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

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Abstract – This is the first 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. The AMI was invented by Hiroshi Motoyama, a Japanese scientist who dedicated his life to studying the bioenergetics of Traditional Chinese Medicine (TCM) meridians. In this first part, the literature reviews on TCM and the AMI, as well as the functioning of the device, are reported. Specifically, medical and biophysical studies supporting the meridian theory are discussed, as well as biofield experiments performed with the AMI. The working of the AMI is explored, explaining in detail its parameters and their relation to the skin electrical activity. In the second part, previous reliability studies on acupoint electrodermal devices will be reviewed, supporting their use in biofield science, and comparing their characteristics and performance with those of the AMI. An original experiment will also be presented: The AMI was used on 100 healthy participants, to evaluate whether it could provide meaningful assessments of their biofield and subtle energy anatomy, in accordance with TCM principles. Results were positive, confirming the usefulness and reliability of the AMI for biofield science.

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 Biofeldwissenschaft. Teil I

Zusammenfassung – Dies ist der erste Teil einer Forschungsarbeit zur Untersuchung der Zuverlässigkeit des Apparatus for Meridian Identification [Apparates zur Meridian-Identifizierung](AMI), eines elektrodermalen Geräts, das die Reaktion von Akupunkturpunkten (Akupunkten) an den Finger- und Zehenspitzen misst. Das AMI wurde von Hiroshi Motoyama erfunden, einem japanischen Wissenschaftler, der sein Leben dem Studium der Bioenergetik der Meridiane der Traditionellen Chinesischen Medizin (TCM) gewidmet hat. In diesem ersten Teil werden die Literatur zu TCM und AMI sowie die Funktionsweise des Geräts vorgestellt. Insbesondere werden medizinische und biophysikalische Studien, die die Meridian-Theorie unterstützen, sowie Biofeld-Experimente, die mit dem AMI durchgeführt wurden, diskutiert. Die Funktionsweise des AMI wird erkundet, wobei seine Parameter und ihre Beziehung zur elektrischen Aktivität der Haut im Detail erklärt werden. Im zweiten Teil werden frühere Studien zur Zuverlässigkeit von Akupunkt-elektrodermalen Geräten diskutiert, die deren Verwendung in der Biofeldwissenschaft befürworten, und ihre Eigenschaften und Leistungen mit denen des AMI verglichen. Außerdem wird ein eigenes Experiment vorgestellt: Das AMI wurde bei 100 gesunden Probanden eingesetzt, um zu prüfen, ob es gemäß den TCM-Prinzipien aussagekräftige Aussagen über ihr Biofeld und ihre subtile Energieanatomie liefern kann. Die Ergebnisse waren positiv und bestätigten die Nützlichkeit und Zuverlässigkeit des AMI für die Biofeldwissenschaft.

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

Introduction

In Traditional Chinese Medicine (TCM) theory, the body is pervaded, nourished, and regulated by subtle energy called "Chi," which runs through invisible pathways called "meridians" and circulation points called "acupoints," located along the meridians (Ma et al., 2021; Matos et al., 2021; Ni, 1995). The flow of Chi can be manipulated to improve health and wellbeing: For example, there is evidence that, by stimulating acupoints, vital energy disruptions can be resolved and the harmonious movement of Chi reestablished. Similar therapeutic effects were observed also with internal Qigong and Tai Chi, where body movements and breathing techniques, combined with conscious intention, are used to cultivate, balance, and activate Chi energy; as well as with external Qigong, where a master practitioner projects Chi onto a healee to promote, enhance, or restore their health, by unblocking, cleaning, and recharging their bioenergetic system. These therapies resulted effective at treating chronic and acute conditions, in internal medicine, gynecology, pediatrics, traumatology, external medicine, dermatology, emergency medicine, and others.

Furthermore, numerous experiments showed that meridians and acupoints have different biophysical characteristics compared to other skin regions, supporting their existence and explaining their functioning (G.-J. Wang et al., 2010; J. Li et al., 2012). These scientific investigations of the human energy field, also called biofield, and specifically of the skin electricity, allowed to understand and validate TCM models, postulates, and techniques. Studies on human electrodermal activity date back to the late 19th century, when methods to measure the skin conductance (or resistance) started to be developed and used as clinical diagnostic tools (Dawson et al., 2000). However, these first instruments and techniques were very rudimental, and the skin electrophysiology was poorly understood. In the past century, technologies and methodologies have improved, and theories have been formulated about electrodermal activity, and its relationship to sweat-gland and nervous-system function. Over time, the correlation between skin conductance and psycho-physiology has been widely investigated, and modern computerized devices have been commercially produced. Research has been focusing on determining the correct electrode material, paste, and placement; improving experimental procedures; and perfecting data processing, through more advanced hardware and software, in order to minimize artifacts, noise, and errors.

In the 1950s and 60s, Yoshio Nakatani and Reinhold Voll, respectively a Japanese and German physician, were pioneer researchers in this field: Their original machines, called Neurometer and Dermatron, inspired the design of many following ones, some of which are still in use today (Hyodo, 1988; Lam et al., 1988; Nakatani & Oiso, 2018; Oliveira, 2016; Saita, 1973; Tsuei, 1995, 1998; Voll, 1980). Nakatani and Voll's bioenergetic studies on acupoint skin resistance and electrical stimulation contributed to the development of reliable measurement techniques, accurate diagnostic interpretations, and effective medical treatments.

The Apparatus for Meridian Identification (AMI), which will be used in this research work, is a biofield machine that measures the skin electrical activity and correlates it with the organism health status (Motoyama, 1997): In particular, this device analyzes the response of specific acupoints, called Sei points and located on the tips of fingers and toes, when a low-voltage stimulus is applied. The AMI was invented by Hiroshi Motoyama, a Japanese scientist, parapsychologist, spiritual instructor, as well as founder of the California Institute for Human Science. Motoyama devoted his life to studying the anatomical location and physiological functioning of the meridians, using his electrodermal device to scientifically verify the principles of TCM. The AMI soon became popular in many countries of the world, including Japan, England, Germany, Netherlands, United States, Korea, China, and India, allowing to conduct novel research in the field of subtle energy and alternative medicine. In this research, a test on the reliability of the AMI will be carried out, analyzing the performance of the device, and its utility for TCM and biofield science.

Literature Review on TCM

According to Traditional Chinese Medicine (TCM), the human body is crossed by an invisible network of channels (meridians), where subtle energy (Chi) flows, sustaining biological function and development (Ni, 1995): The quality, quantity, and fluidity of Chi along the meridians determine the health status of the organism. Impediments, depletions, or congestions in the flow of Chi cause diseases, but can be resolved using a variety of techniques.

