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RESEARCH ARTICLE

# Electrodermal Screening of Asthmatics with AcuGraph 4

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**Abstract**
Traditional Chinese Medicine holds that acupuncture meridian activity is correlated with quality of function of specific organs. This study sets out to determine acupuncture meridian characteristics of subjects with moderate asthma distinguishing them from healthy subjects. Fifty asthma patients (age 35.36 $\pm$ 8.68 years) and fifty similarly aged (34.11 $\pm$ 7.29 years) healthy volunteers were enrolled in the study. Electrodermal conductances at Jing Well points were measured with Acugraph 4 and also Peak Expiratory Flow Rate (PEFR) for the asthma group. All mean meridian conductances were lower for the asthma group, significance differences were in Lung and right Bladder meridians. In contrast, all but two of the standard deviations of group meridian conductances for the Asthma group were higher than those for the Healthy group. Difference in mean PEFR values between Asthma and Healthy groups was significant. These suggest that group measures of electrical conductance at Jing Well points can distinguish asthma from healthy individuals. The study provides support for the usefulness of meridian energy measurements to assess organ related dysfunction and for the idea that pathology groups exhibit higher standard deviations i.e. lower quality of regulation.

## 1. Introduction

All traditional systems of medicine recognize subtle energy as a fundamental constituent of nature and its importance for human health [1]. According to traditional Chinese medicine (TCM) and Indian systems of medicine (ISM), health is maintained by a free flow of subtle energy. TCM posits the existence of a meridian system, similar to the

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Nadi system in ISM, which carries the subtle form of energy known as Qi (or prana in ISM) [2,3]. The meridians form a complex, multilevel network connecting various regions of the body, including skin surfaces, with internal organs. The best known meridians are the 12 regular meridians named for specific organs said to be connected to the organ. Each of these 12 meridians consists of a bilaterally symmetric pair controlling much of the body function, whereas disturbances in the flow of Qi/prana energy are precursors for disease or illness [4].

Electrodermal screening at acupuncture points (APs) is used in complementary medicine in many countries [5]. Based on the precise work of Nakatani [6], Niboyet [7], and Voll [8], skin surface sites corresponding to traditional APs are recognized to have lower electrical resistance, i.e., higher conductance, than surrounding areas. Electrical conductivity measurements at APs thus exhibit unique electrical characteristics, and are now generally assumed to provide vital information about Qi levels in corresponding organs.

At present, many commercial machines are available to measure electrodermal conductance at APs. Examples include AcuGraph from Miridia Technology Inc. (Meridian, ID, USA), the computerized testing instrument used in the experiment described below; Prognos developed by MedPrevent (Waldershof, Germany) [9]; Dermatron from Pitterling Electronic (Munich, Germany); and three from Japan, Apparatus for Meridian Identification from the Institute of Life Physics (Tokyo, Japan), Neurometer from the Ryodoraku Research Center Ltd. (Tokyo, Japan), and Hibiki-7 by Asahi Butsuryooki Research Lab (Kita Kyoto, Japan) [10,11].

Several factors may interfere with measurements of electrodermal conductance: environmental temperature, relative humidity, and various technical issues, all of which may cloud physiological and pathological differences being investigated [10]. Most devices consist of a single electrode shaped like the tip of a pen, which is manually pressed on the skin by an operator. Variations in electrode pressure or angle, or duration of measurement, are known to significantly influence results [10,12], so that different operators with different styles obtain different results [13].

In a paper dealing with measurement problems in AcuGraph device, it is claimed to have a repeatability of $\pm 2.5$ units for individual measurements [12] but reported standard deviations (SDs) referred to groups of 16 patients. For this reason, the preferred use of AcuGraph only reports studies of groups, so that the effective SD is reduced [13,14].

When body function is healthy, APs exhibit good conductivity [15]. By contrast, several studies have found correlations between variations in electrodermal measurements at specific APs and particular pathologies [14,16,17]. Abnormal conductance values, high or low, are indicators of dysfunction in related organs. Specific patterns of meridian conductance may thus be taken as indicators of specific pathologies, and vice versa.

