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Electrodermal Activity at Acupuncture Points Differentiates Patients with Current Pain from Pain-Free Controls

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Abstract This study evaluated whether electrodermal resistance at acupuncture points (AP) systematically varies as a function of pain. The study was conceived as a proof-of-principle study in support of research on acupuncture and other complementary medicine approaches. Specifically, this study investigates whether or not electrodermal activity systematically differentiates arthritis patients with current pain from pain-free controls. Participants with rheumatoid arthritis (n = 32) and a typical pain level of at least 3 (on a 0–10 scale) were compared with case controls (n = 28) who had no medical diagnosis and were pain free. Electrodermal resistance at AP was measured with a commercial ohmmeter and compared to heart rate, blood pressure, and ratings on the Pain Catastrophization Scale and the McGill Melzack Pain Questionnaire. There were consistent differences between the experimental group and the control group on all markers of pain. Similarly, there were significant group differences and some trends for electrodermal activity at the AP labeled 'bladder,' 'gall bladder,' and 'small intestine.' It is concluded that the concept of electrodermal resistance at AP possesses criterion validity for distinguishing pain from a no pain state. This research provides support for the usefulness of measuring electrodermal activity when testing energy-based models of disease, and can be seen as a bridge between Western and Chinese medicine.

Keywords Electrodermal activity · Pain · Arthritis · Acupuncture point · Blood pressure · Heart rate

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Introduction

This study determined whether or not electrodermal resistance at acupuncture points (AP) systematically differentiates arthritis patients with current pain from pain-free controls. At a more global level, the study sought to build a bridge between Western and Chinese Medicine concepts and the introduction will define the key underlying concepts (i.e., meridians, AP, trigger points), build the rationale and formulate the hypotheses for this study. Chinese Medicine posits the existence of a 'meridian' system that is the functional equivalent of the circulatory system in that it carries 'qi energy' throughout the body. Meridians allegedly end at the skin surface in 24 distinct locations, 12 on each, the left/right side of the body respectively. Each of these endpoints is given a name, like 'gall bladder' or "small intestine". The name reflects the organ through which the meridian is believed to travel.

One approach to testing such predictions is by measuring differential electrical resistance at so-called APs. The existence of a meridian system is not accepted by Western Medicine and while this may discourage researchers, Chinese Medicine does allow predictions that can be tested with experiments and observational studies used for acupuncture (Lo 2002). APs located at the tips of the fingers and toes mark the end of each meridian. Researchers have confirmed that APs can be consistently differentiated from surrounding tissue using electrodermal resistance and tissue profusion measures (Ahn et al. 2009; Melzack et al. 1977; Zhang et al. 2004; Hsin et al. 2007; Lo 2002; Yang et al. 2007).

Particularly important for the development of testable hypotheses has been research on trigger points, which are functionally similar to APs, and which are often subjected to pain-reducing manipulation in multidisciplinary pain

clinics (Charlton 2005; Delaney et al. 2002; Garvey et al. 1989; Schultz et al. 2007; Schutze et al. 2010. Trigger points are nodules of fibrous tissue on the skin surface in areas of exposed blood vessels or neural tissue or in areas of past injury. The overlap of APs and trigger points has been studied in depth by Melzack et al. (1977) and their findings have been pivotal in building the rationale and hypotheses for this study. Using two different Traditional Chinese medical textbooks to clarify the relationship of APs and trigger points, they had identified the hypothesized location of trigger points (Kao and Kao 1973) and found that trigger points and the nearest AP were located within 3 cm of each other, and that APs and trigger point location had an overall correspondence in location of 71 %. It appears that pain trigger points and APs are largely in the same locations and equivalent in functional terms. A second important observation was that specific APs were associated with specific locations of pain. When pain was experienced in the joints of the neck, shoulders, back, hands, lower back, hips, knees, ankles and feet, six acupoints out of 24 were consistently implicated in this type of pain. In Chinese Medicine these six acupoints are labeled 'gall bladder', 'small intestine' and 'bladder' (left and right side respectively).

In an effort to expand Melzack et al.'s (1977) work we decided to test our hypotheses using the pain model of rheumatoid arthritis (RA). Patients with RA experience pain as a result of inflammation of the joints of the body. Although the joint locations may vary, the pain model is consistent from patient to patient. The small joints of the fingers, toes, hands, feet, wrists, elbows and ankles are usually involved in a symmetrical fashion. Inflammation and swelling of the joint stimulates pain receptors which activate the subjective perception of pain (McCaffrey and Pasero 1999).

Chinese medicine predicts that this pain is reflected by blocked meridian qi flow and Western medicine predicts that pain and inflammation is reflected in differential skin resistance at APs. Using the results of Melzack and colleagues, specific, testable hypotheses can therefore be generated.

We predicted that individuals with RA and currently in pain would show differences in skin resistance (relative to pain-free controls) at the six sites described as pain-sensitive by Melzack et al. (1977), namely 'gall bladder', 'bladder' and 'small intestine', left/right body side respectively. Furthermore, no between-group differences in electrical resistance were predicted for the remaining 18 APs. As objective markers of pain, blood pressure (BP) and heart rate were measured because they are often elevated in chronic pain reflecting a state of sympathetic overdrive (Delaney et al. 2002). This is considered to arise out of the stress of coping with chronic pain although some authors argue that this measurable sympathetic 'overdrive' may be due to chronic anxiety (Martinez-Lavin and Hermosillo 2000).

