in western medicine and similar calculations are used as in the spinal cord analysis. Brain Tap HRV provides a percentage for each chakra and a 5 star classification. This calculation for Chakras is proprietary.

The body parts associated with each chakra are as follows:

1. Root Chakra is responsible for regeneration and immunity and is associated with the colon, urinary bladder, prostate, uterus and legs (endocrine gonads).
2. Sacral Chakra is responsible for the metabolic rate and is associated with genitals, celiac plexus and appendix (endocrine adrenal gland).
3. Solar Plexus Chakra is responsible for the digestive system and is associated with stomach, pancreas, gallbladder and liver (endocrine pancreas).
4. Heart Chakra is responsible for blood circulation system and is associated with the heart, lungs, and blood circulation (endocrine thymus).
5. Throat Chakra is associated with the larynx, thyroid, vocal cords and upper part of the lungs (endocrine thyroid).
6. Third Eye Chakra is responsible for the nervous system and is associated with vegetative nervous system, eyes, nose and spine (endocrine pituitary gland).
7. Crown Chakra is associated with the endocrine pineal gland.

Meridian Energy Flow: In Chinese medicine blocked energy flow along the meridians can contribute to illness and similar calculations are used as in the spinal cord/Chakra analyses. This information is proprietary.

The meridians include: lung, large intestine, stomach, pancreas & spleen, heart, small intestine, bladder, kidney, pericardium, triple heater, gallbladder and liver. The percentage of energy flow Is provided and this information is further classified into 5 colour-coded categories.

The National Cancer Institute (USA) provides a description of Chinese meridians as follows:

> *In traditional Chinese medicine, meridians are channels that form a network in the body, through which qi (vital energy) flows. Blocked qi causes pain or illness. The flow of qi is restored by using pressure, needles, suction, or heat at hundreds of specific points along the meridians.*
> https://www.cancer.gov/publications/dictionaries/cancer-terms/def/chinese-meridian-theory