A prospective study showed that patients diagnosed with ureteral calculus tend to have lower electrical conductance values over all acupoints compared with healthy individuals [18]. Arthritic pain is caused by pathological changes in the joints often because of inflammation. A study of electrodermal activity compared patients with rheumatoid arthritis with pain levels of $\geq 3$ on a 0—10 visual analogue scale with pain-free controls. The Bladder, Gall Bladder, and Small Intestine meridians were observed to have consistently lower electrodermal conductances in patients with rheumatoid arthritis than the controls and were identified as pain-sensitive meridians—all are Yang meridians corresponding to "hollow" organs [19].

A survey study comparing children with HIV and healthy controls found the HIV group to have lower mean and higher SDs for their group AP conductances at all Jing Well points than the healthy group [14]. Another survey, studying a group of type 2 diabetes patients, identified a characteristic pattern of conductances for the pathology, agreeing with recognized TCM characteristics—with KI (kidney) meridian being lowest and SP (spleen) second lowest [17].

Here, we report Jing Well AP conductances for a group of patients with bronchial asthma, a noncommunicable heterogeneous pulmonary disorder characterized by recurrent episodes of coughing, breathlessness, and wheezing. Episodes may resolve spontaneously or with the help of bronchodilator medication [20]. The global prevalence of asthma is about 4.5%; including all age groups, 334 million patients suffer from asthma [21] worldwide. Its prevalence is increasing with time; a further 100 million people worldwide are expected to contract asthma by 2025 [22]. In India, its estimated prevalence in adults is 17 million [23], causing an annual loss of some 15 million disability-adjusted life years [21].

Control of asthma by modern medicine causes concern over side effects from the long-term use of drugs. Asthma's chronic nature and lack of curative medicines is driving many asthma patients to adjunct complementary medicine treatment [24] such as yoga [25] or acupuncture [26]. In the latter case, patients with bronchial asthma are treated according to the interior—exterior relationship of lung (LU) and large intestine (LI) meridians, in accordance with TCM's "collateral theory" [27].

The main hypothesis behind the present study was that Lung meridian energy can discriminate individuals with asthma from those with normal health in groups of similar age and sex. A second aim was to investigate any relationship between meridian activity (e.g., lung), peak expiratory flow rate (PEFR), and asthma severity through the Mini Asthma Quality of Life Questionnaire (MAQLQ).

PEFR is a tool used in asthma diagnosis and assessment. This involves the maximum flow rate generated during forceful exhalation reflects lung capacity. It also depends on voluntary effort and muscular strength [28].

The MAQLQ is a shorter and simpler version of the Quality of Life Questionnaire for Asthma patients. Fifteen items measure functional problems (physical, emotional, occupational, and social) that are most troublesome to adults with asthma. It is used extensively throughout the world and is available in many languages. MAQLQ is a self-administered questionnaire asking patients to recall their experiences during the past 2 weeks and to respond to each question on a 7-point scale (7 = no impairment, 1 = severe impairment) capable of measuring severity of condition [29].

Regarding AP measurements, each meridian shows diurnal changes in electrodermal conductance [30]. Conductances for both asthma and control groups were therefore measured at similar times of the day, between 9:00 AM and 12:30 PM. Other disturbing influences such as environment temperature and humidity [10] were recorded (temperature, 23.2–30.5°C; humidity, 48–75%) but not controlled. Reduction of instrumental variations [10] due to probe pressure, location, and position was achieved through using a single operator [13] for all measurements.

## 2. Materials and methods

### 2.1. Study design

In this study, a two-group cross-sectional design was used.