Methods

Overall Research Design

An experimental group was compared with a control group in a 2 × 2 repeated measures design. The main biological variables of interest were the electrical resistance at APs, heart rate, and BP. Psychological measures included the Pain Catastrophization Scale and the short form McGill-Melzack Pain Questionnaire. Measurements were completed during one 3-hour session in the second author's laboratory at the University of British Columbia.

Participants

Participants were recruited on a volunteer basis through the Arthritis Society of British Columbia. Control participants were roughly age-matched, and were either friends of the participants with arthritis or staff of the college where the first author works.

Inclusion Criteria

1. All clients spoke and understood English.
2. All clients in the control group were pain free and had no diagnosis of a painful condition or other chronic health condition such as cancer, heart disease, kidney disease, diabetes, or autoimmune disease.
3. All subjects in the experimental group experienced pain from RA and had no other diagnosed conditions; the RA had been diagnosed by a physician; RA pain must have had persisted since their original diagnosis and occurred with a typical pain level of at least 3/10 (Jacox et al. 1994) at the beginning of their study participation. This pain was considered 'controlled' using one or a combination of oral analgesics where 'Controlled' was defined as analgesics that reduce the pain at least two points on a 0–10 scale. Participants in the experimental group were asked to provide information about the year of their medical diagnosis with RA to ascertain length of disease presence. With the exception of being asked to refrain from using their pain medication the morning of participating in the study and to take their pain medication after the first measurement cycle, all other procedures were the same for both groups.

Electrical Resistance Measurement

The Prognos Ohmmeter used in this study is a commercially available ohmmeter (MedPrevent, Waldershof, Germany) consisting of a power source connected by a cable to the measuring probe and a reference electrode (6 × 3.5 cm) that is attached with a Velcro strap to the anterior surface of the forearm. Impedance measurements recorded as direct current analogue values are taken while holding the probe at a 90 degree angle to the acupuncture point (Colbert et al. 2004). The A/D converted values were displayed on a digital screen, showing the measured resistance values in kilo-ohms and the data are imported into a laptop computer via a serial cable (software by MedPrevent, Waldershof, Germany).

The Prognos instrument utilizes a 4.57 mm diameter flexible spring loaded probe tip and calculates an average electrical skin resistance value from 400 measurements taken in approximately 200 ms (www.medprevent.com). The probe tip has a maximum excursion of 6.91 mm, is connected to a linear spring, and lies flush to the plastic insulation at the end of a plastic cylinder. Within the cylinder, a light emitting diode transmits a light beam to a photo detector and the spring loaded probe disrupts the light beam and triggers a reading at an average deflection within 2.90 mm with an average force of 2.68 ± 0.05 Newton (Colbert et al. 2004). When triggered, the Prognos applies 1.1 milliamperes of current from the lower forearm strap to the probe tip for an average of 223 ± 3 ms. The Prognos Ohmmeter makes a consistent sound when a usable measurement is taken and indicates to the assessor to move to the next measure. This sound is optional and can be turned off. The actual location for the placement of the probe is determined by the experimenter based on an anatomical map (personal communication, Dr. Agatha Colbert, October 13, 2010).

Reliability

Trust in the Prognos device arose from two peer-reviewed reliability studies (Colbert et al. 2004; Turner et al. 2010). Colbert et al. (2004) studied electrical resistance at 24 acupoints in 31 healthy participants. Two hundred and eighty eight measurements were taken and all subjects completed three trials. The mean reliability for their first trial was 0.76 with a range of 0.55–0.88. When the acupuncture point was marked with nontoxic washable ink and remeasured, the mean reliability of a single measurement increased to 0.85 (range 0.69–0.96). The highest mean reliability of 0.96 (range 0.89–0.99) was made in trial 3 when four measurements were made in rapid succession. The authors report that higher reliability correlated with lower mean electrical skin resistance. They also suggest that the reliability of measures made for AP on the right side of the body were less reliable than measurements on the left side of the body. In preparation for our main study on arthritis pain, we conducted a second reliability study with 21 healthy subjects also using the Prognos Ohmmeter (Turner et al. 2010). The location of APs was marked with a colored, adhesive paper circle to ensure that the location of each repeated measurement was consistent. The results of this study indicated that when five readings were taken in rapid succession, Cronbach's alpha scores ranged between 0.84 and 0.95 with a mean of 0.88. Reliability scores with five measurements were superior to three measurements.

Blood Pressure and Heart Rate

A VSM-100 BpTRU automatic BP device was attached to the participant's non-dominant arm for the duration of this study to allow for easy access to BP and heart rate. The VSM-100 BpTRU automatic BP device has been found to be a reliable non-invasive measure within pediatric and adult populations aged 3–83 years (Mattu et al. 2004). In terms of validity, when compared to standard auscultatory mercury sphygmomanometer measurements, 89.2 % of the BpTRU measurements were within 5 mmHg, with 96.4 and 99.3 % of these measures being within 10 and 15 mmHg, respectively (Mattu et al. 2004). Furthermore, in a sample of hypertensive patients, the BpTRU monitor was found to correlate significantly better with daytime ambulatory blood pressure BP ($r = 0.57$) than clinic averages ($r = 0.15$; Mattu et al. 2004).

