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The Apparatus for Meridian Identification (AMI): A Promising Electrodermal Device for Traditional Chinese Medicine and Biofield Science
Part II

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Abstract – This is the second part of a research work to study the reliability of the Apparatus for Meridian Identification (AMI), an electrodermal device that measures the response of acupuncture points (acupoints) located on the tips of fingers and toes. In the first part, the literature reviews on Traditional Chinese Medicine (TCM) and the AMI, as well as the functioning of the device, were discussed. In this second part, previous reliability studies on acupoint electrodermal devices are reviewed, reporting their positive findings, and an original experiment is presented, to study the performance of the AMI. The measurement variability and working of this device were investigated, evaluating its capacity to assess human bioenergetics and Chi energy activity throughout the body meridians. The experiment involved 100 healthy participants, who were measured 5 times in the same psychophysical condition: In the analysis, it was determined whether the AMI could provide informative, meaningful, and repeatable assessments of the participants' biofield and subtle energy anatomy, in accordance with TCM principles. Results showed that the AMI parameters return accurate and valuable information about the human bioenergetic system and psychophysical status. Among the results, it was found that the Chi energy relationships between Yin and Yang meridians are consistent with those predicted by TCM, thus validating this millenary philosophy and practice. This trend is best reflected in the acupoint Before-Polarization (BP) current, compared to other electrodermal parameters, revealing its importance for subtle energy research. Considering their reliability, scientific investigations and clinical applications with acupoint electrodermal devices are encouraged.

Keywords: AMI – electrodermal devices – electrodermal activity – TCM – Chi – subtle energy – biofield – biofield devices – electrophysiology – bioelectromagnetism

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Der Apparat zur Meridian-Identifizierung (AMI): Ein vielversprechendes elektrodermales Gerät für die Traditionelle Chinesische Medizin und die Biofeldwissenschaft. Teil II

Zusammenfassung – Dies ist der zweite Teil einer Forschungsarbeit zur Untersuchung der Zuverlässigkeit des Apparates zur Meridian-Identifizierung (AMI), eines elektrodermalen Geräts, das die Reaktion von Akupunkturpunkten (Akupunkten) an den Finger- und Zehenspitzen misst. Im ersten Teil wurde die Literatur über die Traditionelle Chinesische Medizin (TCM) und das AMI sowie die Funktionsweise des Geräts erörtert. In diesem zweiten Teil werden frühere Zuverlässigkeitsstudien zu Akupunkt-elektrodermalen Geräten mit ihren positiven Ergebnissen diskutiert und ein eigenes Experiment zur Untersuchung der Leistung des AMI vorgestellt. Die Messvariabilität und die Funktionsweise dieses Geräts wurden untersucht, um seine Fähigkeit zu bewerten, die menschliche Bioenergetik und die Chi-Energieaktivität in den Körpermeridianen zu messen. An dem Experiment nahmen 100 gesunde Teilnehmende teil, die fünfmal unter den gleichen psychophysischen Bedingungen gemessen wurden: In der Analyse wurde festgestellt, ob das AMI informative, aussagekräftige und wiederholbare Einschätzungen des Biofelds und der feinstofflichen Energieanatomie der Teilnehmenden im Einklang mit den Prinzipien der TCM liefern kann. Die Ergebnisse zeigten, dass die AMI-Parameter genaue und wertvolle Informationen über das menschliche bioenergetische System und den psychophysischen Status liefern. Unter anderem wurde festgestellt, dass die Chi-Energie-Beziehungen zwischen den Yin- und Yang-Meridianen mit den Vorhersagen der TCM übereinstimmen und damit diese jahrtausendealte Philosophie und Praxis bestätigen. Dieser Trend spiegelt sich am besten im Akupunkt-Strom vor der Polarisation (BP) [acupoint Before-Polarization (BP) current] im Vergleich zu anderen elektrodermalen Parametern wider, was seine Bedeutung für die Erforschung der subtilen Energien verdeutlicht. In Anbetracht ihrer Zuverlässigkeit werden wissenschaftliche Untersuchungen und klinische Anwendungen mit Akupunkt-elektrodermalen Geräten empfohlen.

Schlüsselbegriffe: AMI – elektrodermale Geräte – elektrodermale Aktivität – TCM – Chi – feinstoffliche Energie – Biofeld – Biofeldgeräte – Elektrophysiologie – Bioelektromagnetismus

Introduction

The Apparatus for Meridian Identification (AMI) is a biofield device, invented by scientist Hiroshi Motoyama, that measures the skin electrical activity at special acupuncture points (acupoints) (Motoyama, 1976, 1997, 1999b; Motoyama & Nukada, 1989; Motoyama et al., 1995). Specifically, this electrodermal device analyzes the response of Sei (Jing-Well) points, to a 3-V, 512-µs rectangular-wave pulse. These 28 acupoints, corresponding to the beginning or end of Traditional Chinese Medicine (TCM) meridians, are located on the tips of fingers and toes: Historically, Sei points are believed to reflect the overall bioenergetic status and condition of the meridians they belong to, which is why they are often used in diagnostics. For measurement, small electrode patches, made of silver-silver chloride (Ag-AgCl), are placed on the Sei points and touched with the AMI electrode probe, which both stimulates the skin and detects its response; while two larger Ag-AgCl electrode patches are attached to each forearm, and connected to the AMI, as a reference.

Once the measurement is completed, the AMI returns four different parameters of the skin electrical response, having the following biophysical meaning:

- **BP (μA):** Before-Polarization current, which flows as soon as the external potential has been applied. The BP current is the initial response to the external potential and flows mainly in the dermis. According to Motoyama, BP is correlated to the flow of Chi energy in the body meridians. In this experiment, the average BP was 1806 μA (SD = 227 μA), which corresponds to a dermis electrical resistance of 1.66 kΩ (SD = 0.21 kΩ). This result is consistent with Motoyama's (2006).
- **AP (μA):** After-Polarization current, which flows after the polarization process has completed. AP is the residual current which flows mainly in the epidermis, despite the polarization process, which opposes the external potential and suppresses the current flow. Motoyama postulated that AP reflects the condition of the Autonomic Nervous System (ANS), similarly to the Galvanic Skin Response (GSR). In this experiment, the average AP was 9.90 μA (SD = 3.48 μA), which corresponds to an epidermis electrical resistance of 303 kΩ (SD = 107 kΩ). This result is consistent with Motoyama's (2006). Moreover, another author studied the acupoint after polarization current, finding 10 μA as a lower limit for this parameter, generally reached when testing calm, inactive, and relaxed people (Kido, 1997, 2000). Such threshold seems concordant with the average AP value of this study, where participants were measured, while sitting on a comfortable chair, with their legs stretched forward and under no psychophysical stress.
- **IQ (pC):** The Integrated electric charge (Q) that is transferred in the polarization process. IQ measures the charging capacity of the basal membrane, which is an insulating layer between the epidermis and the dermis, where ions accumulate and polarize, screening out the external potential. In Motoyama's model, IQ reflects the homeostasis and immune function of the organism. In this experiment, the average IQ was 1125 pC (SD = 226 pC), which corresponds to a basal-membrane electrical capacitance of 375 pF (SD = 75 pF). However, according to Motoyama, the AMI IQ parameter is 1/10th of its real value, i. e., the real value of the charge mobilized in the skin polarization process; therefore, the capacitance of the basal membrane would equal 3.75 nF (SD = 0.75 nF). This result is consistent with Motoyama's (2006).
- **TC (μs):** The Time Constant that quantifies the duration of the polarization process and thus reflects the velocity of the ion flow. TC measures the time interval when ions are

transferred and the basal membrane is charged. Motoyama theorized that TC is related to the organism's reactivity and response time. In this experiment, the average TC was 3.80 μs (SD = 0.50 μs).

A complete description of the AMI, with detailed explanations about its functioning and parameters, is reported in the first part of this work.[2] In this second part, the AMI was tested in an experiment on 100 healthy people, to evaluate the reliability of its assessments and the biophysical meaning of its parameters. Previous studies on the reliability of acupoint electrodermal devices seemed to return valuable and consistent results, confirming their usefulness (Colbert et al., 2004, 2009, 2011a; Jessel-Kenyon et al., 1998; Lin et al., 2006; Nakatani & Oiso, 2018; Shima et al., 2012; Srinivasan, 1989; Szopinski et al., 2004; Tiller, 1987; Treugut et al., 1998; Tsai et al., 2017; Turner et al., 2010; Voll, 1980). This research work is aimed at exploring further the utility and potentialities of these machines, in order to understand their use in TCM and biofield science.

Previous Reliability Studies on Acupoint Electrodermal Devices

In a previous study on the reliability of the AMI, the measurement variability of two parameters was evaluated in different ways, returning a positive outcome (Lin et al., 2006): 0.61% and 2.02% respectively for BP and AP; based on 165 sets of 27 sequential measurements on the PC Jing-Well (Sei) point of 6 subjects, made without lifting the electrode probe off the electrode patches, by using a micromanipulator.[3] According to the authors, these values represent the minimum achievable reproducibility of the Single Square Voltage Pulse (SSVP) method, under ideal conditions. Experiments were also conducted under normal conditions, where the electrode probe was placed by hand on the electrode patches and all 28 Jing-Well points of 5 subjects were tested 10 times: The measurement variability turned out to be 8.1% for BP and 15.4% for AP, which appear consistent results as well.