For example, through acupuncture, electroacupuncture, acupressure, moxibustion, and cupping, which consist in stimulating biologically active meridian points (acupoints), respectively through a needle, electricity, pressure, heat, and suction. These treatments seem effective at ameliorating or curing numerous medical conditions, including chronic and acute pain syndromes, such as dysmenorrhea, migraine, fibromyalgia, osteoarthritis, musculoskeletal and postoperative pain; stroke, paralysis, motor dysfunctions, neurological diseases, and epilepsy; nausea, vomiting, and gastrointestinal disorders; fatigue, obesity, and metabolic diseases; acne and herpes zoster; cough, asthma, and cold; anxiety, insomnia, depression, panic attack, post-traumatic stress disorder, addictions, and others (Birch et al., 2004; Cabýoglu et al., 2006; Cao et al., 2010, 2012; Faircloth, 2015; H. Wang & Hu, 2019; Hou et al., 2015; J. Zhu et al., 2021; King et al., 2013; Koran & Irban, 2021; Lee & Frazier, 2011; Lu et al., 2022a, 2022b; Mehta & Dhapte, 2015; Mehta et al., 2017; Pyne & Shenker, 2008; Round et al., 2013; Salehi et al., 2016; Sierpina & Frenkel, 2005; T. Y. Choi et al., 2021; Ulett et al., 1998; Vickers et al., 2002; Vieira et al., 2018; W. S. Y. Shan & Ho, 2011; Wagner, 2015).

The patient's physical sensations while being needled, as well as those of the acupuncturist while needling, are called "Deqi" and have been described since the ancient times (Kong et al., 2007; S. Chen et al., 2013; S.-P. Zhu et al., 2013; X.-Y. Yang et al., 2013; Yuan et al., 2013). Although further research is needed to understand this phenomenon, such perceptions seem related to the movement of Chi through the patient's body and to the clinical efficacy of the treatment being performed.

Also internal Qigong and Tai Chi, which consist in physical movements, deep breathing, and focused attention, resembling a blend of yoga and martial arts, are aimed at restoring the proper flow of Chi through the body, promoting healing and regeneration. These mind-body therapies were clinically tested and seemed to return positive health outcomes: for example, improving psychological disorders, fatigue, and pain; cardiovascular and respiratory diseases; metabolic syndrome; neurological and musculoskeletal dysfunctions, such as Parkinson's disease, osteoarthritis, and fibromyalgia; cancer and others; as well as enhancing balance, strength, flexibility, aerobic capacity, immune function, cognitive performance, sleep quality, and overall wellbeing (Aboushanab et al., 2022; Dong & Bergren, 2016; G.-Y. Yang et al., 2015, 2022; Guo et al., 2018; Hallisy, 2018; Horowitz, 2009; Huston & McFarlane, 2016; J. Huang et al., 2021; Jahnke

et al., 2010; Klich & Milert, 2018; Lan et al., 2013; McGee, 2022; Ng & Tsang, 2009; Nyman, 2022; Rubik, 2007; Sancier, 1996; Solloway et al., 2016; Toneti et al., 2020; Zou et al., 2017). While in external Qigong, a master healer emits Chi and focuses it onto living or non-living things, influencing them physically, chemically, and biologically. Studies confirmed that this practice can produce significant changes in humans, animals, plants, cell cultures, and physical systems, which could lead to promising and non-invasive medical applications, both to prevent and cure diseases (K. W. Chen, 2004; Sancier & Hu, 1991; X. Yan et al., 2002).

Researchers have been validating the millenary practices of TCM also by studying the biophysical properties of acupoints and meridians. For example, laser-stimulation of a left-foot acupoint (BL-67), traditionally related to ophthalmic disorders, produced the activation of visual brain areas, as assessed by functional Magnetic Resonance Imaging (fMRI), while placebo stimulation did not (Siedentopf et al., 2002). Similarly, the stimulation of various acupoints led to the modulation of specific cerebral regions, which seem consistent with the therapeutic effects elicited by the treatment of those acupoints (B. Yan et al., 2005; G. Li et al., 2003; Lewith et al., 2005; Liu et al., 2013; M.-T. Wu et al., 1999; Parrish et al., 2005; Romoli et al., 2014; W. Huang et al., 2012; W.-T. Zhang et al., 2004; Wen et al., 2021; Y. Shan et al., 2014; Y. Wu et al., 2010; Yoo et al., 2004; Z. Li et al., 2017, 2018; Zhao et al., 2014).

Moreover, it was observed that after moxibustion (acupoint stimulation through heat), light channels appeared on the body, matching the structure of TCM meridians, as detected by infrared thermography (Schlebusch et al., 2005); however, there was a debate about the reproducibility of this experiment (Litscher, 2005; R. Chen et al., 2011). Additionally, through isotopic tracing in subcutaneous tissue, scientists found that TCM meridians appear as channels of low hydraulic resistance, where more fluid flows compared to other body areas (W.-B. Zhang et al., 2008, 2015); and that acupuncture treatments decrease hydraulic resistance, dredging meridian channels, which would explain how many TCM therapies exert their effects. Besides, there is evidence, although not conclusive, that acupoints and meridians are characterized by lower electrical impedance and higher capacitance, compared to other skin regions (Ahn et al., 2005, 2008, 2010; Becker et al., 1976; Kim et al., 2007; Litscher et al., 2011; Pearson et al., 2007; Reichmanis et al., 1975, 1976; Xu et al., 2018). Finally, among their many biophysical peculiarities, meridians also show high optical properties, i. e., light waves propagate better along these pathways compared to others (C. Choi et al., 2003; H.-Q. Yang et al., 2006, 2007).

It was also discovered, through ultrasound pictures, that connective tissues show cleavage planes at acupoints, suggesting that they constitute a body-wide mechano-sensitive network for signal transmission, which would explain the functioning and therapeutic effects of acupuncture (Langevin, 2006; Langevin & Yandow, 2002; Langevin et al., 2001). Similarly, it was proposed that the acupuncture system may coincide with the liquid crystalline continuum of

the connective tissues, which would act as an intercommunication medium throughout the body and would respond to subtle energy medicine (Ho & Knight, 1998).

Furthermore, it was found that, when there is a change in the blood flow, measured at hand acupoints, there is a corresponding change in the dermis current, measured at finger acupoints (Lin et al., 2007, 2010, 2012): This is in agreement with the TCM fundamental concept that blood is the mother of Chi,[2] as well as with Motoyama's electrophysiological theory of meridians, where the dermis current reflects Chi energy. Among the many scientists, who have worked to validate TCM, Motoyama surely stands out, with his experiments to assess the electrical response of acupoints and find the physiological location of meridians (Motoyama, 1986, 1997, 1999a, 2008).