Psychological Measures

McGill-Melzack Pain Questionnaire (MPQ) The short form of the MPQ (SF-MPQ) was chosen to assess the specific pain experience for participants with RA because it differentiates between different types of pain (Turk 2001) and taps into the sensory and the affective dimensions of pain (Melzack 1987). The short form of the MPQ (SF-MPQ) contains 11 questions referring to the sensory dimension of the pain experience and four related to the affective dimension. Each descriptor is ranked on a four-point intensity scale (scores ranging from 0 to 3). The pain rating index of the standard MPQ is also included as well as a visual analogue scale.

Repeated administrations of the MPQ to cancer patients revealed a consistency index of 75 % (range 35–90 %) between the first two administrations (Melzack 1976). As well, the MPQ was highly replicable in two samples (Graham et al. 1980) and the sensory, affective, and total scores of the MPQ and SF-MPQ were found to be significantly correlated (Melzack 1987). The MPQ was developed

to indicate the extent of change in pain quality and intensity as a result of an intervention. Both the MPQ and SF-MPQ are sensitive to the effects of analgesic drugs, epidural blocks, and Transcutaneous Electrical Nerve Stimulation. The MPQ has been widely used, and MPQ descriptor patterns can discriminate between known pain syndromes, major types of known back pain, and facial pain (Melzack 1976; Turk 2001). A comparison of MPQ scores for acute pain and chronic pain revealed that patients with acute pain displayed a greater use of sensory word groups while chronic pain patients endorse affective and evaluative groups with greater frequency. The SF-MPQ takes about 5 min to administer and was developed to provide a brief assessment. Both the MPQ and SF-MPQ can be interviewer administered or self-administered.

The Pain Catastrophizing Scale

The Pain Catastrophizing Scale (PCS; Sullivan et al. 1995) was chosen because of recent research findings linking the influence of catastrophizing on pain in the context of rheumatic disease. Campbell and Edwards (2009) suggested that catastrophizing may be associated with systemic inflammatory processes and that there is an association between helplessness and physiological inflammatory indices, including erythrocyte sedimentation rates and C-reactive protein levels. Overall, catastrophizing is thought to exhibit a broad influence on the perception of pain. fMRI studies reveal criterion validity in that catastrophizing cognitions are associated with amplification of cortical activation in the context of pain (Campbell and Edwards 2009). The PCS is a 13-item questionnaire developed by Sullivan et al. (1995). Eight statements of the PCS were derived from examples of catastrophizing ideation provided by Spanos et al. (1981), Chaves and Brown 1987). In addition, five items from the catastrophizing subscale of the Coping Strategies Questionnaire (CSQ; Rosenstiel and Keefe 1983) were included in the PCS. The first component, labeled 'rumination,' accounted for 41 % of the total variance and contained four items describing ruminative thoughts, worry, and an inability to inhibit pain-related thoughts. The second component, labeled 'magnification,' accounted for 10 % of the variance and contained three items reflecting magnification of the unpleasantness of pain situations and expectancies for negative outcomes. The third component, labeled 'helplessness,' accounted for 8 % of the variance, and contained the five items from the CSQ and one item reflecting the inability to deal with painful situations. Scale items loaded negatively on the third component so that high scores indicate low levels of helplessness. Rumination and helplessness were correlated, $r = -0.50$. Rumination and helplessness also correlated with magnification ($r = 0.32$ and $r = -0.30$ respectively).

The three subscales corresponding to the component structure of the PCS were computed by summing items within each factor. Coefficient alphas were 0.87, 0.60 and 0.70 for the rumination, magnification, and helplessness subscales, respectively. Coefficient alpha for the total PCS was 0.87 (Sullivan et al.) The moderate correlations among the three components of the PCS and the high internal consistency of the total PCS suggest that rumination, magnification, and helplessness can be viewed as different dimensions of the same underlying construct. This tool has been validated in a sample of chronic pain outpatients where the three subscales have shown good reliability with Cronbach's alpha coefficients of 0.85, 0.75 and 0.86 respectively (Schutze et al. 2010). The total PCS score in the outpatient group had good criterion-related validity and internal consistency with a reliability coefficient of 0.92 (Schutze et al. 2010).

Procedure

A pain level of 3/10 was chosen as a cut-off for participants with RA. A general quantification for 10-point pain scales indicates that mild pain falls in the range of 1–3 (McCaffrey and Pasero 1999).

Thirty-two participants with RA and a current pain level of at least 3 on a 0–10 scale were compared with 28 subjects who were pain free and had no medical diagnosis. Two control subjects were experiencing pain at a level of less than 1 from a headache or muscle strain. Participants were contacted by the principal Investigator by telephone to determine eligibility for the study. A research assistant met with each participant to obtain informed consent and to collect demographic data. All data were collected within a similar time of day given that previous evidence suggested systematic diurnal variations of AP activity. Most patients with RA were normally taking a short-acting pain medication, which they were asked not to take on the day of the test and prior to coming to the laboratory. Nevertheless, five participants were well maintained on long-acting medication such as methotrexate and were unwilling to interrupt their pain management regime for participation in this study. These participants continued with their regular medication regime. The remaining participants ($N = 28$) withheld their pain medication until arriving at the laboratory, completed the first assessment and then took a short-acting medication. Medications taken included plain Tylenol, Aspirin, Tylenol with codeine, Advil, and a variety of non-steroidal anti-inflammatory medications and herbal remedies.