In another study, a group of 30 patients was tested on two consecutive days at the same hour with the AMI, which returned very repeatable and diagnostically-valuable information (Jessel-Kenyon et al., 1998). The Correlation Coefficients (CCs) between the sets of measurements were calculated for all AMI parameters, resulting to be very high (CC ~ 0.92 – 0.95).

2 The values of BP and IQ could also be expressed in mA and nC, however this author has adopted the units used by Motoyama in his work and shown in the AMI health report.

3 A micromanipulator is a laboratory device which is used to perform precision movements that would not be possible with the human hand alone. In this case, the electrode probe was kept still, at the same pressure, on the electrode patches, allowing to evaluate the reliability of the SSVP method under optimal experimental conditions.

Therefore, Jessel-Kenyon et al. (1998) concluded that "the AMI is a useful clinical tool, consistently giving results which tie up with the patient's clinical picture" (p. 42).

In the 1980s, the MED (Multielectrode Electrodermal Diagnostic) System, also known as FAME (FEMRI Acupuncture Meridian Evaluator) device, was developed with the same principle of working of Motoyama's AMI (Srinivasan, 1989). The device performance was put to test, measuring the Jing-Well (Sei) points of the same subject twice with a 30-minute time lag, and the average body values of the four parameters resulted stable.

The device also returned the following Coefficients of Variation (CVs) for each set of readings, where all acupoints were analyzed together: BP (CV = 27.2% ; 26.7%), TC (CV = 38.5% ; 28.6%), IQ (CV = 57.1% ; 51.7%), and AP (CV = 81.2% ; 75.2%). The CVs appear quite large, however in this analysis all Sei points were grouped together to evaluate the variation of their parameters throughout the whole body, probably assuming that different acupoints should return similar results. This may be partially understandable, considering that the body meridians belong to the same subtle energy system; but it should be noted that meridians are associated to different body organs and functions, thus they can have diverse bioenergetic conditions. Therefore, it seems more reasonable to calculate the measurement variability per acupoint. Using the raw data reported by the author and computing the CVs per acupoint, between the two sets of readings, it turned out that the device performed quite accurately: BP (CV = 2.49%), TC (CV = 2.70%), AP (CV = 6.30%), and IQ (CV = 7.54%).

An investigation into the reliability of another acupoint electrodermal device, called Prognos, which measures the skin resistance at Jing-Well (Sei) points, also returned consistent results (Colbert et al., 2004): 31 healthy individuals were tested 4 times in each of 3 trials, characterized by different methodologies, and high measurement correlations were found (CC ~ 0.76 – 0.96, depending on the testing procedure). It should be noted that Colbert et al. reported higher measurement repeatability when the acupoints were ink-marked, which facilitated the application of the Prognos probe on the correct skin locations.

Colbert et al.'s results are consistent with a previous study on the Prognos device, where 30 healthy volunteers were measured 4 times each, every 2–5 min (Treugut et al., 1998): The overall acupoint reliability of individual measurements was found to be 0.72; but a higher 0.91 could be achieved by averaging 4 individual measurements and assessing the condition of the person on the basis of this mean value. A reliability study on the Prognos device was conducted also by other researchers, on 21 healthy subjects, measured 5 times each (Turner et al., 2010): They found that colored marker rings around bare-skin acupoints allowed to obtain more reliable measurements, because ink-marking the acupoints may alter their skin resistance. Excluding the outlier score of one acupoint, the reliability coefficients of all others were very high, ranging 0.84 – 0.95.

The reliability of yet another acupoint electrodermal device, called AcuGraph3, which measures the skin resistance (converted by the software into conductance) at Yuan-Source and Jing-Well (Sei) points, was analyzed (Mist et al., 2011): 30 healthy volunteers were tested 3 consecutive times each. The average CV resulted to be 23.2% for the Yuan-Source points and 25.9% for the Jing-Well points, when a single operator tested the participants (the reliability coefficients ranged respectively 0.78 – 0.95 and 0.56 – 0.91). Based on these results, Mist et al. commented that the reliability of the AcuGraph3 is comparable to that of the Prognos and AMI. However, it seems that the AcuGraph3 is actually less reliable than the other devices, which may be due to an inaccurate measurement procedure: A cotton swab was cut, moistened with tap water, and inserted at the extremity of the probe, to increase conductivity and adherence to the skin; in order to improve measurement precision, Mist et al. attached circular adhesives with center cutouts to acupoints, to highlight their location, similarly to Turner et al.'s study.

In the same experiment, the performance of the Acugraph3 was tested on known resistors and non-human organic material (Mist et al., 2011). Although not specified by the authors, cotton swabs may not have been used or may have adhered differently to the tested surfaces, compared to the human skin: Interestingly, the CV resulted much smaller (0.9 – 2.8%), which suggests that the device is accurate but the measurement procedure is not. In fact, it is implausible that a 10-fold difference or more in precision is attributable exclusively to the physiological variability of living beings.

This conclusion seems to be supported also by Mist et al.'s findings (2011), using the Acugraph3 in trials with multiple novice practitioners and unmarked acupoints, where a very high level of inter-operator variability was found. This proves that the device measurement variability can be increased by inexperienced operators, who are by definition more likely to perform in an inaccurate manner, especially if the testing procedure is already faulty. B. Sharma et al. (2014a) conducted a further study, designed to assess the inter-operator variability of the AcuGraph3 at Jing-Well (Sei) points, where the more experienced operators trained the less experienced: They found that the style of use seemed to be passed from trainer to student, producing systematic variations in the data.

The operator-effect problem of electrodermal devices was raised since the 1980s by O'Regan (1989), who commented the limitations of the Voll machine: While the patient holds an electrode in one hand, the operator presses the electrode probe on acupoints of the other hand. How the operator exerts pressure with the electrode probe, whether consciously or unconsciously, can significantly alter the skin resistance of the acupoints (p. 249).

Therefore, a professional experimenter, standardized measurement procedure, and correct probe-skin interface are fundamental factors to ensure accurate and repeatable readings with electrodermal devices, whether acupoints are measured bare or with electrode patches attached, through a dry or wet electrode probe. However, attaching clean-cut electrode patches to acupoints and using a dry electrode probe for measurement may be the best solution to facilitate reliable readings: In this way, it is possible to easily identify the measurement spots, and create a uniform and homogeneous measurement surface, avoiding wet which can cause artifacts; while polarization and bias potential can be minimized by choosing proper materials, such as silver-silver chloride (Ag-AgCl). Certainly, the fact that no activity or skill is required from the testee to get tested also contributes to the reliability of electrodermal devices, and seems to be an important premise for any reliable diagnostic measurement.

Consistently, machines of this type, such as the Nakatani and Voll devices as well as others – with clear testing methods, effective probe-skin contact, and used by professionals – proved to be accurate and valuable tools in clinical practice, due to the reproducibility and correctness of their results (Colbert et al., 2011a; Nakatani & Oiso, 2018; Szopinski et al., 2004; Tsai et al., 2017; Voll, 1980).

Acupoint electrodermal devices which automatically measure the skin resistance and capacitance were also developed, allowing for continuous measurements that avoid the operator-effect problem (Colbert et al., 2009; Shima et al., 2012). Additionally, in these experiments, sophisticated hardware was used and accurately set up, environmental factors were controlled, and acupoints were carefully selected and cleaned. This allowed to stabilize the measurement system, minimize artifacts and noise, and thus obtain reliable readings with a very small measurement variability.

In the past, a continuous model of the AMI was developed and successfully used for research (Chevalier & Mori, 2007; Lin et al., 2012; Tsuchiya et al., 2010): This 28-channel device enabled quasi-continuous and sequential measurements of the Jing-Well (Sei) point response. Tiller seemed to approve this continuous model of the AMI, compared to operator-assisted electrodermal machines, noting that (Tiller, 1987, 1989 [pp. 292–293]): While in the Voll or any hand-held electrode technique, the operator can consciously or unconsciously influence the readings by changes in pressure, with the continuous AMI, the electrodes are fixed and the data gathered in an automatic mode, avoiding this bias.

In the 1980s, Tiller commented the reliability, usefulness, and potential of acupoint electrodermal devices, as well as the future of this field, in optimistic terms (Tiller, 1987): He explained that there were several electrodermal techniques in use, which were effective; understood in their workings and measurements; as well as partly supported by experimental findings and theoretical models of the connectivity between organs and corresponding acupoints. He considered electrodermal technology still in its infancy and expected that more precise devices would be developed, potentially reducing healthcare costs. He believed that electrodermal diagnosis of the human body could be much faster, cheaper, and more accurate than chemical methods (Tiller, 1989): In fact, "the body can be looked at as a complex interconnected electrical power generation, power distribution and power use system", whose energy streams reach a set of special surface points (acupoints), which thus "become information access windows to the functioning state of specific organ and body systems" (Tiller, 1989, pp. 259–260).