### 2.2. Participants

Fifty asthmatic patients aged 20–50 (35.36 ± 8.68) years under treatment in three clinics in West Bengal, and a health center in Bengaluru, and a comparison group of 50 healthy similarly aged (34.11 ± 7.29 years) controls from the same locations were recruited. The inclusion criteria called for participants who were diagnosed with asthma and who agreed to participate in the study. The exclusion criteria included any serious mental problem; hypertension; cuts or mole on, or close to, Jing Well meridian endpoints; finger or toe missing; implanted electronic devices.

The Swami Vivekananda Yoga Anusandhana Samsthana Institution Ethical Committee, an independent academic body gave approval for this study (Bangalore, India). All participants signed informed consent forms.

### 2.3. Assessments

AcuGraph4, the Digital Meridian Measuring System (Meridian Technologies Inc.) was used to measure each Jing Well point, i.e., acupuncture meridian endpoints or starting points on hands and feet, related to main organs: Lung (LU_L, LU_R), Pericardium (PC_L, PC_R), Heart (HT_L, HT_R), Small Intestine (SI_L, SI_R), Triple Energizer (TE_L, TE_R), Large Intestine (LI_L, LI_R), Spleen (SP_L, SP_R), Liver (LR_L, LR_R), Kidney (KI_L, KI_R), Bladder (BL_L, BL_R), Gall Bladder (GB_L,GB_R), and Stomach (ST_L, ST_R). Twenty-four independent measurements were thus taken on each patient, creating effectively 24 independent data sets for pairwise comparison between each group.

PEFR was also used to measure lung function, whereas the MAQLQ was administered to assess asthma severity.

Regarding the measurement procedure for AcuGraph4, participants were instructed to sit comfortably on a chair with feet on an electrically insulating mat. A damp cotton wool is applied to the probe to improve conductivity, and the participant holds a "ground bar" in the hand opposite to the one on which AcuGraph probe is applied. The monitoring computer records readings at specified points in a standard sequence.

### 2.4. Data analysis

Data analysis was carried out using SPSS version 19 (SPSS Inc., Chicago, IL, USA) and GraphPad QuickCalcs to compare the means and SDs of the two groups. Statistical tests used were independent samples $t$ test to compare group means, and Fisher's $F$ test to compare variances.

## 3. Results

Experience over several previous published experiments has shown that the important results from AcuGraph measurements on groups of participants are the means of AcuGraph measurements for each meridian, and also the variance about the mean generated by all the members of the group. This is because healthy individuals can generally be expected to show "healthier" distributions of acupoints skin conductance values, i.e., closer to the healthy young person's values of about 100 units, and, second, because smaller variances suggest that the subtle energies in each meridian are being more accurately maintained.

Accordingly, results of the measurements on the two groups, "Asthma" and "Healthy," are presented in Tables 1 and 2. Table 1 displays the group means and SDs for measurements of individual meridians, whereas corresponding values for the averages of various meridian selections are presented in Table 2. In Table 1, all group means of meridian conductance levels were higher for the Healthy group, as expected, whereas 10 out of 12 SDs were smaller for the upper meridians of the Healthy group, and 12 out of 12 SDs for the lower meridians of the Healthy group. Although the Fisher's $F$ statistic values were not highly significant, the statistical test on the categorical variables of greater than (gt) or less than (lt) achieves high significance. It confirms that the pathology group seems to exert poorer control over the AP conductances ("energies") than the Healthy group.

Table 3, therefore, compares SDs for the two groups, Asthma and Healthy, for groups of meridians, Upper, Lower and Overall. This shows very clearly that variances are significantly higher for the unhealthy group, i.e., Asthma. Table 4 compares the PEFR data for the two groups, showing clearly that values of this variable were much higher in the Healthy group. The MAQLQ, given only to the Asthma group, showed a mean value of 4.17 ± 0.87 (range, 2.53–5.46), corresponding to average to moderately bad asthma severity.