For the baseline assessment, a research assistant asked each participant to complete the MPQ and the PCS. The research assistant then measured participants' heart rate, BP, and electrical resistance at APs. After completion of

the baseline measures, all participants were asked to wait an hour during which they relaxed in a chair, and then the measurements of heart rate, BP, and electrodermal activity were repeated along with the MPQ pain score. The PCS was not repeated as it was felt that no change could reasonably take place during the 1 h period given that the construct is conceived as possessing a trait character.

Measurement with Prognos Ohmmeter

The principal investigator was trained in the use of the Prognos Ohmmeter by a representative from the Med Prevent Company, Waldershof, Germany, and practiced taking measurements over a 9 month period prior to beginning this study. The representative from Med Prevent determined that the principal investigator was proficient in both taking measurements and in teaching others how to take the measurements according to standards set by the company related to operation of this device. Both research assistants were trained by the principal investigator for 3 weeks in several supervised practice sessions until criteria set by Med Prevent had been met. Criteria included the ability to operate the ohmmeter, obtain and retrieve measurements from the computer program, basic trouble shooting, and knowledge of available resources (Med Prevent Company, Waldershof, Germany).

Testing took place between the hours of 8:00 AM and 12:00 PM to account for potential diurnal rhythmicity (Colbert et al. 2006). Ambient temperature during testing ranged from 19 to 22 °C.

Participants were asked to sit quietly in an upright reclining chair. The time between arrival at the laboratory and the first AP measurement was approximately 20 min. When data were collected from the toes, the reclining chair was activated so that the feet were elevated. Participants were told that the measurements would be repeated 5 times in rapid succession.

The research assistant wore clean white cotton gloves to prevent any contamination of measurements by the research assistant's skin oils. Research assistants briefly cleansed the participants' skin with alcohol and allowed the skin to dry. Coloured adhesive reinforcers (otherwise used for 3-hole punch note paper) were used to mark the APs on the fingers and toes of each participant at each of the 24 AP locations to save time and and ensure the correct placement of the Prognos probe with each measurement.

The reference electrode was secured to the left wrist with a Velcro strap. Participants were not able to see the computer screen as measurements were taken. Electrical resistance at the 24 APs was recorded during 5 rapid repeat measurement cycles. Once a participant was prepared and the marker rings were placed over the APs, each complete measurement cycle took about 2 min. All 5 measurements were used in the calculation of the average results presented in this study (Colbert et al. 2004; Turner et al. 2010). The study was approved by the University of British Columbia Clinical Research Ethics Board.

Results

Analytical Strategy

The results section has three subsections:

1. Description of the sample and validation check. The goal of the validation check was to assure that the pain sample, at rest, was truly distinct from the pain-free control sample in terms of objective markers of pain;
2. Test the main hypothesis that there would be group differences in AP activity at rest by determining the nature of associations of AP readings relative to objective pain measures;
3. Assessment of change over time, testing the hypothesis that pain patients show a distinct change in pain measures and corresponding AP activity after taking an analgesic.

The first two sets of questions were assessed by one-way ANOVAs with group as the independent variable. Given that the measures comprised different classes (i.e., self-report and biological), no correction for family-wise error was undertaken with the exception of the AP data. Given that they represent 24, likely intercorrelated, variables, this called for attention regarding a potential family-wise error problem. Analysis of group differences for AP activity was therefore subjected to multivariate testing using MANOVA (Hotelling's t test), which controls for family-wise error.

The third set of questions, related to change over time, was assessed via multivariate one-way residualized change score analysis controlling for group differences at rest. In this research, given its exploratory nature, it was determined that a 0.05 level of significance would be considered supportive evidence for the hypothesis of a group difference.

Description of the Sample

A description of the sample is found in Table 1.

All subjects in the experimental group experienced joint pain and 4 subjects experienced additional musculoskeletal pain. Two control group participants had reported very minor pain at a level of less than 1 from headache or musculoskeletal pain, the others scored 0. Although the two groups were generally very similar, a notable group difference was that 25/32 participants with arthritis lived alone whereas only 11/23 no-pain participants lived alone.

Table 1 Sample description

Sample size (N)	Pain 32	No pain 28
Age	54.9 (15.7)	47.3 (11.8)
Pain level at baseline	4.5 (2.1)	0.21 (0.5)
Usual pain level	4.45 (1.9)	0.15 (0.5)
Pain level, 1 h later	2.66 (2.0)	0.36 (0.9)
Male (N)	8	7
Female (N)	24	21
Married or stable relationship (N)	7	17
Living alone (N)	25	11
Participants with children (N)	14	11
Religious (N)	18	19
Regular exercise (N)	14	8

Table 2 Cardiovascular and pain measures (means and SDs)

	Pain N = 32	No pain N = 28	Significance of difference
Systolic BP, mmHg	117 (16)	107 (10)	$p = .005$
Diastolic BP, mmHg	74 (8)	69 (8)	$p = .021$
Heart rate, b/min	67 (8)	63 (7)	$p = .037$
McGill pain rating	30 (20)	6 (7)	$p < .001$
Pain Catastrophization	21 (11)	8 (8)	$p < .001$