By measuring the signal speed, location, and direction, Motoyama deduced that the meridian system is different from the nervous one. He observed that the meridian reaction propagates much slower than the nervous one, because it is mediated by the body fluids and not by the nerves. He demonstrated that, when a certain acupoint is electrically stimulated, an electrophysiological response tends to occur only at specific acupoints of the same meridian or those associated through the Yin–Yang or Three Yin–Three Yang relationship.

Furthermore, he found that removing layers of epidermis from the skin does not affect much the meridian signal transmission: This corroborates his hypothesis that such electric flow lies deeper, in the dermal connective tissues, where the water content is high and there are few cellular components. He noted that only the dermis current tends to have the same direction of movement predicted for Chi by TCM (in healthy subjects) – upwards in Yin meridians and downwards in Yang meridians – while the epidermis current does not show a well-defined directionality. He discovered that the electric current, flowing in the dermis, tends to respect the Yin-Yang meridian relationship (in healthy subjects) – where the current of Yin meridians is higher than that of their Yang partners – which is a TCM principle for the flow of Chi; while this relationship is much weaker for the epidermis current.

Therefore, Motoyama concluded that the meridian function and flow of Chi energy are reflected mostly in the electrical activity of the dermal connective tissues.

He also discovered that, after thermally stimulating an acupoint, a higher-temperature band, matching the specific meridian pathway, appears on a temperature-sensitive liquid-crystal coating applied on the testee's body, which suggests the presence of real information channels crossing the organism. The existence of a physiological network beneath the skin seems to be confirmed by

2 In TCM, the complete expression of this concept is that blood is the mother of Chi and Chi is the commander of blood. This principle highlights the interrelationship between blood and Chi, which govern, support, and nurture each other, playing a vital role in the sustenance of the organism.

other studies of his: He identified a non-localized electric circuit component, which resides in the deeper tissues of the skin and would act as a core pathway that underlies and connects the body (Motoyama et al., 1984); he also developed an equivalent electric circuit of the skin, which resulted consistent with his experimental measurements of the acupoints (Motoyama, 2006).

TCM modalities are helpful to treat a variety of health conditions, thus further studies should be carried out to fully explore their clinical efficacy and potential. Novel scientific technologies and methodologies, aimed at understanding the physiological mechanisms of these therapies, have been utilized with positive results. Among these, studying the biophysics of acupoints and meridians seems to be a promising research frontier, thus investigations of this topic are recommended and encouraged. In this experiment, the acupoint electrical response of healthy people will be analyzed through the Apparatus for Meridian Identification (AMI), to assess the reliability of the signal and the bioenergetic relationships of TCM meridians. This literature review on TCM is summarized in Appendix A.

Literature Review on the AMI

Motoyama's Apparatus for Meridian Identification (AMI) measures the skin electrical response at very informative acupoints (Sei points), allowing to detect subtle variations in the testees' bioenergetic system. With this technology and purpose, many Complementary and Alternative Medicine (CAM) modalities have been investigated.

The bioelectrical effects of osteopathic cranial manipulation were assessed with the AMI, on a group of volunteers, who received a real or sham treatment (Hendryx et al., 2023): The treated group showed a decrease in their nervous system activity after the therapy, suggesting a shift towards a more parasympathetic state, which may elucidate a potential therapeutic mechanism underlying this healing modality; while the control group did not show any significant change. In another investigation, a group of subjects was earthed for ~ 30 min through a wiring system, attached to the soles of their feet and connected to the outdoor ground (Chevalier & Mori, 2007): As expected, measurements with the AMI showed a decrease in stress and inflammation after Earthing, which was not found in the controls.

The Aikido technique – a Japanese martial art where two practitioners reach energetic union and unison – was tested with the AMI (Tsuchiya, 2008): Results indicated an activation and balancing of Chi energy, and a resonance between the paired partners, whose energetic parameters correlated during the practice. While Chinese martial art and mind-body exercise Tai Chi was performed by experienced practitioners, who were assessed before and after with the AMI, which showed a consistent increase in their Chi energy (Lin et al., 2006).

Interventions on a breast cancer patient, through Pranic Healing – a non-touch modality where the healer manipulates the healee's biofield, using hand movements, mental visualizations, and conscious intentions – were evaluated with the AMI (Tsuchiya & Motoyama, 2009). Throughout the four-session trial, the device detected energetic changes in the healee that were consistent with the healing protocol and recovery process. In another experiment, a subject unable to walk, due to emaciated lower limbs, went through three sessions of Reconnective Healing, a non-touch subtle-energy modality (Tsuchiya et al., 2010a): Before the therapy, the AMI detected in his lower body significant energetic deficiencies and imbalances, which started to replenish and adjust as the healing progressed. At the end of the third session, the subject stood up and managed to walk slowly without help, in accordance with the bioenergetic improvements reported by the AMI.

During a four-session hypnotherapy intervention – where verbal induction is utilized to stimulate physical and emotional healing – synchronous changes were found in the AMI-assessed meridian activity of healer and healee, suggesting the establishment of a subtle energetic connection between the two (Tsuchiya et al., 2010b). Moreover, the effects of an energy psychology treatment, aimed at reducing anxiety and fear, through self-applied acupressure, focused thought, and breathing exercises, were quantified with the AMI (Lambrou et al., 2003): After a 30-min healing session, claustrophobic individuals, put to test in a small enclosure, showed a significant relaxation effect, which was not observed in the control group.

Furthermore, the AMI was used to detect illnesses, such as lung and liver diseases, showing that the electrical properties of the patients' acupoints reflected the diseased condition of their organs and body (Motoyama, 1999b, 2000; Nagayama, 2010; Nagayama & Motoyama, 2007).

Whether the AMI could detect bioenergetic differences between gifted and average boys was also investigated, with successful results (Borg, 2003). Group membership, which was previously determined by intelligence tests, manifested in the AMI health assessments, where on average the gifted children resulted to have a calmer nervous system compared to the control group. Therefore, the application of the AMI as a screening tool to detect giftedness, by analyzing the bioelectrical pattern of the nervous system, seems to be a promising approach to identify and fulfill children educational needs. Moreover, the AMI was used in a card-guessing parapsychology test, with tens of participants and thousands of trials (Onetto, 1998): Although it was not found that better psi performers had higher meridian activity, as hypothesized by the researcher, a moderate-to-high degree of correlation was found between positive performers and gastric system meridians, which confirmed previous AMI findings by Motoyama.