## 4. Discussion

The results show very clearly that measured AP conductance values for the two groups are very different, and that they conform to the general principle that healthy individuals exhibit better controlled, higher values of acupoints conductances/energies. The value of $p$ taken to be statistically significant was $< 0.05$ for all tests. Values of means to be compared on all meridian pairs were generated by completely independent sets of measurements, meaning that they involved independent degrees of freedom. Table 1 shows that for individual meridians, the Asthma group values were lower in all

**Table 1** Comparison of group means for the 24 organ linked meridians.

| | Asthma | Healthy | $t$ | $p$ |
|---|---|---|---|---|
| Upper meridians | | | | |
| LU_L | $69.16 \pm 34.45$ | $87.92 \pm 28.67$ | 2.96 | 0.004 |
| LU_R | $64.64 \pm 28.49$ | $76.00 \pm 25.36$ | 2.11 | 0.038 |
| PC_L | $62.88 \pm 29.59$ | $63.40 \pm 23.83$ | 0.097 | 0.923 |
| PC_R | $57.07 \pm 23.16$ | $60.88 \pm 22.12$ | 0.827 | 0.41 |
| HT_L | $56.68 \pm 27.45$ | $63.04 \pm 23.26$ | 1.25 | 0.214 |
| HT_R | $58.92 \pm 30.97$ | $62.00 \pm 24.16$ | 0.554 | 0.581 |
| SI_L | $66.32 \pm 26.55$ | $70.72 \pm 26.22$ | 0.834 | 0.406 |
| SI_R | $56.60 \pm 24.86$ | $65.56 \pm 25.88$ | 1.765 | 0.081 |
| TE_L | $59.04 \pm 29.03$ | $64.40 \pm 26.40$ | 0.966 | 0.337 |
| TE_R | $53.32 \pm 23.84$ | $60.40 \pm 25.88$ | 1.423 | 0.158 |
| LI_L | $68.56 \pm 31.75$ | $74.44 \pm 25.50$ | 1.021 | 0.31 |
| LI_R | $62.84 \pm 26.77$ | $67.76 \pm 21.37$ | 1.015 | 0.312 |
| Lower meridians | | | | |
| SP_L | $53.60 \pm 31.17$ | $58.48 \pm 25.61$ | 0.855 | 0.394 |
| SP_R | $52.20 \pm 33.92$ | $58.80 \pm 27.45$ | 1.07 | 0.287 |
| LR_L | $62.60 \pm 33.04$ | $65.36 \pm 29.88$ | 0.438 | 0.662 |
| LR_R | $57.56 \pm 37.15$ | $61.24 \pm 27.27$ | 0.565 | 0.574 |
| KI_L | $47.40 \pm 27.59$ | $57.76 \pm 25.86$ | 1.937 | 0.056 |
| KI_R | $44.32 \pm 26.85$ | $50.68 \pm 23.18$ | 1.268 | 0.208 |
| BL_L | $55.72 \pm 32.45$ | $72.64 \pm 29.83$ | 2.714 | 0.008 |
| BL_R | $50.76 \pm 31.07$ | $72.60 \pm 29.63$ | 3.597 | 0.001 |
| GB_L | $58.84 \pm 37.14$ | $72.20 \pm 26.77$ | 2.063 | 0.042 |
| GB_R | $54.48 \pm 33.49$ | $70.84 \pm 25.94$ | 2.731 | 0.007 |
| ST_L | $60.80 \pm 34.83$ | $69.44 \pm 26.95$ | 1.387 | 0.169 |
| ST_R | $53.40 \pm 31.35$ | $70.58 \pm 28.42$ | 2.87 | 0.005 |

Data are shown as means and SDs of AcuGraph conductance readings at Jing Well points for the Asthma and Healthy groups. This table also gives the $t$ and $p$ values for independent $t$ tests comparing group means for each meridian. Meridian names given in the first column are explained in the Materials and methods section, e.g., LU_L and LU_R indicate the left and right side branches of the Lung meridian.
BL = bladder; GB = gall bladder; HT = heart; KI = kidney; L = left; LI = large intestine; LU = lung; PC = pericardium; R = right; SD = standard deviation; SP = spleen; ST = stomach; TE = triple energizer.