Previous studies on the reliability of acupoint electrodermal devices returned overall positive results. The goal of this experiment is to conduct a new reliability study on the current AMI, to assess whether and to which extent the conclusions of the previous studies are supported.

Experiment Hypotheses

For this experiment, the following hypotheses were formulated:

1. It was hypothesized that the AMI would show small measurement variability and high consistency in its assessments, at least in most of its parameters. In fact, previous studies on the same or similar technologies showed that the acupoint electrical response is a reliable physiological parameter, and that commercial electrodermal devices tend to return accurate and reproducible results (Colbert et al., 2004, 2009, 2011a; Jessel-Kenyon et al., 1998; Lin et al., 2006; Nakatani & Oiso, 2018; Shima et al., 2012; Srinivasan, 1989; Szopinski et al., 2004; Tiller, 1987; Treugut et al., 1998; Tsai et al., 2017; Turner et al., 2010; Voll, 1980).
2. It was hypothesized that the BP value of the Yin meridians would be higher than that of their Yang partners, in 5 out of 6 meridian couples, as postulated by Traditional Chinese Medicine (TCM) and experimentally found by Motoyama (1986, 1997 [pp. 45–54], 2008). For one meridian couple (PC-TE), no anticipation could be made, since Yin-Yang inversions can occur, as observed by Motoyama. It was also hypothesized that the other AMI parameters (AP, IQ, and TC) would show a less clear and significant, or even absent, Yin >Yang trend, as found by Motoyama.

Methods

Power Analysis

A power analysis was conducted to evaluate the variation of the Effect Size (ES) with the number of participants. The power analysis was performed on a standard case, using a two-tailed dependent Student's t-test, with α (type-I error rate) = 0.05, Power (1 - β, β = type-II error rate) = 0.80, and Cohen's d ES. It was concluded that a sample size of 100 healthy participants would be feasible to reach; it would allow to detect even small ESs of potential energetic differences between couples of Yin-Yang meridians; and it would return results that could be compared with those of Motoyama, whose largest Yin-Yang meridian study included a similar number of participants. Specifically, with a group of 100 participants, the minimum ES that can be detected, if there is a real energetic difference between their Yin and Yang coupled meridians, is 0.28.

Sample

The experiment thus involved 100 subjects, healthy with no diseases, and with an average age of 48 years (SD = 13 years). The sample was variegated, but on average it was populated by middle-aged Caucasian women: In fact, the Caucasian ethnicity is predominant in California, where this experiment was conducted, and middle-aged women seem more open to alternative medicine.

Experiment Procedure

The procedure of the experiment follows:

1. Participants were asked to come in with an empty stomach and bladder, so that their meridian activity would not be influenced by temporary physiological conditions. It was also recommended that, for 2-3 hours prior to the experiment, participants did not drink any beverage different from water – no coffee, tea, soda, alcohol, etc., which tend to alter the body physiology. The ambient temperature of the laboratory room was kept in a comfortable range, so that participants would feel at ease, neither cold nor hot, and thus their skin would be in a normal state.
2. Removal of rings, bracelets, and electronic devices, from the participants and investigator's body.
3. Cleaning of participants' fingertips, toe tips, and wrist areas with alcohol wipes. Packing peanuts were placed as toe separators to facilitate the measurement process on foot acupoints.
4. Fresh electrode patches were used for each participant. The AMI electrode probe was regularly cleaned.
5. 5 measurements with the AMI.
6. Participants were engaged in the experiment for about 45 minutes.

Data Analysis

- The measurement variability was evaluated through the Intra- and Inter-Subject Variability (SV), which were calculated using the Coefficient of Variation (CV): The CV is defined as the ratio between standard deviation and absolute value of the mean. The CVs for the Intra- and Inter-SV were computed using respectively each participant and all participants' data.
- The normality of data distributions was checked with D'Agostino-Pearson, Shapiro-Wilk, and Anderson-Darling's tests, using a 5% threshold to define significance, i. e., non-normality. Only if all tests resulted non-significant, the distribution was considered normal.
- An equal-variance test was performed on distribution couples, to evaluate whether they were homoscedastic or heteroscedastic, for further analyses reported below. If distributions were normal, Bartlett's test was used, if they were non-normal, Levene's test (median-based version by Brown-Forsythe) was utilized, with a 5% threshold to define significance, i. e., heteroscedasticity.
- The correlation between distribution couples was calculated with Pearson's test, if they were normal and with equal variances, otherwise Spearman's test was carried out.
- Null Hypothesis Significance Tests (NHSTs) were performed on distribution means: The dependent Student's t-test was used for normal and equal-variance distributions, otherwise Wilcoxon signed-rank (W) test was carried out. Two distributions were considered dependent if the absolute value of their Correlation Coefficient (CC) was > 0.1. In this experiment, all distribution couples resulted to be dependent and positively correlated. All tests were conducted on two tails, with a 5% threshold to define significance, i. e., rejection of the null hypothesis. Only two-tailed tests were used, which are more conservative, given the explorative nature of this research.
- The Effect Sizes (ESs) of NHSTs were computed using Hedges' g.
- For normal distributions, parametric Confidence Intervals (CIs) were calculated as Standard Error (SE) multiplied by T statistic; for non-normal distributions, non-parametric CIs were calculated through the Bias-Corrected and Accelerated (BCa) Percentile Bootstrap method, with 10^5 iterations (resamples). 95% was chosen as probability coverage for all CIs.
- A Weighted Orthogonal Distance Regression (WODR) was performed to fit the linear relationship between two distributions. Since the fit residuals resulted to be non-nor-

mally distributed, non-parametric CIs were calculated for the fit parameters, using the BCa Percentile Bootstrap method.

- Statistical analyses were conducted using distributions with independent values, without replicates, so that each entry of each data set corresponded to a tested participant. The various AMI parameters, with their multiple components and measured repeatedly on participants, were averaged.
- Python was used to analyze the data, following the most rigorous and accepted guidelines for computer programming.

Results

Measurement Variability Analysis

The Intra- and Inter-Subject Variability (SV) of the AMI parameters are reported in Table 1, while the Intra-SV analysis between Yin and Yang meridians is reported in Table 2.

AMI Parameter	Intra-SV [0.95 CI] (%)	Inter-SV (%)
BP	3.51 [3.18, 3.89]	15.3
AP	15.0 [13.9, 16.1]	65.5
IQ	4.09 [3.87, 4.43]	25.1
TC	4.02 [3.70, 4.39]	17.9

Table 1. Intra-Subject Variability (Intra-SV), with its 95% Confidence Interval (CI), and Inter-Subject Variability (Inter-SV) of the four AMI parameters, BP, AP, IQ, and TC.

BP has the smallest Intra-SV, followed by TC, IQ, and AP, which has the largest one. This result was expected since the AMI software calculates BP more accurately than the other parameters, while AP reflects the Galvanic Skin Response (GSR), which can be a very variable signal. AP was found to have a small number of outliers (0.29% of all AP values), which were not discarded because they seemed to be consistent measurements, rather than an extreme fluctuation, experimental error, or device malfunctioning. In fact, these outliers belong to the same participants' acupoints, where all AP measurements are similarly out of average.

The Inter-SV is much larger than the Intra-SV for all AMI parameters, which thus can span a large range of values and accurately assess the bioenergetic differences among the testees.

AMI Parameter	Yin vs Yang Intra-SV [0.95 CI] (%)	*P*-Value	ES [0.95 CI]	Trend
BP	3.56 [3.20, 3.97] vs 3.50 [3.17, 3.86]	$3.37\ E^{-01}$	0.031 [-0.023, 0.082]	Yin > Yang
AP	14.8 [13.7, 15.8] vs 15.1 [14.0, 16.3]	$1.15\ E^{-01}$	0.065 [-0.013, 0.14]	Yin < Yang
IQ	3.94 [3.70, 4.32] vs 4.20 [3.97, 4.53]	$1.36\ E^{-03}$	0.18 [0.039, 0.33]	Yin < Yang
TC	4.29 [3.82, 4.76] vs 3.72 [3.32, 4.16]	$2.31\ E^{-02}$	0.25 [0.022, 0.48]	Yin > Yang

Table 2. Analysis of the Intra-Subject Variability (Intra-SV), of the AMI parameters, between Yin and Yang meridians. The *p*-value, as well as the Means and Effect Size (ES) with their 95% Confidence Intervals (CIs), are reported.

The comparison of the Intra-SV between Yin and Yang meridians shows mixed results, with a trend depending on the AMI parameter. Therefore, it is not possible to conclude that one type of meridian always tends to be more variable than the other for all parameters.

Parameter Variability Body Analysis

The analysis of the Intra-Subject Variability (Intra-SV) of the AMI parameters, between left-right body sides and upper-lower body parts, is reported in Table 3.