Experimental subjects reported that they typically used a wide variety of analgesic and other types of medication. The following list provides the number of experimental subjects who reported using each medication: Vitamins, glucosamine, herbal medication, (N = 18); Non-steroidal anti inflammatory medication, (N = 13); Methotrexate, (N = 12); Tylenol, (N = 11); Plaquenil, (N = 9); Prednisone, (N = 8); Ativan, (N = 5); Enbrel, (N = 4); Amitriptyline, (N = 4); Oxycodone, (N = 3); Leflunomide, (N = 3); Baclofen, (N = 2); Orencia, N = 2); Arthrotec, (N = 2); Myochrisine, (N = 1); Lamictal,(N = 1); Acterma, (N = 1) and other (N = 12), (numbers exceed 32 due to participants taking multiple medications).

Comparison of Pain/No Pain Groups at Rest: Validation Check

It was critical for this study to show that the pain group was indeed distinguishable from the pain-free control group on indicators of sympathetic activation (i.e., BP and heart rate, Delaney et al. 2002) as well as standardized reports of the pain experience. The data (see Table 2) show significant group differences on all markers of pain including heart rate, BP, MPQ, and PCS.

Table 3 Location of APs in pain participants

Pain location	Pain location in (N) experimental subjects	Acupuncture point and meridian implicated
Legs, musculoskeletal	2	Gall bladder
Shoulder back arm	2	Gall bladder, bladder
Neck	14	Small intestine, gall bladder
Joint pain feet	14	Bladder
Joint pain ankles	13	Gall bladder
Joint pain knees	16	Gall bladder
Joint pain hips	6	Gall bladder
Joint pain hands	25	Small intestine
Joint pain lower back	25	Bladder

Comparison of Pain/No Pain Groups at Rest and Association of Acupuncture Point Measures to Other Pain Markers

All participants in the pain group marked the location of their pain on the diagram of the MPQ. These locations were identified and tabulated. See Table 3 for an outline of the types of pain experienced by this group of experimental participants. The Melzack et al. (1977) findings described above had provided the empirical basis for predicting which APs would reveal pain-related differences between the two groups. The multivariate F-test for these six dependent variables revealed an overall significant difference between pain and no pain control groups ($F [6, 54]) = 2.22$, $p = .05$). The pertinent mean scores for all AP measurements are listed in Tables 4 and 5. Post hoc *t* tests indicated a significant difference in the 'left' and 'right small intestine' AP between subjects with pain and those who were pain free. This AP according to Melzack et al. (1977) is related to joint pain in the neck and hands, which most subjects in the pain group experienced.

All AP measurements had a large standard deviation. In order to correct for this, the log of each measurement had been taken and a subsequent *t* test of the logarithms remained significant between the groups. Given that acute use of pain medication could be a confound, and that five participants had indicated using their long-term analgesic regimen even on the test day, the data from these participants were removed and the analyses were rerun without them. The pattern of results was the same, indicating that the inclusion of these five participants had not distorted the observed results.

Concordance of Self-Reported Pain and AP Activity

Given this study's objective to serve as a validation of the AP concept, and to attempt a proof-of-principle, it is valuable to not only show group differences by comparing

Table 4 Mean resistance in Kilo Ohms over specific APs at baseline

	No pain (N = 28)	Pain (N = 32)
Left lung	14,703 (10,257)	18,875 (11,326)
Right lung	14,806 (11,140)	19,477 (11,946)
Left large intestine	14,938 (10,906)	18,950 (11,976)
Right large intestine	15,040 (11,756)	20,280 (14,265)
Left stomach	10,418 (6,008)	13,889 (9,896)
Right stomach	9,682 (8,781)	12,436 (11,503)
Left spleen pancreas	10,001 (8,340)	15,206 (13,929)
Right spleen pancreas	10,721 (7,859)	16,654 (13,205)
Left heart	15,808 (12,029)	18,361 (11,424)
Right heart	14,718 (9,911)	15,950 (9,532)
Left small intestine	12,263 (8,133)	18,641 (12,509)
Right small intestine	12,528 (9,676)	18,373 (9,394)
Left bladder	14,951 (10,562)	21,955 (14,606)
Right bladder	14,892 (10,788)	16,648 (11,858)
Left kidney	11,482 (9,337)	14,033 (11,548)
Right kidney	11,207 (10,201)	13,529 (11,369)
Left circulation	16,460 (10,348)	19,577 (12,544)
Right circulation	16,839 (11,415)	21,414 (13,459)
Left triple heater	17,189 (12,532)	21,855 (13,624)
Right triple heater	18,878 (14,199)	23,417 (11,681)
Left gall bladder	12,388 (9,425)	15,125 (11,078)
Right gall bladder	9,554 (6,414)	14,755 (12,069)
Left liver	10,022 (8,050)	13,499 (10,698)
Right liver	8,759 (5,640)	12,772 (11,829)

Table 5 Mean resistance in Kilo Ohms for APs hypothesized to be pain-sensitive

	No pain	Pain	Significance
Left small intestine	12,263 (8,133)	18,641 (12,509)	.037
Right small intestine	12,528 (9,676)	18,373 (9,394)	.026
Left bladder	14,951 (10,562)	21,955 (14,606)	.058
Right bladder	14,892 (10,788)	16,648 (11,858)	.652
Left gall bladder	12,388 (9,425)	15,125 (11,078)	.375
Right gall bladder	9,554 (6,414)	14,755 (12,069)	.063

means but to study synchrony between measures by computing correlations between measures that had been predicted to be inter-related. In this vein, we correlated the McGill pain scores with electrodermal resistance at APs. See Table 6 for the results of this computation. Table 6 reveals small to moderate correlations of subjective pain ratings with AP activity for almost all pairings, with eight out of 24 scores reaching statistical significance at $p < .05$, one at $p = .01$, and 5 scores reaching $p < .001$ levels. Together this suggests a modestly strong but consistent linkage between self-reported pain and elevated skin resistance at APs.