**Table 2** Comparison of means and standard deviations of meridian groups.

| Variable | Asthma | Healthy | $t$ | $p$ |
|---|---|---|---|---|
| LOW | $47.8 \pm 23.61$ | $54.90 \pm 18.56$ | 1.67 | 0.98 |
| MEDIUM | $56.94 \pm 24.63$ | $66.16 \pm 20.59$ | 2.03 | 0.045 |
| HIGH | $64.66 \pm 27.25$ | $77.22 \pm 22.12$ | 2.53 | 0.013 |
| YIN | $57.10 \pm 24.72$ | $63.96 \pm 20.33$ | 1.515 | 0.133 |
| YANG | $58.28 \pm 25.06$ | $69.38 \pm 21.16$ | 2.393 | 0.019 |
| FIRE | $57.78 \pm 22.46$ | $63.42 \pm 22.61$ | 0.86 | 0.214 |
| EARTH | $54.98 \pm 30.70$ | $64.08 \pm 23.75$ | 0.098 | 0.101 |
| METAL | $65.96 \pm 27.87$ | $76.76 \pm 23.15$ | 2.108 | 0.038 |
| WATER | $49.28 \pm 27.32$ | $63.18 \pm 24.59$ | 2.673 | 0.009 |
| WOOD | $58.16 \pm 32.07$ | $67.00 \pm 24.69$ | 1.544 | 0.126 |
| PIE | $60.78 \pm 12.01$ | $63.86 \pm 10.07$ | 1.389 | 0.168 |
| E_L | $57.34 \pm 24.64$ | $66.16 \pm 20.39$ | 1.95 | 0.054 |
| E_S | $75.66 \pm 11.48$ | $74.50 \pm 7.17$ | 0.606 | 0.546 |
| U_L | $15.78 \pm 27.65$ | $7.96 \pm 24.30$ | 1.502 | 0.136 |
| L_R | $6.78 \pm 10.93$ | $3.78 \pm 9.14$ | 1.489 | 0.14 |
| YANG_YIN | $2.40 \pm 11.74$ | $7.00 \pm 9.58$ | 2.146 | 0.34 |
| PEFR | $273.91 \pm 90.44$ | $397 \pm 84.92$ | 6.89 | 0.0001 |

Data are shown as means and standard deviations (SDs) of groups of meridians for AcuGraph conductance readings at Jing Well points and peak expiratory flow rate (PEFR) for the Asthma and Healthy groups. Furthermore, $t$ and $p$ values are provided for the two groups.
E_L = overall energy level; E_S = energy stability; L_R = left to right meridians imbalance; U_L = upper to lower meridian imbalance.

**Table 3** Comparison of standard deviations for groups of meridians.*

| Meridian | Asthma | Healthy | $F$ | $p$ |
|---|---|---|---|---|
| Upper | $61.33 \pm 28.45$ | $68.04 \pm 25.97$ | 1.20 | 0.013 |
| Lower | $54.30 \pm 32.75$ | $65.05 \pm 27.97$ | 1.37 | $<0.0001$ |
| Overall | $57.8 \pm 30.85$ | $66.51 \pm 27.02$ | 1.31 | $<0.0001$ |

* $F$ values and corresponding $p$ values for 600 readings in each of the Upper and Lower blocks of meridians and for 1200 overall meridian readings for each group.

**Table 4** PEFR means and SDs by sex in Asthma and Healthy groups.*

| Sex | Asthma | Healthy | $t$ | $p$ |
|---|---|---|---|---|
| Male | $311.67 \pm 102.73$ | $448.33 \pm 61.14$ | 6.07 | $<0.0001$ |
| Female | $232.73 \pm 50.63$ | $320.5 \pm 50.72$ | 5.6 | $<0.0001$ |

PEFR = peak expiratory flow rate; SD = standard deviation.
* In the Asthma group, the number of males was 30 and the number of females was 20, whereas in the Healthy group, the number of males was 24 and the number of females was 22.

meridians, a result with a sign test significance ($p < 0.0001$), although only Lung, Bladder, and Gall Bladder pairs of meridians and Stomach Right (ST_R) reached significance of $p < 0.05$ individually. Here, the significant difference in Lung Meridian conductances between the two groups may be interpreted as attributable to impairment of function in lung, bronchioles, and bronchi because of the pathology.