Body Sides or Parts	AMI Parameter	Intra-SV [0.95 CI] (%)	*P*-Value	ES [0.95 CI]	Trend
Left vs Right	BP	3.62 [3.27, 4.04] vs 3.39 [2.98, 3.88]	1.02 E^{-01}	0.11 [-0.094, 0.31]	L > R
	AP	15.7 [14.6, 16.8] vs 14.2 [13.2, 15.4]	4.51 E^{-05}	0.26 [0.14, 0.38]	L > R
	IQ	4.22 [3.99, 4.57] vs 3.95 [3.72, 4.30]	8.16 E^{-04}	0.18 [0.070, 0.32]	L > R
	TC	4.36 [3.91, 4.81] vs 3.69 [3.27, 4.19]	1.21 E^{-02}	0.29 [0.025, 0.56]	L > R
Upper vs Lower	BP	3.79 [3.40, 4.21] vs 3.23 [2.90, 3.63]	9.72 E^{-06}	0.28 [0.13, 0.43]	U > L
	AP	16.8 [15.4, 18.1] vs 13.2 [12.2, 14.3]	1.92 E^{-07}	0.57 [0.36, 0.78]	U > L
	IQ	4.21 [3.95, 4.60] vs 3.96 [3.74, 4.28]	1.95 E^{-02}	0.16 [0.0057, 0.33]	U > L
	TC	4.45 [3.99, 4.92] vs 3.59 [3.18, 4.05]	7.95 E^{-03}	0.38 [0.13, 0.63]	U > L

Table 3. Analysis of the Intra-Subject Variability (Intra-SV), of the AMI parameters, between left-right body sides and upper-lower body parts. The *p*-value, as well as the Means and Effect Size (ES) with their 95% Confidence Intervals (CIs), are reported.

For all AMI parameters, the left-body Intra-SV is larger than that of the right body, while the upper-body Intra-SV is larger than that of the lower body. Such effect cannot be due to the functioning of the device, since all Sei points are measured the same way, but seems to be a natural physiological reaction of the organism. This finding is relevant because differences in electrodermal activity between body sides and parts can be used for diagnostic purposes.

Parameter Value Body Analysis

The analysis of the AMI parameter values, between left-right body sides and upper-lower body parts, is reported in Table 4.

Body Sides or Parts	AMI Parameter	Value [0.95 CI]	*P*-Value	ES [0.95 CI]	Trend
Left vs Right	BP	1801 [1754, 1844] μA vs 1811 [1762, 1853] μA	1.09 E^{-01}	0.042 [-0.038, 0.12]	L < R
	AP	10.1 [9.40, 11.3] μA vs 9.69 [9.11, 10.5] μA	9.78 E^{-01}	0.099 [-0.057, 0.31]	L > R
	IQ	1129 [1083, 1175] pC vs 1121 [1077, 1166] pC	2.69 E^{-01}	0.033 [-0.17, 0.23]	L > R
	TC	3.82 [3.72, 3.92] μs vs 3.79 [3.69, 3.89] μs	1.07 E^{-01}	0.059 [-0.14, 0.26]	L > R
Upper vs Lower	BP	1851 [1801, 1895] μA vs 1761 [1710, 1806] μA	1.21 E^{-06}	0.37 [0.21, 0.53]	U > L
	AP	9.85 [9.11, 11.1] μA vs 9.95 [9.33, 10.8] μA	7.21 E^{-02}	0.023 [-0.24, 0.23]	U < L
	IQ	1115 [1071, 1159] pC vs 1135 [1081, 1189] pC	6.66 E^{-01}	0.080 [-0.12, 0.28]	U < L
	TC	3.77 [3.66, 3.87] μs vs 3.84 [3.73, 3.95] μs	7.50 E^{-02}	0.14 [-0.061, 0.34]	U < L

Table 4. Analysis of the AMI parameter values, between left-right body sides and upper-lower body parts. The *p*-value, as well as the Means and Effect Size (ES) with their 95% Confidence Intervals (CIs), are reported.

BP seems to follow a different trend compared to the other parameters, which may reveal that subtle energy has a different and opposite distribution throughout the human body, compared to gross energy.

A follow-up study was conducted on the TC parameter value. Participants were asked about their handedness: Out of 100 testees, 97 replied and 84 declared to be purely right-handed. The analysis of the TC parameter value, between left and right body sides, for purely right-handed participants, is reported in Table 5. The L>R trend has become more significant, which may indicate that TC is related to handedness, being shorter in the dominant hand.

Body Sides	AMI Parameter	Value [0.95 CI]	*P*-Value	ES [0.95 CI]	Trend
Left vs Right	TC	3.80 [3.69, 3.91] μs vs 3.76 [3.65, 3.86] μs	3.97 E^{-02}	0.083 [-0.13, 0.30]	L > R

Table 5. Analysis of the TC parameter value, between left and right body sides, for purely right-handed participants. The *p*-value, as well as the Means and Effect Size (ES) with their 95% Confidence Intervals (CIs), are reported.

Parameter Correlation Analysis

The Correlation Coefficients (CCs) between couples of AMI parameters are reported in Table 6. The correlation between IQ and TC, which is the highest, is graphically shown and linearly fitted in Figure 1. The IQ-TC fit parameters and the results of the normality tests on the fit residual distribution are reported respectively in Tables 7 and 8.

AMI Parameter	CC [0.95 CI]
BP-AP	0.32 [0.13, 0.48]
BP-IQ	0.63 [0.48, 0.74]
BP-TC	0.24 [0.030, 0.44]
AP-IQ	0.59 [0.43, 0.71]
AP-TC	0.56 [0.40, 0.68]
IQ-TC	0.82 [0.73, 0.88]

Table 6. Correlation Coefficients (CCs), with their 95% Confidence Intervals (CIs), between couples of AMI parameters.

These findings suggest that the immune function (IQ) is significantly connected to the reactivity of the organism (TC) and Chi energy activity (BP). The Galvanic Skin Response (AP) is moderately correlated to the organism immune function (IQ) and reaction time (TC). Finally, the Chi energy activity (BP) is scarcely related to the Galvanic Skin Response (AP) and organism reaction time (TC). This conclusion seems important because it reveals that measuring the GSR at acupoints or other body locations, which is often done experimentally, provides poor information about Chi energy, despite the experimenters' wishes and interpretations.

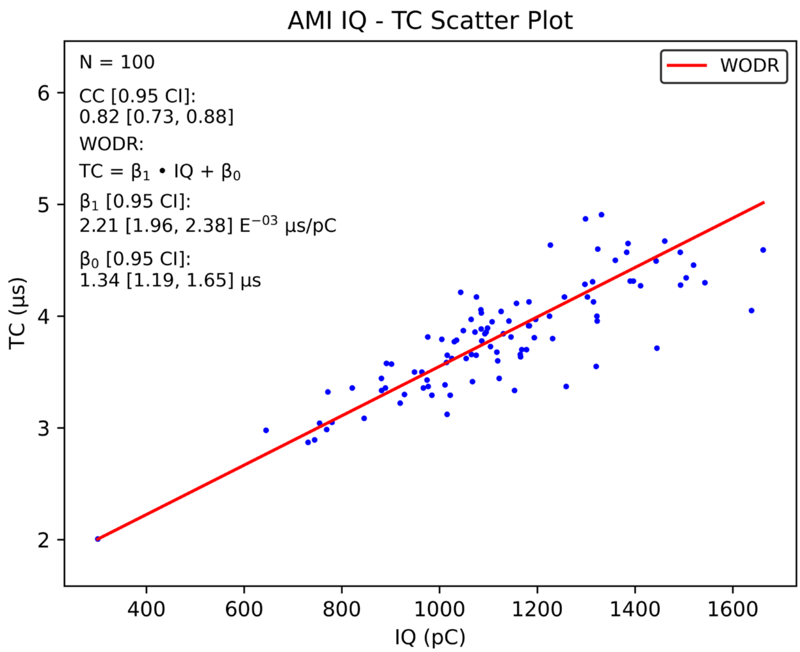

Figure 1. Analysis of the correlation between AMI parameters IQ and TC. Data were linearly fitted using a Weighted Orthogonal Distance Regression (WODR). The standard deviations (not shown) of the IQ and TC measurements were taken into account to estimate the fit parameters (β_1=slope, β_0=intercept), reported on the graph with their 95% Confidence Intervals (CIs). The Correlation Coefficient (CC), with its 95% CI, is also reported.

WODR Parameter	Value [0.95 CI]
Slope (β_1) (µs/pC)	2.21 [1.96, 2.38] E^{-03}
Intercept (β_0) (µs)	1.34 [1.19, 1.65]

Table 7. Parameters of the Weighted Orthogonal Distance Regression (WODR), with their 95% Confidence Intervals (CIs), performed on the relationship between AMI parameters IQ and TC. The slope (β_1) and intercept (β_0) of the linear fit were estimated taking into account the standard deviations of the IQ and TC measurements.

Test	*P*-Value/Statistic
D'Agostino-Pearson	2.02 E^{-02}
Shapiro-Wilk	2.12 E^{-02}
Anderson-Darling	0.82 (CrV for 5% SL: 0.76)

Table 8. Results of the D'Agostino-Pearson (D-P), Shapiro-Wilk (S-W), and Anderson-Darling (A-D) normality tests. *P*-values are reported for the D-P and S-W tests, while the statistic for the A-D one, whose critical value (CrV) for a 5% significant level (SL) is 0.76.