In other experiments, differences in meridian function were investigated between males and females, as well as among different races. After AMI-measuring thousands of subjects, results

showed that male meridian function is more active during cold and hot seasons, whereas that of females during mild seasons (Motoyama et al., 2003). However, the frequency distribution of the most active and inactive meridians throughout the year appears to have the same pattern between the two, indicating that both males and females share the same subtle energy system. Furthermore, a study on several thousand people from different nationalities was carried out, testing their meridian function with the AMI and drawing the following conclusions, which may be due to anthropological and evolutionary reasons (Motoyama et al., 1998): Japanese, Asians, and Hispanics have a similar bioenergetic system, with a very active functioning of the digestive organs, suggesting that they might belong to the same racial group; while Caucasians constitute a different group, with a more active circulatory system.

The AMI is a sophisticated biofield machine, with great potential for research purposes and clinical applications: Through this device, the understanding and validation of CAM modalities can be pushed forward, advancing the frontiers of conscious healing. A past research work on the measurement variability of the AMI returned positive results (Lin et al., 2006); while an investigation into its clinical reliability supported its usefulness as a diagnostic tool (Jessel-Kenyon et al., 1998). Additionally, previous studies on a similar electrodermal device, called Prognos and manufactured during the Soviet space program for cosmonaut health maintenance, concluded that such technology performs accurately and consistently (Colbert et al., 2004; Treugut et al., 1998; Turner et al., 2010). Finally, other electrodermal machines and testing methods have been shown to work reliably and effectively, providing correct and valuable diagnoses (Colbert et al., 2009, 2011; Nakatani & Oiso, 2018; Shima et al., 2012; Srinivasan, 1989; Szopinski et al., 2004; Tiller, 1987; Tsai et al., 2017; Voll, 1980).

This research work is aimed at examining further the AMI, exploring the repeatability and validity of its assessments. Specifically, an experiment originally carried out by Motoyama will be repeated (1986, 1997 [pp. 45–54], 2008): It will be investigated whether the Chi energy relationship between couples of Yin–Yang meridians is respected, i. e., whether in every Yin–Yang meridian pair of healthy subjects, the Chi of Yin meridians is more abundant than that of their Yang partners, as predicted by Traditional Chinese Medicine (TCM).[3] The purpose of this study is to verify Motoyama's results from the 1980s, with a newer and more accurate model of the AMI, as well as conduct further analyses to test Motoyama's theory and device. This literature review on the AMI is summarized in Appendix B.

3 According to TCM, there are 12 meridians, characterized by a Yin–Yang relationship. Over time, other extra meridians have been discovered, of yin and yang type, and have been utilized clinically. Through the AMI, the 12 regular meridians and 2 extra meridians can be assessed.

AMI Functioning

The Apparatus for Meridian Identification (AMI), invented by Hiroshi Motoyama, is a biofield device that measures and analyzes the skin electrical response to a 3-V, 512-μs rectangular-wave pulse (Motoyama, 1976, 1997, 1999b; Motoyama & Nukada, 1989; Motoyama et al., 1995). The measurement is performed by applying an electrode probe on "Sei" points,[4] which are located close to the edges of finger and toe nails: These 28 special acupoints, shown in Figure 1, correspond to the beginning or end of Traditional Chinese Medicine (TCM) meridians and are thought to reflect their overall functioning with sensitivity. Specifically, square silver-silver chloride (Ag-AgCl) electrode patches, with 0.7 cm sides, are placed on the Sei points and touched with the AMI pen, which both stimulates the skin and detects its response; while two circular Ag-AgCl electrode patches, with a ~ 3.7 cm diameter, are attached to each forearm, approximately 5 cm above the wrists, and connected to the AMI, serving as a reference. A picture of the device is shown in Figure 2.

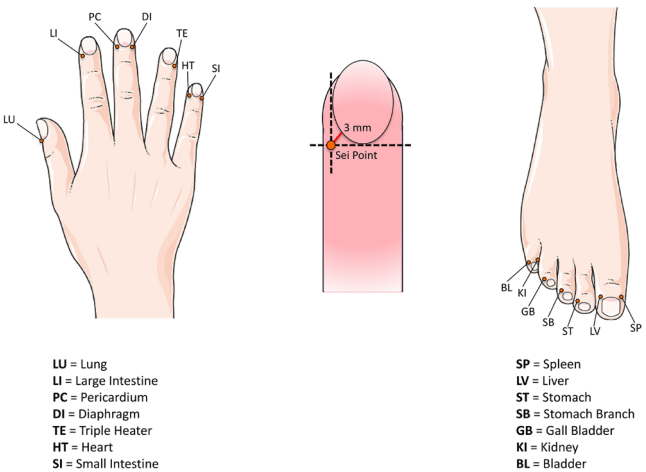

Figure 1. Location of the Sei points on the right hand and foot. Their position on the left hand and foot is symmetrical, since the reported meridians are bilateral. The hand meridians are Lung (LU), Large Intestine (LI), Pericardium (PC), Diaphragm (DI), Triple Heater (TE), Heart (HT), and Small Intestine (SI); while the foot meridians are Spleen (SP), Liver (LV), Stomach (ST), Stomach Branch (SB), Gall Bladder (GB), Kidney (KI), and Bladder (BL). Each meridian is associated to a particular organ, except for PC and TE, which reflect the functioning of the whole organism: In particular, TE controls the energy distribution of the body, while PC regulates the cardiovascular system. Similarly, DI and SB are not associated to any specific organ, but reflect respectively the metabolic activities of respiration and digestion. DI and SB are extra meridians, while the others are regular meridians. The figure was partly generated using Servier Medical Art, provided by Servier, licensed under a Creative Commons Attribution 3.0 Unported License.

4 The Japanese "Sei" points are called "Jing" in Chinese and "Well" in English.

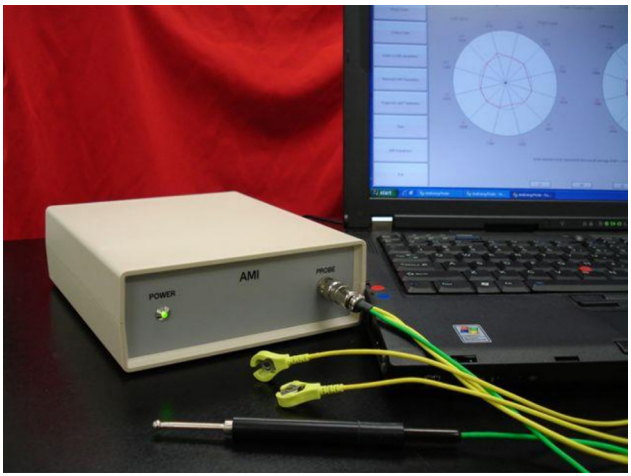

Figure 2. The Apparatus for Meridian Identification (AMI). The grey box is the CPU of the device, while the metallic pen-like tool (probe) and the yellow cables are respectively the active and reference electrodes. In the measurement process, a 3-V, 512-μs rectangular-wave pulse is applied between the active electrode, placed on a Sei point, and the reference electrodes, placed on the forearms above the wrists. The transient current, flowing across the electrodes, is detected and parameterized. The picture was kindly provided by the California Institute for Human Science.