Table 6 Correlation of AP resistance and MPQ scores

Meridian	Correlation coefficient
Left lung	.294*
Right lung	.225
Left large intestine	.222
Right large intestine	.192
Left stomach	.320**
Right stomach	.360***
Left spleen pancreas	.391***
Right spleen pancreas	.348**
Left heart	.181
Right heart	.096
Left small intestine	.310*
Right small intestine	.259*
Left bladder	.228
Right bladder	.287*
Left kidney	.258*
Right kidney	.276*
Left circulation	.228
Right circulation	.093
Left triple heater	.261*
Right triple heater	.246
Left gall bladder	.247
Right gall bladder	.300*
Left liver	.391***
Right liver	.450***

*** $p < .001$ ** $p < .01$ * $p < .05$

Comparison of Pain/No-Pain Groups, 1 h Interval

Residualized change score analysis was used to determine the difference between pain and no pain groups for the repeated measures taken before and after the 1-h interval during which the pain patients ingested an analgesic. One hour is considered to be an adequate amount of time for a short acting oral analgesic to take effect (Brunton et al. 2006). Residualized change score analysis is a type of covariance analysis that individually adjusts for any potential confound of differences in baselines that may affect subsequent degree of change. Residualized change scores are derived by calculating the predicted change score as a function of the correlation between baseline and subsequent change scores.

Recall that there were five participants who did not take a short acting medication during the break as they were maintained on long acting medications. Analyses were performed including and excluding these five participants. None of the analyses were significant.

The multivariate F test for the 24 AP measures between pre-medication and post- medication was not significant (F [24, 35] = 1.28, $p = .250$). The multivariate F test result, when participants who did not take a short acting medication are removed from the group, was also non-significant (F [24, 30] = 1.04, $p = .452$). The multivariate F test for only the AP labeled "bladder", "gall bladder," and "small intestine" was similarly non-significant both when all subjects were included (F [6,53] = 0.43, $p = .859$) and also when subjects who did not take a short acting medication were removed (F [6.48] = 0.77, $p = 0.597$). Tables 7 and 8 describe the group differences in change over time.

Discussion

The purpose of this study was to explore electrical skin resistance at APs implicated in certain locations of pain and their ability to distinguish pain from non-pain individuals. An experimental protocol aiming at high internal validity was chosen to assure interpretability of findings.

The main finding of this study was that electrodermal measurements at APs revealed significant group differences at two APs and revealed a trend on two other APs. The overall multivariate F-value was significant and this type of analysis is considered to be a conservative test. The four responsive APs, in turn, are included in the cluster of six AP suggested by Melzack et al. 1977) as reflective of differential pain experiences. Interestingly, no significant differences were observed at any of the other 18 APs, thus reflecting a degree of specificity in the results. Furthermore, the group differences on the electrical resistance measure were consistently matched by group differences on pain self-report as well as other physiological markers, and there was a significant correlation between self-reported pain and elevated electrodermal scores on 14/24 APs.

Critical to the internal validity of this protocol was that the pain group was clearly different from the control group on traditional measures of pain including BP, heart rate, PCS, and MPQ. The results indicated that this requirement was consistently met and this speaks to the internal validity of this protocol. Nevertheless, it is possible that the group differences simply reflected that one group had a chronic illness whereas the other did not. The current study was not designed to absolutely rule out such an interpretation; however, this question can be resolved in replication studies where arthritis patients with high levels of pain are compared to arthritis patients with low levels of pain. Another worthwhile replication attempt would use another clinical condition that is also characterized by chronic pain. Having said that, the consistency of results and the high degree of synchrony between self-reported pain and objective electrical resistance at APs speaks against the likelihood of this alternative explanation being true.

Not yet discussed is a singular difference in participant characteristics, namely that about 2/3 of the arthritis patients were living alone whereas only a 1/3 of the controls were living alone. An attempt to interpret this result remains speculative because this was not a longitudinal study. It is possible that a painful chronic disease may put additional strains on a relationship that could result in a high rate of marital dissolution. Notably, the average number of children that participants in both groups had were very similar which suggests that the arthritis patients may not always have been in greater social isolation. Social