The relationship between IQ and TC was analyzed through a linear fit, whose parameters allow to draw some conclusions about the biophysics of the acupoint electrical response, in healthy people. The small angular coefficient (~ 10^{-03} µs/pC) indicates that a large variation in the mobilized charge corresponds to a small variation in the polarization time length; while the non-zero intercept (~ 1 µs) shows the physiological limit of the polarization time length, when the charge approaches zero. In this participant sample, the length of the polarization process varies, as a function of the mobilized charge, from a minimum of ~ 2 µs to a maximum of ~ 5 µs.

It should be noted that the fit residual distribution is close to normality but non-normal and the Correlation Coefficient (CC) is high but not equal to 1, not even within the confidence interval – a Weighted Orthogonal Distance Regression was performed, which takes into account the uncertainties of both variables, and Spearman's CC was calculated, which tests for monotonicity between the two variables. These results suggest that the IQ-TC relationship is approximately but not entirely linear, and not fully monotonic, thus it may include smaller non-linear terms, such as periodic oscillations, and it may also saturate into a plateau. This aspect should be investigated in further experiments.

Yin-Yang Meridian Analysis

The Yin-Yang meridian relationships, relative to the four AMI parameters, BP, AP, IQ, and TC, are shown in Figure 2, while the final averages are reported in Table 9.

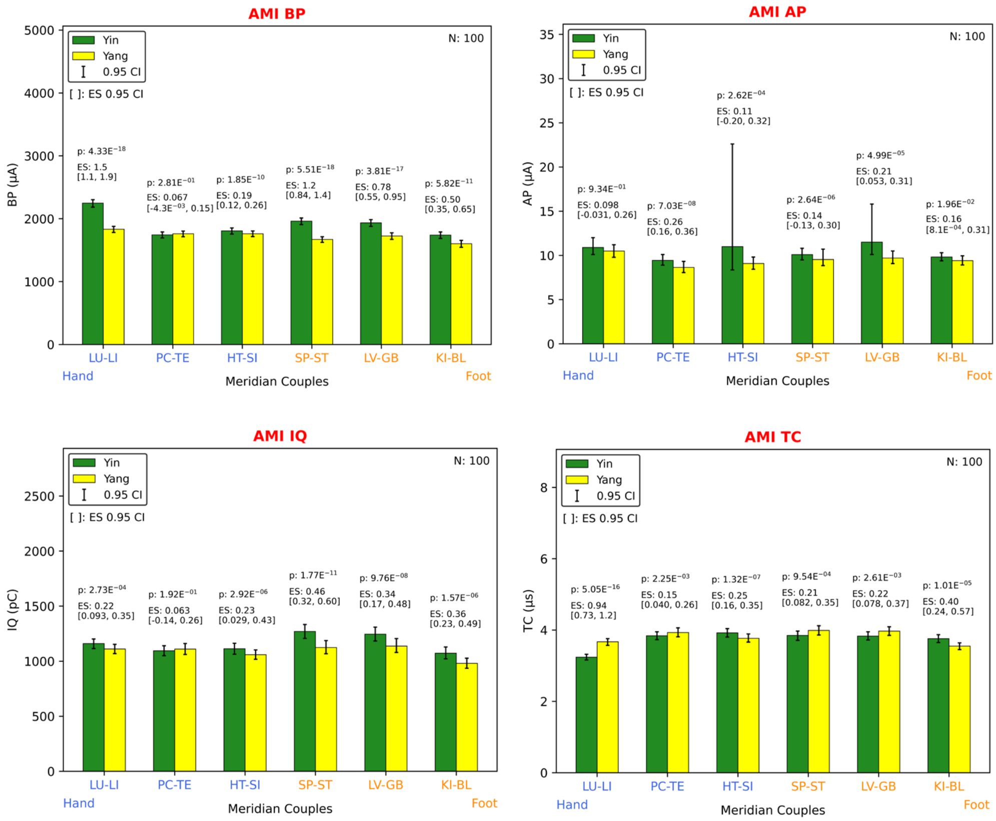

Figure 2. Means, with their 95% Confidence Intervals (CIs), of the Yin-Yang meridian couples, in the hands and feet, relative to the four AMI parameters, BP (upper left), AP (upper right), IQ (lower left), and TC (lower right). The *p*-value (p) and Effect Size (ES), with its 95% CI, are reported for each meridian couple. The large CIs of some AP means are due to outliers.

Among all AMI parameters, the acupoint before-polarization current (BP) appears to reflect best the Chi energy relationship between couples of Yin-Yang meridians, as shown by their *p*-values and effect sizes: The Yin meridians tend to have higher energetic activity compared to their Yang partners, as predicted by Traditional Chinese Medicine (TCM). This finding is of great importance for subtle energy research, thus the interconnection between BP and Chi energy should be further explored and validated.

AMI Parameter	Yin vs Yang [0.95 CI]	Relative Difference (%)	*P*-Value Exponent [0.95 CI]	ES [0.95 CI]	Yin > Yang Meridian Couples
BP	1906 [1704, 2108] μA vs 1726 [1642, 1809] μA	9.47	-12.5 [-19.5, -5.52]	0.70 [0.11, 1.3]	5/6
AP	10.4 [9.63, 11.3] μA vs 9.47 [8.83, 10.1] μA	9.30	-4.33 [-7.04, -1.62]	0.16 [0.098, 0.23]	6/6
IQ	1159 [1073, 1245] pC vs 1087 [1026, 1149] pC	6.22	-6.00 [-9.57, -2.43]	0.28 [0.13, 0.42]	5/6
TC	3.74 [3.44, 3.86] μs vs 3.81 [3.62, 4.00] μs	-1.93	-6.33 [-12.5, -4.00]	0.36 [0.22, 0.71]	2/6

Table 9. Averages of the Yin-Yang meridian relationships for each AMI parameter, BP, AP, IQ, and TC. The average Means, *p*-value Exponent, and Effect Size (ES) are reported, with their 95% Confidence Intervals (CIs); as well as the Relative Difference between the Means, and the number of meridian couples where Yin > Yang. The relative difference between the Means of Yin and Yang meridians was calculated as (Yin-Yang)/Yin.

Meridian Correlation Analysis

The average Correlation Coefficients (CCs), of the four AMI parameters, among all meridians, hand meridians, foot meridians, and between hand-foot meridians, are reported in Table 10.

AMI Parameter	All Meridians CC [0.95 CI]	Hand Meridians CC [0.95 CI]	Foot Meridians CC [0.95 CI]	Hand-Foot Meridians CC [0.95 CI]
BP	0.70 [0.67, 0.73]	0.89 [0.87, 0.90]	0.82 [0.78, 0.86]	0.57 [0.55, 0.59]
AP	0.75 [0.73, 0.78]	0.86 [0.84, 0.88]	0.83 [0.80, 0.85]	0.68 [0.66, 0.70]
IQ	0.68 [0.65, 0.71]	0.86 [0.84, 0.87]	0.78 [0.74, 0.82]	0.57 [0.55, 0.59]
TC	0.65 [0.62, 0.67]	0.82 [0.80, 0.84]	0.74 [0.70, 0.77]	0.53 [0.51, 0.55]

Table 10. Average Correlation Coefficients (CCs), with their 95% Confidence Intervals (CIs), among all meridians, hand meridians, foot meridians, and between hand-foot meridians, relative to the four AMI parameters, BP, AP, IQ, and TC.

For all AMI parameters, two separate groups appear, composed of hand and foot meridians, which are highly correlated among themselves and moderately correlated to those in the other group. This demonstrates the consistency of the AMI measurements and its assessments of the human subtle energy system, which is interconnected. Moreover, AP shows the highest degree of correlation between hand and foot meridians, compared to the other AMI parameters. This supports the hypothesis that AP is related to the GSR, which is a non-local reaction involving the whole body.

Discussion

Measurement Variability Analysis

The measurement variability analysis shows that the BP parameter has the smallest Intra-Subject Variability (Intra-SV) (CV = 3.51%), followed by TC (CV = 4.02%), IQ (CV = 4.09%), and AP (CV = 15%), which has the largest one: These results seem consistent with the functioning of the device, as well as with the biophysics of its parameters, according to Motoyama's theory.

In fact, BP is calculated more accurately by the AMI, compared to the other parameters, being potentially correlated to Chi energy activity; while AP is a type of Galvanic Skin Response (GSR), and thus a measure of the variations in the skin conductance, caused by sweat-gland perspiration processes, which are regulated by the Autonomic Nervous System (ANS) (M. Sharma et al., 2016). Therefore, the GSR can change rapidly and considerably, depending on the momentary psychophysical condition of the testee, whose skin electrical properties are continuously fluctuating: It has been observed that the skin conductance can be very variable, not only at acupoints but also at any other skin point, both in sick and healthy people, reflecting the current mind-body status of the testee (Zhang, 2003). This may be evidence that Motoyama's theory is correct, and also an indication that the AP parameter should be dealt with cautiously, both in research and practice, due to its relatively large variability.