In measuring the electrical characteristics of the skin, the magnitude and duration of the applied voltage significantly influence the results. When a high voltage is applied (tens of V), electrolysis of water and dielectric breakdown occur in the cells, especially if the pulse duration is long (a few s). This phenomenon is no more than a breakdown test, with poor measurement reproducibility. Conversely, when a low voltage (a few V) is applied for a short time (a few ms), Ohm's law holds, allowing for accurate and reproducible results. Therefore, in order to obtain a good and informative outcome, it is necessary to apply a voltage, which is as low-intensity and short-duration as possible, but which also induces a skin electrical response that is large enough to be detectable.

Motoyama studied the electrophysiology of high and low voltage stimuli, drawing the following conclusions: If the stimulus is strong (tens of V), it is accompanied by a certain sensation of pain and by a non-local depolarization of the sweat gland cells, which become more negative in electric potential compared to their surrounding area. This reaction spreads throughout a wide area of the body, very quickly (~ 0.5–100 m/s), because it is mediated by the Autonomic Nervous System (ANS). Instead, when a weak stimulus is applied (a few V), no physical pain is felt, and a local polarization occurs at the contours of the skin layers. As a result, the electric potential becomes more positive in the stimulated area, relative to its surroundings. This reaction involves only specific points of the same or associated meridians, which do not even have a direct neural connection; therefore, it propagates more slowly (~ 4–50 cm/s), because it is not mediated by the nervous system, but it is related to the flow of body fluids in the connective tissues. Motoyama theorized that this response is correlated to meridian activity.

A mathematical model was developed by others, to describe meridian activity, and resulted in agreement with Motoyama's experimental findings about the propagation velocity of electrical signals associated to the flow of Chi (Friedman et al., 1989a, 1989b).

A typical meridian electrophysiological reaction is visible in Figure 3: Immediately after the voltage is applied to the skin, a response current I(t) peaks (I(0)) and then it attenuates, within a few tens of μs, into an almost-constant direct current (I_{DC}).[5]

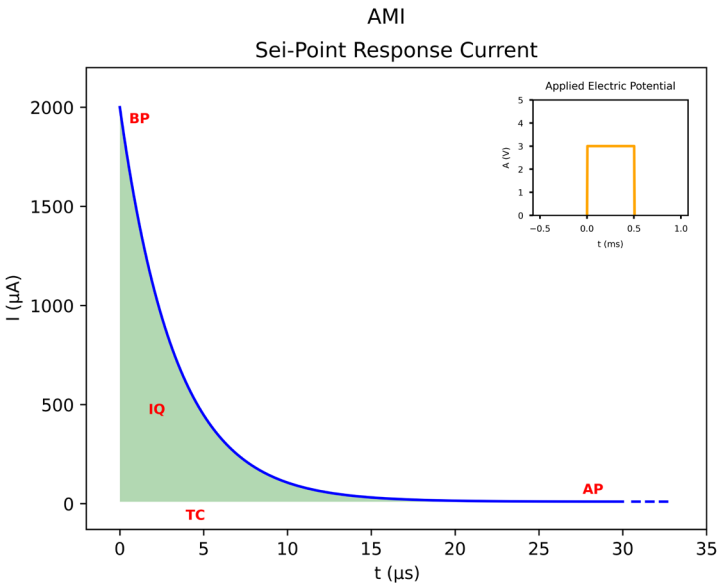

Figure 3. Response current of the skin when a low voltage is applied to a Sei point. The reported curve parameters are BP (Before-Polarization current), AP (After-Polarization current), IQ (Integrated Charge [Q]), and TC (Time Constant). As the voltage is applied to the skin, an electric current I(t) reaches its maximum I(0), then it exponentially decreases, and finally it stabilizes into an almost-constant direct current I_{DC}, within a few tens of μs. This waveform represents the skin electrical response, to a low voltage stimulus, in any region of the body surface; however, its shape, parameters, and thus diagnostic value, may vary depending on the body location. Copyright with the author.

5 It should be specified that, while I_{DC} (AP) is a direct current, I(0) (BP) is an alternating current, with a frequency of ~ 3 MHz (Motoyama, 2006). In fact, the rising edge of the applied rectangular pulse contains an AC signal (a composite of sinusoidal waves with a frequency of ~ 5 MHz), which determines the alternation of I(0).

Over the range of approximately 1 ms, the acupoint response curve is accurately described by Eq. (1):

$$I(t) = I_0 \cdot e^{-\frac{t}{\tau}} + I_{DC} \quad \text{Eq. (1)}$$

$$t \in [0, 1]ms$$

where the AMI parameters can be theoretically calculated as:

$$BP = I(0) = I_0 + I_{DC} \quad \text{Eq. (2)}$$

$$AP = I(\infty) = I_{DC} \quad \text{Eq. (3)}$$

$$IQ = \int_0^{\infty} (I(t) - I(\infty))dt \quad \text{Eq. (4)}$$

$$TC = \frac{I(0)}{-\frac{dI}{dt}|_{t=0}} \quad \text{Eq. (5)}$$

The AMI parameters are experimentally calculated by the AMI software, from the measured current waveform, as follows:[6]

- The AMI measures a value of the Sei-point response current every μs and sends 500 data points to the pc.
- BP is the value of the first data point:

$$BP = 1^{st}point \quad \text{Eq. (6)}$$

- AP is calculated as the average value of 64 data points, from the 187th to the 250th one:

$$AP = \frac{\sum_{i=187}^{250} value_i}{64} \quad \text{Eq. (7)}$$

- IQ is calculated as the sum of the differences between each of 500 data points and the AP value:

$$IQ = \sum_{i=1}^{500} (value_i - AP) \quad \text{Eq. (8)}$$

6 It should be noted that, when the current waveforms are not transferred from the AMI to the PC, the four parameters are calculated inside the AMI itself, with a different algorithm, used to create backward compatibility with a previous AMI model from the 1980s. With this method, the resulting values of the four parameters can be considerably different.