Table 7 Electrical resistance pre- and post medication

	Pre medication	Post medication
Left lung	16,711 (10,992)	16,316 (12,904)
Right lung	17,137 (11,269)	14,908 (10,516)
Left large intestine	16,901 (11,556)	15,156 (11,671)
Right large intestine	17,586 (13,339)	14,587 (11,164)
Left stomach	12,116 (8,442)	11,919 (7,777)
Right stomach	11,012 (10,302)	10,081 (7,898)
Left spleen pancreas	12,639 (11,809)	11,575 (9,925)
Right spleen pancreas	13,712 (11,336)	12,152 (9,866)
Left heart	17,084 (11,602)	15,274 (10,291)
Right heart	15,211 (9,652)	14,446 (10,151)
Left small intestine	15,457 (11,107)	14,109 (10,515)
Right small intestine	15,551 (9,837)	14,244 (10,483)
Left bladder	18,436 (13,284)	17,446 (11,749)
Right bladder	15,613 (13,472)	15,282 (10,417)
Left kidney	12,724 (10,517)	12,364 (9,013)
Right kidney	12,433 (10,722)	12,794 (9,157)
Left circulation	17,900 (11,615)	16,374 (11,186)
Right circulation	19,045 (12,680)	16,589 (12,421)
Left triple heater	19,450 (13,234)	18,117 (13,495)
Right triple heater	21,155 (12,947)	17,122 (12,313)
Left gall bladder	13,675 (10,347)	12,600 (9,013)
Right gall bladder	12,162 (10,108)	12,367 (9,323)
Left liver	11,721 (9,632)	11,753 (8,802)
Right liver	10,749 (9,591)	10,173 (6,769)

Note that none of these group means differ significantly in a pairwise comparison

Table 8 Residualized change score results for medication effects on BP, HR, and MPQ

Measurement	F value	Significance
Systolic blood pressure	0.040	.843
Diastolic blood pressure	1.619	.210
Heart rate	1.821	.185
Mc Gill pain questionnaire	20.23	<.001

isolation itself can be seen as a greater stressor that could account for greater sympathetic arousal.

Electrical Resistance at APs: Differences Over Time

There was no significant difference between AP measurements taken at rest compared to measurements taken 1 h after taking an analgesic medication. While disappointing, this result may not be particularly surprising. Objective measures of physiological activation (BP and HR) also showed no differences whereas subjective pain reports showed a significant and clinically meaningful decline. This desynchrony may be a reflection of the fact that subjective pain levels can change relatively quickly and that changes in physiological markers (which at baseline reliably discriminated the two groups) naturally follow a slower time course. The biological markers could be reflective of a more generalized, and therefore more slowly changing, response to pain. This would be consistent with the fact that participants had been instructed to take a pain medication that they typically used for short term pain relief and the self-reported level of pain did decrease significantly. No attempt was made to control what type of medication the participant took. In five cases, the participant's pain was controlled by a long acting pain medication. In order to find a difference between rest and post analgesic medication, it would be important to control the type of medication taken. AP measurements taken at baseline compared to those taken 1 h later showed a non-significant tendency to habituate during the hour of laboratory wait time. This small habituation effect, even though non-significant, can still make it difficult to show group-specific differences.

Relationship of Electrical Resistance over APs to Location of Pain

When the multivariate analysis was conducted considering the electrical resistance of APs reflecting the 'small intestine', 'bladder' and 'gall bladder' APs, the results demonstrate a significant difference between pain patients and pain-free control participants. The confirmation of this predicted finding is seen as the most important and exciting finding of this study. Although we found support for our hypothesis working with the arthritis pain model, extending these results to other disease states will require large scale validation of the AP concept. Our results encourage such future studies and testing specificity of the presumably underlying meridian activity will require systematic mapping of AP activity across all diseases for which acupuncture and other alternative medicine approaches are posited to be clinically effective. As such, the current findings are merely a beginning of such needed validation processes.

Weaknesses and Strengths

The readings in KOhms obtained with the ohmmeter were high in comparison to those obtained by Colbert et al. (2004, 2006). Colbert suggests that the size of the probes may have differed between laboratories, and also suggests that the absolute values are not important due to the naturally high degree of variability between subjects (Dr. A. Colbert, personal communication, August 15, 2010).

The study had a relatively small sample. Research assistants could not be blinded to the participants group status. Research assistants found that individuals in pain needed help to settle into the chair and were recognizably different from control participants. It is theoretically possible that measurements were taken in a different way between experimental and control group but given that experimenters followed a written manual for the protocol steps, such a confound is not likely.

Strengths of the study include the reliability of the Prognos Ohmmeter, which had been clearly established prior to the beginning of the study. The reliability, reflected in a Cronbach's alpha of 0.88, replicated the results of Colbert et al. (2004). Being able to replicate the reliability in a different laboratory and obtaining such a high reliability score supports the usefulness of this ohmmeter. Another strength is that all measurements were taken between 9:00 am and 12:00 pm to account for the potential influence of diurnal rhythm changes.

Conclusions

An ohmmeter previously shown to have good reliability was able to differentiate between a pain and a non-pain group when measuring electrical resistance at certain acupoints. The device and the construct measured by it therefore possess criterion validity. This work represents a bridge between traditional Chinese medicine and Western medicine and shows the inter-relatedness of concepts used by both types of approaches. Further, this study demonstrates that the principles of Chinese Medicine can be empirically tested.

References

Ahn, A. C., Schnyer, R., Conboy, L., Laufer, M. R., & Wayne, P. M. (2009). Electrodermal measures of jing-well points and their clinical relevance in endometriosis-related chronic pelvic pain. *The Journal of Alternative and Complementary Medicine, 15*, 1293–1305.