Taking into account those AMI parameters with Intra-SV < 10%, i. e., BP, IQ, and TC, the average Intra-SV turns out to be 3.87%, while the average Inter-Subject Variability (Inter-SV) 19.4%, which is 5.02 times larger (here and throughout the discussion, raw unrounded numbers were used for calculations). This result suggests that the AMI parameters can span a large range of values, depending on the testees and their psychophysical condition (large Inter-SV); but return similar values when the same subject is measured repeatedly (small Intra-SV), which demonstrates that the device is sensitive and reliable. It should be noted that all participants were healthy and tested in the same psychophysical condition, otherwise their Inter-SV would have been even larger. The Inter-SVs, calculated in this study, seem in agreement with those found by Motoyama (1997, pp. 26–29), although not in their absolute values: Using a previous model of the device and a smaller sample size, he concluded that IQ and AP have the largest Inter-SVs, while TC and BP have the smallest ones.

In this investigation, the Coefficient of Variation (CV) was chosen over other methods to evaluate the AMI measurement variability, for its simplicity and versatility (Abdi, 2010; Brown, 1998; Li et al., 2019). Calculated as standard deviation over absolute value of the mean, it is intuitively understandable and dimensionless, allowing for an effective comparison among parameters with diverse units and widely different means. Besides, the CV method is recommended for positive and non-null parameters, that do not range through or close to zero. These prerequisites are consistent with the characteristics of the AMI.

The measurement variability analysis between Yin and Yang meridians returned mixed results: The difference in variability seems to change in direction and extent, depending on the AMI parameter that is analyzed and thus on the acupoint biophysical characteristic that is considered. Two previous studies, with another electrodermal device that measures the skin resistance, or GSR, found opposite results, i. e., Yin acupoints are significantly less variable than Yang ones and vice versa (Colbert et al., 2004; Treugut et al., 1998). These previous and contrasting results could be compatible with the current study, where the acupoint GSR, represented by the AMI AP parameter, showed a non-significant difference between Yin and Yang acupoints. Therefore, a significant variability in one or the other meridian type may occur with specific participant samples, which in these cited experiments were actually small, leading to uncertain results. This point will be elaborated further on in the discussion. Besides, the variability of Yin and Yang meridians may be only partially understood by analyzing exclusively the acupoint GSR, because other parameters with different biophysical meaning show different trends. Therefore, additional studies on this front are suggested, on variegated participant samples and acupoint parameters.

Parameter Variability Body Analysis

The analysis of the AMI parameter variability, across the body, shows that the left-body Intra-SV of all AMI parameters is larger than that of the right body (p-value ~ 10^{-01} – 10^{-05}, ES ~ 0.21). Interestingly, the left body side is governed by the right brain hemisphere, which is the creative, intuitive, flexible, emotional, and holistic one, and thus may respond more variably to external stimuli (Đorđević et al., 2013; Gazzaniga, 1967, 1998; Scola, 1984). Conversely, the right body side is controlled by the left brain hemisphere, which is the practical, analytical, logical, repetitive, and sequential one, and thus may be characterized by more stable responses. These findings suggest that the left-right brain split may be manifested in the variability of the acupoint electrical response and thus in the body bioenergetics: This would include, but would not be limited to, the nervous system, considering that only the AP parameter is directly related to it, in Motoyama's theory. Other pathways of communication may connect the brain halves with the body sides, since also parameters that are not regulated by the nervous system appear to be influenced by the left-right brain split; for example BP, which is reflective of the connective tissue fluids.

In the two previously mentioned studies, performed with an electrodermal device on ~ 30 healthy participants, the analysis of the Intra-SV between left- and right-body acupoints returned different results (Colbert et al., 2004; Treugut et al., 1998): Colbert et al. found larger measurement variability on the right-body acupoints, compared to the left-body ones, while Treugut et al. found no difference between the two. Colbert et al. (2004) thus concluded: "These differences between the two studies with similarly low sample sizes should be considered inconclusive and need to be further explored with substantially larger samples" (p. 615). An additional experiment with the same device, on 21 healthy participants, confirmed Colbert et al.'s findings, which are opposite to those here presented (Turner et al., 2010). However, in the current investigation, the sample size was 3–5 times larger than that of these previous studies and four different parameters of the skin electrical response were analyzed, not only the GSR: Results consistently show a larger variability of the left-body acupoints, compared to the right-body ones. Nevertheless, additional research on this topic is encouraged, because left-right and upper-lower body differences in electrodermal activity can have an important diagnostic value.

In this experiment, it was also found that the upper-body Intra-SV of all AMI parameters is larger than that of the lower body (p-value ~ 10^{-02} – 10^{-07}, ES ~ 0.35): A possible explanation for this finding is that all foot acupoints belong to meridians of the digestive and urinary systems, while most of the hand acupoints belong to meridians of the respiratory and cardiovascular systems. Since participants came in with an empty stomach and bladder, the digestive and urinary meridians responded more stably to the AMI electrical stimuli, being physiologically at rest; compared to the respiratory and cardiovascular meridians, which are instead always at work and thus responded more variably. Besides, the hand meridians include the Triple Heater (TE), which regulates the energy distribution of the whole body and it is therefore reflective of any change occurring throughout the organism. Although, in this study, the TE meridian was not found to be specifically more variable than other hand meridians, a large and unexplained variability of the right-TE GSR was found by others and could not be improved with repeated measurements (Turner et al., 2010).

It should be noted that variability does not equal intensity, which is why the upper body was found to be bioenergetically more variable than the lower one, but overall less intense. In Traditional Chinese Medicine (TCM), the activity of the body meridians, and thus the intensity of their Chi energy flow, is not only related to the status of their corresponding organs, i. e., whether they are healthy, sick, or physiologically at work; but it is also influenced by the Earth's biorhythms, such as the hour of the day and season of the year. Therefore, since these experiments were conducted at different hours of the day and over a few months, only the factors that were common to all participants, throughout the trials, were taken into account to analyze and compare their meridian bioenergetics.

Parameter Value Body Analysis

The analysis of the AMI parameter values, across the body, highlights that BP follows a different trend compared to the other parameters (p-value ~ 10^{-01} – 10^{-06}, ES ~ 0.11). After testing several thousand people, Motoyama (1997) had found this pattern in the BP and AP parameters, concluding that "the autonomic nervous system [AP] and meridian system [BP] can be thought of as maintaining the organisms' health through a dynamic antagonistic functional balance" (pp. 147–148). The current findings confirm Motoyama's observation and may push it further: It is possible that all AMI parameters, related to physical functions (AP, IQ, and TC), tend to follow the same and opposite trend compared to the parameter reflecting a metaphysical function (BP). This may be the correct and salubrious energetic balance of the body, considering that all tested subjects were healthy and disease free.

Moreover, according to the *Neijing*, which is the fundamental treatise of TCM, dating back thousands of years: "In the elderly, the qi flows upward because of the deficiency in the lower body. In the youthful, the qi flows downward because of the abundance in the lower body" (Ni, 1995, p. 299). This observation should be complemented with the notion that, at the time of the *Neijing*: "people age prematurely, living only fifty years" (Ni, 1995, p. 1). In this experiment, all participants were healthy, with an average age of 48 years, which by today's standards can be considered a group of middle-aged people with no clinical sign of body deterioration. However, it is reasonable to assume that today's healthy middle-aged people may show a bioenergetic pattern and tendency, where the lower body part, although not necessarily deficient, has less Chi energy than the upper part, as noticed by the ancient Chinese in their elderlies.

Therefore, traditional Chinese knowledge seems to be supported by these findings, where the BP parameter, which is supposedly correlated to Chi (qi) energy, resulted on average less intense in the lower body compared to the upper one, in this group of participants (p-value = $1.21 \cdot 10^{-06}$, ES = 0.37). Simultaneously, this result may provide evidence that BP is indeed correlated to Chi energy, because it is the only parameter to show the trend expected for Chi by TCM.

TC Parameter Analysis

The AMI TC parameter was investigated to understand whether it is related to the organism reaction time, as suggested by Motoyama. In the literature, studies report that physiological reaction times – visual, auditory, and motor – tend to be shorter on the right body side compared to the left one, in right-handed individuals, while the opposite is true for left-handed individuals (Badwe et al., 2012; Chan & Ng, 2012; Chouamo et al., 2021; Efron, 1963; Jha et al., 2020, 2021; Kalyanshetti & Vastrad, 2013; Mali et al., 2012; Misra et al., 1985; P.I. Singh et al., 1977; Peters & Durding, 1979; Rahman & Islam, 2021; Rayan & Narhare, 2017; Shen & Franz, 2005). This seems due to the cerebral hemisphere specialization and dominance, which is opposite in right- and left-handed individuals, and which determines faster pathways for information transmission, and thus faster response velocities, on the dominant body side. In this study, which included mostly right-handed people, this trend was found, since the TC parameter resulted smaller on the right body side compared to the left one (p-value = $1.07 \cdot 10^{-01}$, ES = 0.059). Moreover, by performing this analysis on purely right-handed participants, the time difference reached statistical significance, with a decrease in p-value, and showed a slight increase in effect size (p-value = $3.97 \cdot 10^{-02}$, ES = 0.083).

In one of the studies (Misra et al., 1985), it was also found that reaction times tend to be shorter in hands than in feet, probably due to shorter information pathways between hands and brain, compared to the feet. In this research, the difference between the TC parameter value in the upper and lower body, of all participants, is characterized by this trend: smaller in the upper body part compared to the lower one, with a p-value which is very close to the threshold of statistical significance (p-value = $7.50 \cdot 10^{-02}$, ES = 0.14). Therefore, these results may be evidence that the time constant of the acupoint polarization process is related to the organism response time, which is in agreement with Motoyama's theory.