- TC is calculated as the first data point divided by the difference between the first and second data points:

$$TC = \frac{1^{st}point}{1^{st} - 2^{nd}point} = \frac{BP}{-\frac{\Delta I}{\Delta t}|_{\Delta t=1}} \quad \text{Eq. (9)}$$

In the AMI measurement process, the voltage pulse is applied to the acupoint 6 times and each time BP is calculated, but the first BP value is discarded since it may be affected by instrumental errors. The deviations (D_i) over the mean (M), of the remaining 5 BP values, are calculated:

$$\frac{D_i}{M} = \frac{BP_i - BP_M}{BP_M}|_{i=2,\ldots,6} \quad \text{Eq. (10)}$$

If at least 3 ratios fall within the range [-0.03, +0.03], the four AMI parameters are calculated from the average of the passed waveforms and a high sound is emitted, informing the experimenter that the measurement was successfully completed. Otherwise, a low sound is emitted, indicating that the measurement failed and has to be repeated. The pass/fail criterion is based on the BP parameter because it is the most important and critical, being potentially correlated to meridian function and Chi energy activity. The measurement of an acupoint lasts ~ 3 s.

So far, the AMI model and software used in this experiment were described. In the new AMI software, the distance between voltage pulses has been reduced and the measurement of an acupoint lasts ~ 1 s. This leads to less failures of the previous algorithm, because the shorter measurement time reduces the measurement variability, which could be due to the movement of the probe by the experimenter and/or to the physiological fluctuations of the testee.

With this new software, it is also possible to use a new electrode probe, where a small electrode patch is directly attached to it and placed on bare-skin acupoints for measurement. While this set up reduces the time to prepare the testee for an AMI test, it can also lead to errors, because acupoints have to be identified in real time by the experimenter during the measurement process. Besides, with the new electrode probe, the measurement of an acupoint lasts ~ 6 s, so that the electrode patch can properly adhere to the testee's skin – the electrode-skin connection is repeatedly checked by the AMI prior to the actual measurement.

It should be noted that, in his decade-long work, Motoyama experimented with many different versions of the device, where the amplitude of the applied voltage could vary from 0.5 to 5 V and its duration from 256 μs to 1 s, while the skin electrical parameters were

calculated differently.[7] The various ways to measure acupoints with electrodermal devices will be discussed in the second part of this work, highlighting the strengths and limitations of these techniques.

Based on Motoyama's studies, the four AMI parameters have the following biophysical meaning:

BP (μA): Before-Polarization current, which flows mainly in the dermis, in less than 1 μs after the external potential has been applied, and before the generation of a polarization potential, reverse in direction with respect to the external one. The BP current is the initial response to the external potential, and decreases with time due to the opposition of the polarization potential: The ion polarization screens out the applied voltage, flattening the current curve. The BP value is determined by the intrinsic resistance of the skin structure. Motoyama observed that BP is larger in healthy people and smaller in sick ones: In fact, the skin resistance is lower in healthy people, whose body fluids flow well, and higher in sick people, whose fluids are more stagnant; as a result, the value of BP is larger or smaller, reflecting the condition of the dermal connective tissues. According to Motoyama, this parameter is correlated to the flow of Chi energy in the body meridians, that would correspond to the paths of least resistance for ion movement in the water-rich and colloid-poor phase of the dermal connective tissues, which act as a reservoir of electrolytes. The properties of Chi would thus influence the ion mobility, affecting the BP parameter, which would explain their correlation.

AP (μA): After-Polarization current, which flows mainly in the epidermis, after the polarization process has completed. This residual current indicates that the ion dispersion continues to a much lesser extent through the basal membrane, even after and despite the polarization, which opposes the applied voltage and suppresses the current flow. If the larger dermis current (BP) is effectively shut down by the polarization process, a smaller epidermis current (AP) continues to flow afterwards. Motoyama postulated that the AP parameter reflects the condition of the ANS, similarly to the Galvanic Skin Response (GSR) – the GSR is the change in the skin's electrical conductivity, caused by the sweat glands, which are controlled by the ANS. AP would thus measure a fast and global GSR of the body, while BP a slow and localized meridian response.

IQ (pC): Integrated electric charge (Q). After the BP current begins to flow, the ions of the skin connective tissues start to polarize above and below the basal membrane, an insulating

7 For example, in the 1990s, a model of the AMI was developed, which calculated its parameters through the Sei-point current waveform and equivalent circuit (Motoyama et al., 1995). With that model, the non-linear behavior and complex electrophysiological characteristics of the skin could be taken into account, allowing for a more detailed and informative biological assessment. However, that model of the AMI was limitedly used and never commercialized: Despite the improvements, it had a lower performance and some technical limitations, for example a long time to measure and calculate parameters (~ 30 s per acupoint), as well as incompatibility with common Western computers.

layer which separates the epidermis from the dermis and acts as a capacitor. The polarization potential is opposite in direction to the externally-applied potential, causing the downward curve of the BP current. The total electric charge that is transferred in the polarization process determines the IQ value, which measures the charging capacity of the basal membrane. In Motoyama's model, IQ reflects the homeostasis and immune function of the organism: In sick people, it appears to be smaller than in healthy ones, signaling a low immune energy.[8] This is because, in a broader sense, the polarization phenomenon is within the functions of the homeostatic system, which defends the body from external stimuli and tries to keep it in a constant condition.

TC (μs): The Time Constant quantifies the duration of the polarization process, which is related to the velocity of the ion flow, that depends on the skin resistance, as well as the ion type and condition within the body fluids. TC indicates the time that is required for the ion transfer and the charging of the basal membrane, against the intrinsic resistance of the skin structure. Its value determines the steepness of the BP curve. In analogy with electric circuits, this parameter can be represented as the mathematical product between C (capacitance of the basal membrane) and R (sum of the total resistance of the skin layers). Motoyama theorized that TC is related to the organism's reactivity and response time, reflecting the velocity of the organic defense against the externally applied potential.

The efficiency and advantages of using the Single Square Voltage Pulse (SSVP) method, to study human biological information and psychophysical changes, were confirmed also by another author, who analyzed the before and after polarization currents (Kido, 1997, 2000). Similarly to Motoyama's studies, the conclusion was that the former (BP) is related to meridian function, as well as blood flow, while the latter (AP) to the ANS activity. A representation of the skin anatomy is shown in Figure 4.