Brunton, L., Lazo, J., & Parker, K. (Eds.). (2006). *Goodman and Gillman's: The pharmacological basis of therapeutics* (11th ed.). New York: McGraw-Hill Company.

Campbell, C. M., & Edwards, R. R. (2009). Mind-body interactions in pain: The neurophysiology of anxious and catastrophic pain-related thoughts. *Translational Research, 153*, 97–101.

Charlton, J. E. (Ed.). (2005). *Core curriculum for professional education in pain*. Seattle: IASP Press.

Chaves, J. F., & Brown, J. (1987). Spontaneous coping strategies for pain. *Journal of Behavioral Medicine, 10*, 263–276.

Colbert, A., Hammerschlag, R., Aickin, M., & McNames, J. (2004). Reliability of the prognos electrodermal device for measurement of electrical skin resistance at acupuncture points. *The Journal of Alternative and Complementary Medicine, 10*, 610–616.

Colbert, A., Hayes, M., Aickin, M., & Hammerschlag, R. (2006). Physiological variability of electrical skin resistance measurements at the ting acupuncture points. *Medical Acupuncture, 17*, 1–10.

Delaney, J. P. A., Leong, K. S., Watkins, A., & Brodie, D. (2002). The short-term effects of myofascial trigger point massage therapy on cardiac autonomic tone in healthy subjects. *Journal of Advanced Nursing, 37*, 364–371.

Garvey, T. A., Marks, M. R., & Wiesel, S. W. (1989). A prospective, randomized, double-blind evaluation of trigger-point injection therapy for low-back pain. *Spine, 14*, 962–964.

Graham, C., Bond, S., Gerkovich, M., & Cook, M. (1980). Use of the McGill pain questionnaire in the assessment of cancer pain: Replicability and consistency. *Pain, 8*, 377–387.

Hsin, H., Huang, S. M., Chao, P. T., Jan, M. Y., Hsu, T. L., Wang, W. K., et al. (2007). Microcirculatory characteristics of acupuncture points obtained by laser doppler flowmetry. *Physiological Measurement, 28*, N77–N86.

Jacox, A., Carr, D., & Payne, R. (1994). *Management of cancer pain clinical practice guidelines, no 9, AHCPR*.

Kao, F. F., & Kao, J. J. (1973). *Acupuncture therapeutics*. New Haven, Conn: Eastern Press.

Lo, S. Y. (2002). Meridians in acupuncture and infrared imaging. *Journal of Medical Hypotheses, 58*, 72–76.

Martinez-Lavin, M., & Hermosillo, A. G. (2000). Autonomic nervous system dysfunction may explain the multisystem features of fibromyalgia. *Seminars in Arthritis and Rheumatism, 29*, 197–199.

Mattu, G. S., Heran, B. S., & Wright, J. M. (2004). Overall accuracy of the BP tru an automated electronic BP device. *Devices and Technology, 9*, 47–52.

McCaffrey, M., & Pasero, C. (1999). *Pain, clinical manual* (2nd ed.). Toronto: Mosby.

Melzack, R. (1976). The Brompton mixture: Effects on pain in cancer patients. *Canadian Medical Association Journal, 115*, 125–129.

Melzack, R. (1987). The short-form McGill pain questionnaire. *Pain, 30*, 191–197.

Melzack, R., Stillwell, D. M., & Fox, E. J. (1977). Trigger points and acupuncture points for pain: Correlations and implications. *Pain, 3*, 3–23.

Rosenstiel, A. K., & Keefe, F. J. (1983). The use of coping strategies in chronic low back pain patients: Relationship to patient characteristics and current adjustment. *Pain, 17*, 33–44.

Schultz, S., Driban, J. B., & Swanik, C. B. (2007). The evaluation of electrodermal properties in the identification of myofascial trigger points. *Archives of Physical Medicine Rehabilitation, 88*, 780–784.

Schutze, R., Rees, C., Preece, M., & Schutze, M. (2010). Low mindfulness predicts pain catastrophizing in a fear-avoidance model of chronic pain. *Pain, 148*, 120–127.

Spanos, N., Brown, J., Jones, B., & Horner, D. (1981). Cognitive activity and suggestions for analgesia in the reduction of reported pain. *Journal of Abnormal Psychology, 90*, 554–561.

Sullivan, M. J. L., Bishop, S., & Pivik, J. (1995). The pain catastrophizing scale: Development and validation. *Psychological Assessment, 7*, 524–532.

Turk, D. (2001). Combining somatic and psychosocial treatment for chronic pain patients: Perhaps $1 + 1 = 3$. *Clinical Journal of Pain, 17*, 281–283.

Turner, L., Linden, W., Talbot-Ellis, A., & Millman, R. (2010). Measurement reliability for acupoint activity determined with the Prognos ohmmeter. *Applied Psychophysiology and Biofeedback, 35*, 251–256.

Yang, H. Q., Xie, S. S., Liu, S. H., Li, H., & Guo, Z. Y. (2007). Differences in optical transport properties between human meridian and non-meridian. *American Journal of Chinese Medicine, 35*, 743–752.

Zhang, W., Jeong, D., Lee, Y., & Lee, M. S. (2004). Measurement of subcutaneous impedance by four-electrode method at acupoints located with single-power alternative current. *American Journal of Chinese Medicine, 32*, 779–788.