Another significant observation is lower SDs for 22 out of 24 meridians for the Healthy group, a result with binomial test significance, again $p < 0.0001$. Measurements of variables for a group tend to have narrower distributions in healthy individuals for whom a given variable is well controlled. Loss of health can in general be equated with loss of quality of regulation of key variables, e.g., blood pressure in hypertension and blood sugar levels in diabetes. People with hypertension and diabetic individuals will in general exhibit poorer regulation of such variables, which may in turn be taken to correspond to lower quality of health of the group. Health can in general be equated with optimized regulation [31], and poorer quality of regulation in some form will always be found in a pathology group. Here, asthma seems to reduce the quality of regulation of all 24 variables being measured, resulting in higher variances in acupoint conductances at each acupoint for the Asthma group. Lower SDs may therefore be taken as an indication of better energy regulation for the group as a whole, confirming the identification of quality of regulation as an indicator of health: better quality of regulation corresponds to better health [31].

Table 2 shows corresponding results for selected groups of meridians, various kinds of imbalance, and PEFR. Again, note that for the meridians, the same points hold as for Table 1: means for the Asthma group are all lower, whereas SDs are all higher—as might be expected because Table 2 results are mostly derived from Table 1. Upper—Lower (U_L) and Left—Right (L_R) imbalances were both higher for the Asthma group. A hypothesis has been suggested that such imbalances are a measure of stress [17]; these imbalances are consistent with this idea, and the general observation that living with asthma is an ongoing cause of stress to the sufferer.

Table 3 shows that the variances of the two groups were significantly different according to Fisher's *F* test. This was applied to blocks of data for the two groups, the blocks of ($12 \times 50$) data points for both upper and lower meridians, and 1200 data points for all meridians. In all three cases, the Asthma group showed significantly higher variances, thus confirming the more informal comparison of SDs in Table 1, and the conclusion that lower quality of regulation corresponds to lower quality of health.

Table 4 displays results of PEFR tests by group and sex, confirming the results of Table 2. Considering the PEFR results by sex is important because mean female PEFR values are lower than corresponding male values, and it is important to show that differences between Asthma and Healthy groups on the PEFR scale are not attributable to sex differences.

Regarding the lower group of meridians, which also showed significant differences between normal and healthy groups, part of the difference was caused by the 7.82 difference in Upper—Lower imbalances given in Table 2. But all the meridians concerned had differences between Asthma and Healthy Groups between 14 and 22, so the U_L difference only accounts for about half that amount. The Bladder meridians are said to be connected to the emotion of anxiety [4], and lower values have indeed been observed for anxiety groups. The reason for Gall Bladder meridian being lower is not clear, nor is the distinction between kidney (not significant) and bladder (highly significant). TCM identifies both Lung and Large Intestine meridians as being compromised in asthma, but this study only identified the former as being significantly disturbed.

The strength of the study is that highly robust, significant results obtained between the two groups and that experimental hypotheses were confirmed. It is possible to identify characteristics of asthma by the energy values displayed in Tables 1 and 2. The limitation of the study was the possible inaccuracies introduced by AcuGraph measurements themselves. Because any such inconsistencies would have contributed to SDs, they would only have degraded the significance of the results, and the low *p* values observed are robust against any such interference.

## 5. Conclusion

Data obtained in this study confirmed the research hypotheses, and also the interpretation of lower SDs as a significant sign of higher quality of health in the control group. It also confirmed that lung meridian activity is compromised in asthma, and that the pathology generates high levels of imbalances, notably upper—lower and left—right imbalances. More surprising were observations of significantly lower activity in both Gall Bladder meridians and the Stomach right meridian.

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