After the electrical response curves of each Sei point have been analyzed and all parameters calculated, a health report is returned by the AMI software, including the following information: The value of the four parameters at each Sei point; for BP, AP, and IQ, the average value of each meridian between the left and right body sides, as well as the difference between the two – for BP, criteria are reported showing reference values, based on Motoyama's studies; for BP, AP, and IQ, the average value of the whole body, with a reference range based on Motoyama's studies, as well as the ratios between left/right body sides and upper/lower body parts, with marks if they fall outside the range [0.95, 1.05]; the two deficient meridians, that have the lowest BP, and the two excessive meridians, that have the highest BP; the two imbalanced meridians, that have the

8 Motoyama noticed that BP, AP, and IQ tend to have higher values than normal at the initial stages of an illness, when the body is inflamed, overactive, and fighting the disease; while they drop to very low values if the condition becomes chronic.

largest BP difference between left and right body sides; the inverted paired meridians, whose BP Yin-Yang relationship is not respected; the condition of the chakras, which is extrapolated from the meridian BP values – extra meridians are excluded from deficiency, excess, imbalance, inversion, and chakra analysis; if needed, holistic practices are suggested, such as acupoint stimulation, breathing techniques, and physical exercises, to rebalance Chi energy, ANS activity, and immune function; if selected, it is possible to transfer the acupoint raw waveforms from the AMI to the pc, and include those of the excessive and deficient meridians in the health report, but this increases the measurement time. The summary page of an AMI health report is displayed in Figure 5.[9]

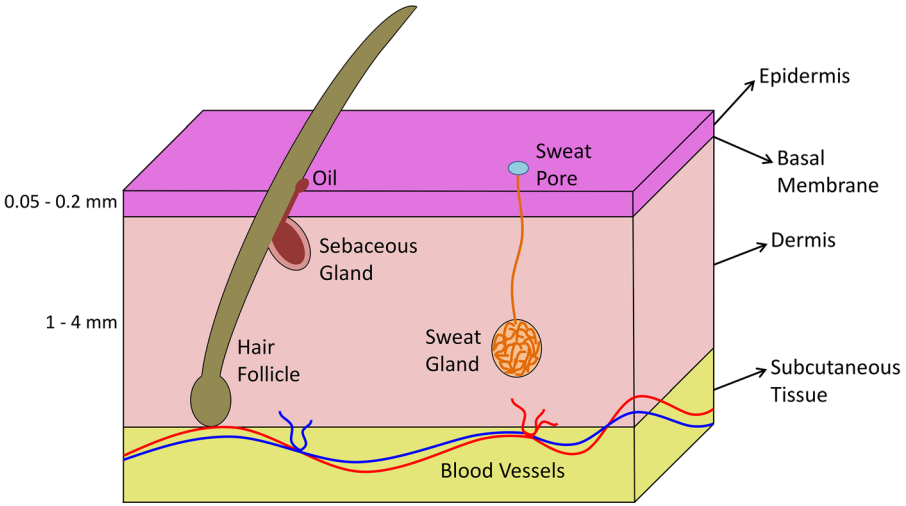

Figure 4. Anatomical structure of the skin, which is composed of three subsequent strata: epidermis, dermis, and subcutaneous tissue. The epidermis and dermis, which primarily define the electrical characteristics of the skin, are separated by the basal membrane (or basement membrane), which is an insulating layer. In Motoyama's model, BP and AP are the currents that flow respectively in the dermis and epidermis; IQ reflects the charging capacity of the basal membrane, where the polarization occurs; and TC is the time length of the polarization process. Copyright with the author.

9 The description of the AMI here presented is based on Dr. Motoyama's publications, as well as the information kindly provided by Mr. Toshimasa Kinoshita, Mr. Yukihiro Takeshima, and the International Association for Religion and Parapsychology (IARP); all of whom this author sincerely acknowledges and thanks.

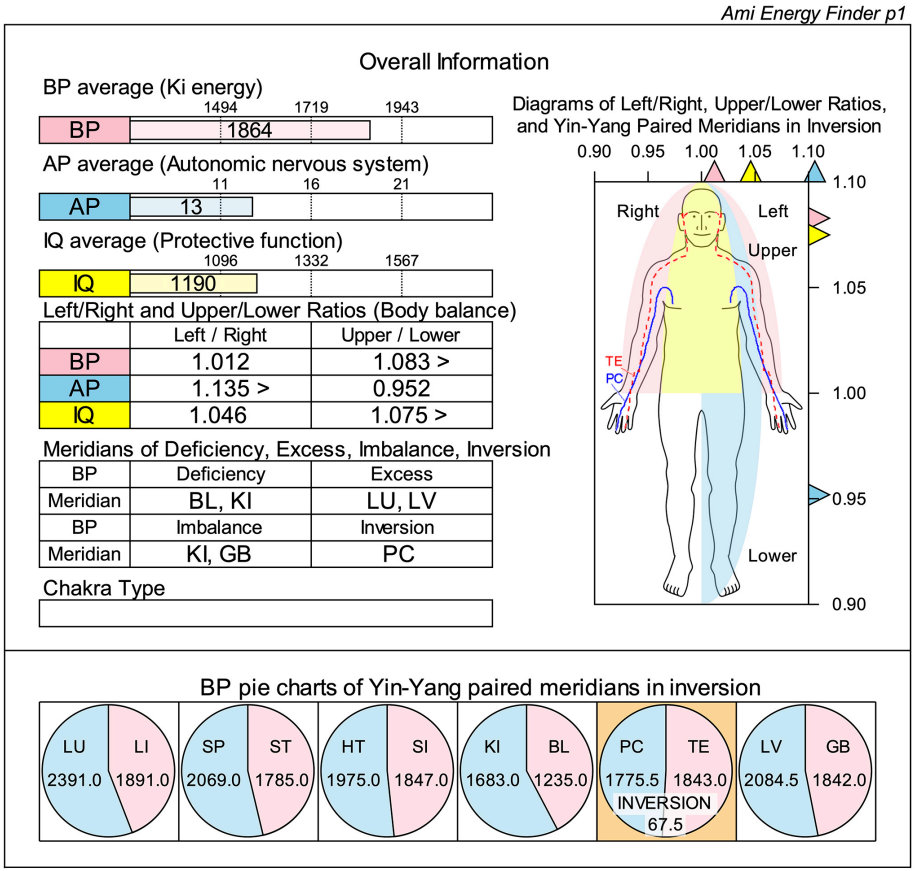

Figure 5. Summary page of an AMI health report. The whole-body averages of BP (μA), AP (μA), and IQ (pC) are shown on top; the left/right and upper/lower ratios of BP, AP, and IQ are also returned, with marks if they are more than 5% below or above equality; in the bottom part, the meridians that are in BP deficiency, excess, imbalance, or inversion are listed; finally, the chakra that results active is specified (none in this case). All BP Yin-Yang relationships of the main TCM meridians are displayed at the very bottom, with highlights on inverted couples. On the right, the bioenergetic status of the testee is mapped on a human figure. The reference ranges and values depend on the characteristics of the testee, such as age and gender, as well as on the date of measurement. "Ki" energy, which is transliterated Japanese, corresponds to "Chi" energy, which is transliterated Chinese. Copyright with the author.