IQ Parameter Analysis

The AMI IQ parameter was investigated to understand whether it is related to the organism immune function, as suggested by Motoyama. The investigation was based on the premise that biochemistry and bioenergetics are interrelated and integrated within the human body. Biochemical studies that analyzed the distribution of the immune system cells, in healthy individuals, concluded that such distribution is continuous in nature, without gaps, clusters, or outliers; and that it has a large spread, which is influenced by age, gender, viral infections, environmental and genetic factors (Kaczorowski et al., 2017; Liefferinckx et al., 2021). Basically, it was found that, across the healthy human population, the immune system varies considerably but continuously, showing a large Inter-SV but no discrete groups.

In this study, excluding AP which has outliers, the IQ parameter has the largest Inter-SV and is also continuously distributed across this participant group, which included only healthy subjects. In fact, while AP, which has the largest Inter-SV among all AMI parameters, is a non-normal and non-continuous distribution, characterized by outliers, IQ is normally distributed, and thus continuous, without gaps, clusters, or outliers (D'Agostino-Pearson's p-value = $1.07 \cdot 10^{-01}$; Shapiro-Wilk's p-value = $1.88 \cdot 10^{-01}$; Anderson-Darling's statistic = 0.45, critical value = 0.76). As visible in Figure 1, the IQ distribution shows a data point which is detached from the others, however that point should not be considered an outlier. In fact, the IQ distribution passed all normality tests, therefore that data point does not lie outside but on the tail of the IQ Gaussian distribution. Motoyama as well (1997, pp. 26–29) had found that the AP distribution is multi-phasic, with multiple peaks and data clusters, unlike the distributions of the other AMI parameters, which are mono-phasic. Therefore, this may be evidence that the integrated charge of the acupoint polarization process is reflective of the organism immune function, as postulated by Motoyama.

Parameter Correlation Analysis

The analysis of the AMI parameter correlation shows that IQ and TC are highly correlated (CC = 0.82), which is consistent and expected, given their biophysical meaning. In fact, IQ represents the integrated charge, i. e., the total number of ions involved in the polarization process, while TC is the time constant, i. e., the time length of the charge transfer. Therefore, it is logical that these two parameters are highly correlated, because the more charge is mobilized, the more time it takes to move it. This finding was theoretically predicted by Motoyama's skin model, where the time constant of the polarization process (TC) is proportional to the charging capacity of the basal membrane (C), which is itself proportional to the integrated charge moved during the polarization process (IQ). Mathematically, $TC = C \cdot R$, where R is the skin resistance, and $C = {}^{IQ}\!/_{V}$, where V is the applied voltage (external potential).

BP and IQ show a medium-high degree of correlation (CC = 0.63); this indicates that a significant fraction of the total charge (IQ), involved in the acupoint electrical response, is moved through the pre-polarization current (BP), which is the immediate reaction of the skin to the external potential. This seems reasonable, considering that BP is a high peak of current, not yet attenuated by the screening effect of the polarization potential, which exponentially reduces the acupoint response current and thus the amount of charge in transit. Besides, the BP-IQ correlation may explain why IQ is the AMI parameter, where the Yin>Yang meridian relationship is best reflected after BP, suggesting that also IQ may provide some information about Chi energy. The Yin-Yang meridian analysis will be discussed further on.

AP appears moderately correlated to IQ and TC (CC = 0.59, CC = 0.56), which can be interpreted as follows: The more charge (IQ) is moved during the polarization process, the longer the time length (TC) of the process and the larger becomes the residual after-polarization current (AP); which is why these three parameters show a certain degree of correlation among themselves.

Finally, BP-TC and BP-AP are poorly correlated (CC = 0.24, CC = 0.32), which suggests that the pre-polarization current (BP) does not influence much the time length (TC) of the polarization process nor the after-polarization current (AP). This can be explained by noting that

BP precedes the polarization process, lasting less than 1 μs after the external potential has been applied; and that it differs from AP, because the former flows mostly in the dermis and is related to the connective tissue fluids, while the latter flows mostly in the epidermis and is related to the nervous system activity. Besides, BP and TC, which show the lowest degree of correlation, are also those AMI parameters whose Yin-Yang meridian relationships are more opposite, which seems consistent with their lack of correlation. It is important to emphasize that the GSR (AP), measured by most acupoint electrodermal devices, appears poorly correlated to Chi energy (BP), despite common claims.

These overall results are mostly in agreement with Motoyama's (1997, pp. 23–25), where a high correlation appeared between IQ-TC, followed by AP-IQ and AP-TC, while no significant correlation was identified between BP-TC and BP-AP, as found in this research. However, no significant correlation was reported by Motoyama between BP-IQ, unlike current data show. It should be noted though that Motoyama's analysis was carried out using an old model of the AMI, testing 10 people once; while, in the current study, a newer and more accurate model of the AMI was used on 100 people, who were tested 5 times each. The correlation between BP-IQ could also be deduced theoretically from the equivalent circuit of the Sei-point electrodermal response, which however was developed by Motoyama et al. (1995) after his parameter correlation study.

The IQ-TC relationship was further investigated through a linear fit, which returned a small angular coefficient: The conclusion that the polarization time length is very small, regardless of the amount of mobilized charge, was drawn also by Motoyama (1997, pp. 28–29), by analyzing the Inter-SVs of TC and IQ. From this, he deduced that the variety of ions, involved in the polarization process, must be limited; otherwise, a larger variation in the polarization time length would result, as the amount of transferred charge varies across individuals.

Yin-Yang Meridian Analysis

The analysis of the Yin-Yang meridians confirms Motoyama's theory and results (1986, 1997 [pp. 45–54], 2008). In fact, the AMI BP parameter, which corresponds to the acupoint before-polarization current, seems to reflect best the Chi energy relationship between couples of Yin-Yang meridians. The BP current of the Yin meridians appears significantly higher than that of their Yang partners, in terms of *p*-value and Effect Size (*p*-value exp. ~ -12.5, ES ~ 0.70), followed by IQ (*p*-value exp. ~ -6.00, ES ~ 0.28) and AP (*p*-value exp. ~ -4.33, ES ~ 0.16), while TC tends to follow the opposite trend (*p*-value exp. ~ -6.33, ES ~ 0.36); results that are in agreement with Motoyama's. Consistently, the degree of similarity between the

Yin-Yang meridian relationships of BP and those of the other AMI parameters is in accordance with the degree of correlation between BP and the other parameters.

One meridian couple, Pericardium-Triple Heater (PC-TE), is in an unclear relationship, since the Yang-meridian's BP current is higher than the Yin's, although their difference is not statistically significant (p-value = $2.81 \cdot 10^{-01}$, ES = 0.067). However, as observed by Motoyama, these meridians frequently go through Yin-Yang inversions, generally during seasonal change and adaptation periods of the human subtle energy system. In fact, they are reflective of the condition of the whole body, with the TE meridian being traditionally related to the organism bioenergetics and affected by psychophysical stress. Therefore, they can get imbalanced when mind and body are under pressure. Motoyama noticed that the PC-TE inversion is quite common in today's society: Modern life stress causes this meridian couple to invert its healthy Yin-Yang relationship, even in people with no clinical pathologies and regardless of the season, which is why these meridians should be monitored often and rebalanced if needed.

Furthermore, Motoyama reported that the Heart-Small Intestine (HT-SI) and Kidney-Bladder (KI-BL) meridian couples showed a weaker BP Yin>Yang relationship, which is consistent with the results of this study. Conversely, he found that the Lung-Large Intestine (LU-LI), Spleen-Stomach (SP-ST), and Liver-Gall Bladder (LV-GB) meridian couples showed a stronger BP Yin>Yang relationship, which is also in agreement with this study.

Therefore, these findings seem to corroborate Motoyama's theory and results that BP is the AMI parameter more related to and expressive of Chi energy. How this correlation may occur is still a mystery, which lies within the larger mystery of how subtle energy interacts with and influences the physical world. Even though Chi energy is metaphysical, it may undergo a transduction into an electrical energy or potential, becoming physical; or it may impose an informational pattern on an electrical energy or potential, determining their behavior, without turning into them. In either case, Chi energy seems to influence the physico-chemical condition of the dermal connective tissues, affecting their electric current. The conclusion that can be drawn from this study, as well as Motoyama's, is that the acupoint before-polarization current may be the physiological parameter where metaphysics becomes physics, which opens novel frontiers for subtle energy research. The philosophical and medical background of the Yin-Yang principle, in Asian culture, will be covered in another publication.