Conclusion

For millennia, Traditional Chinese Medicine (TCM) techniques have been used to heal diseases and promote health, by rebalancing the flow of Chi energy throughout the body meridians. With the advancement of modern science and the development of novel technologies, TCM is being investigated in clinical trials and laboratory settings: Its theoretical postulates are being verified and its healing modalities validated, from a medical and biophysical perspective. The concept of life force, specifically Chi, now appears closer to our reach. The Apparatus for Meridian Identification (AMI) seems to be an interesting electrodermal device to push forward our understanding of TCM, and biofield science at large. In the second part of this work, the AMI will be used in an original experiment, to analyze its functioning and assess its reliability. Results will confirm the usefulness of the AMI for TCM and biofield science, in agreement with the conclusions of previous studies, which will be reviewed.

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Appendix A

A summary of the literature review on Traditional Chinese Medicine (TCM) is reported in Table 1. All references can be found in the bibliography of the main article.

TCM Map		
Topics	**Studies**	**Findings**
Acupoint stimulation	• Birch et al. (2004) • Cabýoglu et al. (2006) • Cao et al. (2010, 2012) • Faircloth (2015) • H. Wang & Hu (2019) • Hou et al. (2015) • J. Zhu et al. (2021) • King et al. (2013) • Koran & Irban (2021) • Lee & Frazier (2011) • Lu et al. (2022a, 2022b) • Mehta & Dhapte (2015) • Mehta et al. (2017) • Pyne & Shenker (2008) • Round et al. (2013) • Salehi et al. (2016) • Sierpina & Frenkel (2005) • T.Y. Choi et al. (2021) • Ulett et al. (1998) • Vickers et al. (2002) • Vieira et al. (2018) • W.S.Y. Shan & Ho (2011) • Wagner (2015)	Amelioration or cure of physical and mental conditions
Deqi	• Kong et al. (2007) • S. Chen et al. (2013) • S.-P. Zhu et al. (2013) • X.-Y. Yang et al. (2013) • Yuan et al. (2013)	Patient and acupuncturist's physical sensations of Chi, during acupoint needling

Internal Qigong and Tai Chi	• Aboushanab et al. (2022) • Dong & Bergren (2016) • G.-Y. Yang et al. (2015, 2022) • Guo et al. (2018) • Hallisy (2018) • Horowitz (2009) • Huston & McFarlane (2016) • J. Huang et al. (2021) • Jahnke et al. (2010) • Klich & Milert (2018) • Lan et al. (2013) • Mcgee (2022) • Ng & Tsang (2009) • Nyman (2022) • Rubik (2007) • Sancier (1996) • Solloway et al. (2016) • Toneti et al. (2020) • Zou et al. (2017)	Improvement of physical and mental conditions
External Qigong	• K.W. Chen (2004) • Sancier & Hu (1991) • X. Yan et al. (2002)	Physical, chemical, and biological influence of emitted Chi on living and non-living things
Neuroscience	• B. Yan et al. (2005) • G. Li et al. (2003) • Lewith et al. (2005) • Liu et al. (2013) • M.-T. Wu et al. (1999) • Parrish et al. (2005) • Romoli et al. (2014) • Siedentopf et al. (2002) • W. Huang et al. (2012) • W.-T. Zhang et al. (2004) • Wen et al. (2021) • Y. Shan et al. (2014) • Y. Wu et al. (2010) • Yoo et al. (2004) • Z. Li et al. (2017, 2018) • Zhao et al. (2014)	Acupoint stimulation modulated cerebral regions, related to the therapeutic effects of acupoint treatments, assessed with fMRI

Heat	• Litscher (2005) • R. Chen et al. (2011) • Schlebusch et al. (2005)	Evidence, although not conclusive, that acupoint thermal stimulation lights up channels matching TCM meridians, assessed with infrared thermography
Hydraulics	• W.-B. Zhang et al. (2008, 2015)	TCM meridians appear as channels of low hydraulic resistance, assessed with isotopic tracing
Electricity	• Ahn et al. (2005, 2008, 2010) • Becker et al. (1976) • Kim et al. (2007) • Litscher et al. (2011) • Pearson et al. (2007) • Reichmanis et al. (1975, 1976) • Xu et al. (2018)	Evidence, although not conclusive, that acupoints and meridians have lower electrical impedance and higher capacitance, compared to other skin regions
Optics	• C. Choi et al. (2003) • H.-Q. Yang et al. (2006, 2007)	Light waves propagate better along TCM meridians compared to other body pathways
Physiology	• Langevin (2006) • Langevin & Yandow (2002) • Langevin et al. (2001)	Connective tissues show cleavage planes at acupoints, assessed with ultrasound imaging
Other experiments	• Lin et al. (2007, 2010, 2012)	A change in blood flow at hand acupoints corresponds to a change in dermis current at finger acupoints
Motoyama's studies	• Electrical activity of dermal connective tissues reflects meridian function (Motoyama, 1986, 1997, 1999a, 2008) • Electric circuits of the skin (Motoyama, 2006; Motoyama et al., 1984)	Parameterization of electrodermal activity, physiological location and functioning of TCM meridians

Table 1. Summary map of TCM studies and findings about various topics.

Appendix B

A summary of the literature review on the Apparatus for Meridian Identification (AMI) is reported in Table 2. All references can be found in the bibliography of the main article.

AMI Map		
Topics	**Studies**	**Findings**
Validation of Complementary and Alternative Medicine (CAM) modalities	• Osteopathic cranial manipulation (Hendryx et al., 2023) • Earthing (Chevalier & Mori, 2007) • Aikido (Tsuchiya, 2008) • Tai Chi (Lin et al., 2006) • Pranic Healing (Tsuchiya & Motoyama, 2009) • Reconnective Healing (Tsuchiya et al., 2010a) • Hypnotherapy (Tsuchiya et al., 2010b) • Energy Psychology (Lambrou et al., 2003)	Biofield healing, activation, balancing, relaxation, and synchronization due to these interventions, assessed with the AMI
Assessment of diseases and psychophysical states	• Lung and liver diseases (Motoyama, 1999b, 2000; Nagayama, 2010; Nagayama & Motoyama, 2007) • Gifted children (Borg, 2003) • Parapsychology test (Onetto, 1998)	Correct identification of the bioelectrical pattern and bioenergetic status of the testees
Other experiments	• Differences in meridian function between males and females (Motoyama et al., 2003) • Differences in meridian function among races (Motoyama et al., 1998)	Interesting findings in life science, through the AMI
Approvals	• Colbert et al. (2004, 2009, 2011) • 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)	Small measurement variability, clinical reliability, accurate and consistent assessments, correct and valuable diagnoses of acupoint electrodermal devices

Table 2. Summary map of AMI studies and findings about various topics.