In a study with a different electrodermal device, which detects the skin conductance at acupoints, some authors investigated the energetic differences among meridians in 43 healthy individuals, comparing genders, left-right body sides, Yin-Yang partners, and times of measurement (Lee et al., 2018): They identified their assessments with the function of meridians and the status of Chi energy, drawing a series of variegated conclusions. However, it should be noted that, in Motoyama's theory, the skin conductance or GSR is related to the epidermal activity and corresponds to the AMI AP parameter, which does not reflect well the meridian function and Chi energy; which is instead highly related to the dermal activity and corresponds to the AMI BP parameter, a conclusion that was validated also in this research. Besides, the tested acupoints were not the Sei points, but the Yuan-Source ones, located on wrists and ankles: While they are effective in therapy, they may not be as accurate in diagnostics, because they intersect with different meridians. In yet another study, the skin conductance, at the Yuan-Source points of 8637 acupuncture patients of different age and gender, resulted higher in all the Yin meridians compared to their Yang partners (Chamberlin et al., 2011): This is consistent with the AP results of the current study, but it should be noted again that this electrodermal parameter is not the most suitable to assess the function of meridians, because it is poorly correlated to the activity of Chi energy.

Meridian Correlation Analysis

The analysis of the meridian correlation is a new study, which was not conducted by Motoyama. Two separate groups appear, composed of hand and foot meridians, highly correlated among themselves (CC ~ 0.74 – 0.89) and moderately correlated to those in the other group (CC ~ 0.53 – 0.68), for all AMI parameters. This indicates that the AMI acupoint measurement does not return random results, but provides an assessment which is consistent throughout the body, since all acupoints belong to the same bioenergetic system. Additionally, it stands out that the AP parameter presents the highest degree of correlation between hand and foot meridians, compared to the other AMI parameters (~ + 20-30%). This finding may provide further validation that the acupoint after-polarization current can be identified as the GSR: a non-local current spreading fast throughout the body, which is concordant with a higher uniformity and homogeneity of this parameter between distant body parts. The significant correlation degree (medium to high) of the skin conductance or GSR, between hands and feet, was found also by other researchers (Hossain et al., 2022; Kappeler-Setz et al., 2013; Kasos et al., 2020; Kushki et al., 2011; Ranogajec & Geršak, 2014; Sanchez-Comas et al., 2021; van Dooren et al., 2012).

Limitations

All participants' information, such as age, health status, physiological condition, and handedness, was self-declared. For data analysis, frequentist statistics was used: Null Hypothesis Significance Testing (NHST) on means was performed with the customary thresholds for type-I and type-II errors ($\alpha = 0.05$, $\beta = 0.20$).

Conclusion

In this research work, the Apparatus for Meridian Identification (AMI) was put to test. A thorough investigation into the reliability of the AMI was conducted and compared with previous studies, to evaluate the strengths and limitations of this technology, and allow for a correct interpretation of the experiment results. The AMI resulted to be effective at detecting the Sei-point electrical response and inferring the properties of subtle energy Chi: The assessments returned by this device seem reliable and in accordance with Traditional Chinese Medicine (TCM) principles. The overall findings of this research indicate that the applications of the AMI to assess human bioenergetics should be further explored. Among the results, the Chi energy relationships between couples of Yin-Yang meridians appear consistent with TCM predictions: Specifically, the acupoint Before-Polarization (BP) current seems to reflect best the higher energetic activity of the Yin meridians over their Yang partners. This suggests that the BP parameter may be intimately connected to Chi energy activity, and thus its behavior within the human body should be further studied.

The AMI is part of the acupoint electrodermal devices, which appear to be accurate in their measurements, correct in their assessments, and clear in their workings, as well as supported by theoretical models of the skin electric circuitry (Colbert et al., 2004, 2009, 2011a; Jessel-Kenyon et al., 1998; Lin et al., 2006; Nakatani & Oiso, 2018; Shima et al., 2012; Srinivasan, 1989; Szopinski et al., 2004; Tiller, 1987; Treugut et al., 1998; Tsai et al., 2017; Turner et al., 2010; Voll, 1980). These devices are often used in clinical settings to diagnose diseases, monitor and assess medical treatments, and also define patients' prescriptions (Lam et al., 1988; Oliveira, 2016; Tsuei, 1995, 1998; Voll, 1980). For example, these machines can be helpful to test in advance the effectiveness of medicines, herbs, supplements, and homeopathics, by measuring the bioelectrical impedance of acupoints, when these substances are placed in the same electric circuit with the patient.

Investigations of human electrodermal activity and its correlation to psycho-physiology should continue, opening new possibilities for correct diagnoses and effective treatments. Methodological recommendations have been developed to facilitate accurate, reproducible, and standardized electrodermal measurements, with consistent interpretations and reports (Boucsein et al., 2012; Colbert et al., 2011b; Fowles et al., 1981; Geršak, 2020): Suggestions range from recording instruments and techniques, to electrode material, paste, placement, and contact area, to experiment design and data analysis.

Considering their reliability, usefulness, safety, non-invasiveness, and relative inexpensiveness, acupoint electrodermal devices should be integrated more consistently into our healthcare system. Further research with the AMI is encouraged, to explore its full potential for TCM and biofield science.

Future Prospects

Among the many acupoint electrodermal devices, the AMI is unique in its functioning: In fact, out of the skin response signal, it extracts and analyzes multiple parameters, which have different biophysical meanings, and make this machine sophisticated and versatile. Based on the reliability and potentialities of the AMI, the following research directions are suggested, in order to continue the validation of Motoyama's theory and device, as well as Traditional Chinese Medicine and biofield science at large.

The BP parameter may be reflective of subtle energy activity, which could allow to explore the metaphysical aspect of the human body, beyond the physical one. The Yin-Yang Chi-energy relationship between coupled meridians seems to corroborate this hypothesis, however further evidence should be gathered, in order to support such claim. The behavior of BP could be systematically analyzed in groups of testees, who perform or receive subtle energy modalities that are traditionally known to stimulate, increase, and rebalance the flow of Chi energy in the body. Moreover, the capacity of the AMI to correctly assess health and disease should be further investigated, in order to prove its clinical utility. The relationship between IQ and the immune system could be better established, by monitoring the behavior of this parameter in clinical patients, during and after various diseases, and comparing the results with conventional biochemical analyses. Although some studies have already been conducted to understand the nature of BP and IQ, which seem the most interesting and unique AMI parameters, more research is needed to fully evaluate their accuracy and usefulness.

Also the AP and TC parameters should be further investigated to assess their diagnostic value. AP seems to be a measure of the Galvanic Skin Response (GSR), or skin conductance, and thus may be correlated to the Autonomic Nervous System (ANS) activity. Therefore, it could be analyzed in groups of people, before and after they practice yoga, meditation, breathing, mental, and visualization techniques, which have been shown to alter the ANS and GSR (B. Sharma et al., 2014b; Blain et al., 2008; Corby et al., 1978; Dangi, 2013; Das & Anand, 2012; De & Mondal, 2020; Fujisaki, 2019; Kumar & Joshi, 2009; Latha et al., 2019; Nagilla et al., 2013; P. Singh et al., 2020; Raghuraj & Telles, 2008; Suresh et al., 2018; Tang et al., 2009; Telles et al., 1994; Toussaint et al., 2021; Turankar et al., 2013; Y. Singh et al., 2012).

TC instead may be related to the organism reaction time, which varies with age, gender, athletic skills, physical activity levels, body mass index, and pathological conditions, and can be shortened through yoga, meditation, breathing techniques, and physical training (A. Jain et al., 2015; Bhavanani et al., 2017; Chandak & Makwana, 2012; Fozard et al., 1994; Gupta et al., 2019; Jadhav et al., 2016; Jore et al., 2013; Karia et al., 2012; Kumbhar et al., 2020; Lohot et al., 2017; Malathi & Parulkar, 1989; Muhil et al., 2014; Nene et al., 2011; Nikam & Gadkari, 2012; P. Jain et al., 2014; Pandian et al., 2019; Patil & Phatale, 2015; Pophali et al., 2018; Ramanathan & Bhavanani, 2020; Rupali & Aruna, 2020; Şenol et al., 2020; Sivagami & Bhutkar, 2018). Therefore, it could be monitored in athletes, patients, and laypeople, correlating their physical status and performance with their reaction time, as well as checking for improvements after they perform spiritual or sport activities.

Finally, electrodermal devices, whose measuring electrodes are fixed to the testee's acupoints (continuous), tend to be more reliable than those whose measuring probes are subsequently applied by the experimenter on acupoints (discrete) – bare or with electrode patches attached. However, in cases where the condition of the testee is assessed before and after a certain intervention or performance, the measurement is interrupted, and the electrodes may have to be removed and replaced. This could increase the chances of committing errors, whether or not the measurement process is continuous. Even though the continuous devices may be more accurate in all cases, because data taking is automatic, the measurement time may be longer, unless also the discrete devices are used to take multiple sets of measurements. For all these reasons, it is advisable to use both types of devices, depending on the experiment goal and design, as well as its time limit and financial budget. The continuous version of the AMI has not been used for years, thus it is recommended that such device is retrieved, utilized, and put to test.

Ethics

The investigator confirms that he conducted this research rigorously, using the AMI as indicated by the inventor. This study was approved by the BioMed IRB (Biomedical Research Institute of America): a non-profit and independent Institutional Review Board, committed to protecting human research subjects and maintaining the highest ethical standards. All participants received and signed an informed consent. The investigator self-funded this experiment. The experiment participants were not financially compensated, but received as a gift the health report returned by the AMI.

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