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An infrared radiation study of the biophysical characteristics of traditional moxibustion

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KEYWORDS
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Summary
Objectives: Moxibustion has been a part of acupuncture practice for thousands of years. Traditionally, it includes direct moxibustion, in which moxa sticks are burned at acupuncture points on the skin, and indirect moxibustion, in which monkshood cakes or ginger or garlic slices are used to insulate the skin from burning moxa cones. Recently randomised clinical trials and clinical observations suggest that moxibustion can enhance physiological and immune functions, but there has been little investigation of the scientific basis of these traditional techniques. The present study compared the infrared radiation caused by these techniques to that of non-specific controls and to that of the human body surface at an acupuncture point.
Methods: A highly sensitive, infrared-spectrum detection device was used to compare the spectra of traditional moxibustion materials ($n = 4$/group) with those of control materials ($n = 4$/group) and to the spectrum at the surface of an acupuncture point LI 4 (Hegu) in healthy volunteers ($n = 7$).
Results:
(1) The infrared radiation intensity produced by a traditional moxa stick was 43300.41 mV, with a peak on the infrared spectrum of 3.5 μm, while the respective radiation intensities of two controls, a smokeless moxa stick and a 555 cigarette, were 31.15 mV and 37.03 mV with peaks of 7 μm and 3.5 μm.
(2) The infrared radiation intensities of the three traditional media of indirect moxibustion, monkshood cake, ginger slices and garlic slices, were 520.27 mV, 594.79 mV and 681.87 mV, respectively, all with peaks around 7.5 μm and similar spectra. In contrast, the infrared radiation intensities of slices of cucumber and carrot, used as control media for indirect moxibustion, were 274.47 mV and 50.53 mV, respectively, substantially different from those of the traditional media.

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[(3)]Infrared radiation at LI 4 (Hegu) was 20.40 mV, and peaked on the infrared spectrum at about 7.5 μm.
The experiment showed that the thermal action of the traditional moxa stick was more potent than that of indirect moxibustion and its radiation peak was different from that at the acupuncture point on the human body. In contrast, the thermal action of traditional indirect moxibustion was modest and its radiation peak matched that at the acupuncture point.
Conclusion: Direct moxibustion with a traditional moxa stick may produce its potent therapeutic effects by thermal action, while traditional indirect moxibustion may act by producing modest thermal action and a sympathetic vibration at the skin surface. Non-traditional thermal materials and media may not be suitable substitutes for traditional materials. The data provide a scientific, biophysical rationale for traditional moxibustion.

Introduction

Moxibustion entails burning the moxa herb, *Artemisia vulgaris*, on or above the skin at acupuncture points to warm the points in order to alleviate symptoms.[1] It has been a part of acupuncture practice for thousands of years in China and other Asian countries. Recently reported randomised clinical trials and clinical observations have evaluated the effect of moxibustion on such conditions as fetus breech presentation[2–5] and acute lymphangitis.[6] Preclinical studies suggest that moxibustion can enhance immune function[7–9] and improve such physiological functions as cerebral blood flow in animals.[10]

There are various ways of practising moxibustion. Commonly used techniques are burning a moxa stick directly over the skin at an acupuncture point,[5] and indirect moxibustion, that is, placing insulating materials such as monkshood cake or sliced ginger or garlic between the body and a burning moxa cone.[11] The actions of these different techniques on the human body require scientific investigation.

Since the effects of moxibustion on the human body are thought to be produced by thermal radiation, we postulated that these effects might be due to associated infrared radiation.[12] All objects in the universe, including human beings, produce infrared radiation, but the human body is not only a source of such radiation, it also absorbs it easily.[13] Infrared has strong penetrability and is readily absorbed by objects, including the human body, in which it is transformed into internal energy. It is not known whether the therapeutic effect of traditional moxibustion is induced simply by the thermal irradiation of acupuncture points, or whether other materials can be substituted for those used in traditional indirect moxibustion.

Despite progress in research on the biophysical specificity of infrared radiation on the surface of the body, the available methods were until recently still at the level of infrared thermography.[15–18] Infrared thermographic devices have limited power and can only detect wavelengths between about 3 μm and 6 μm at any given time; they cannot simultaneously cover the body's 1.5–16 μm infrared radiation spectrum to provide a comprehensive analysis. Furthermore, such devices are not sensitive enough to detect physiological and pathological changes in the body's infrared radiation. In the present study, we employed a recently developed system for detecting the infrared radiation spectrum adapted from advanced space technology.[19] This device is highly sensitive, with low noise, a wide range of wavelengths and stable performance.[20–22]

The purpose of the present study was to adapt this device to determine (1) whether traditional moxibustion produces a unique infrared radiation spectrum compared to that of non-specific controls and (2) to examine the relation between these spectra and that of the surface of the body at an acupuncture point.

Two separate variables of infrared radiation were measured and analysed: (a) the intensity of radiation emitted in mV; (b) the range of emission across the infrared spectrum in μm and where on that spectrum the peaks occurred.

Materials and methods

Materials

Three sets of experiments were conducted. The first concerned infrared radiation detected directly from a burning moxa stick. Traditional sticks, 1.7 cm in diameter and 10 cm in length, were used. Smokeless moxa sticks, 1.4 cm in diameter and 10 cm in length, and commercially available tobacco cigarettes (555 Band; Ardath Tobacco Co. Ltd.)

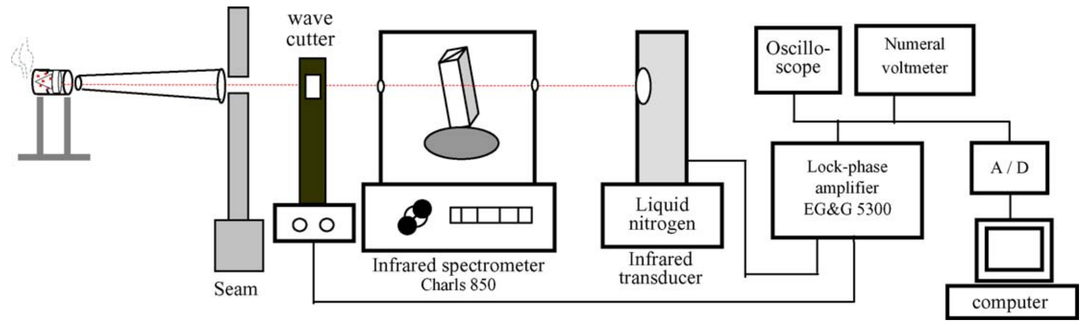

Figure 1 The highly sensitive, infrared radiation spectrum-detecting system. There is a narrow seam about 0.2 cm. A speed-fixed wave cutter, the rotational speed of which is adjustable between 0 rpm and 1500 rpm, is set behind the seam, and its frequency signal is sent to the referring signal input of the lock-phase amplifier behind it. Infrared light, transformed into pulse signals, is spectralised by a spectrometer and then irradiated on a highly sensitive $Hg_{1-x}Cd_xTe$ infrared transducer (wafer area 2.5 cm^2, liquid nitrogen working condition). To avoid power interference, the transducer is supplied by a dry battery. The weak signal output by the transducer is sent to the lock-phase amplifier to be amplified. Only those frequencies and phases identical to those of the wave cutter can be amplified 100,000 times or so while other signals are filtered. The amplified signals are sent to the oscilloscope and the computer for observation and data processing.

were used as controls. The second set concerned infrared radiation detected from the indirect burning of moxa. Pure moxa wool for moxa cones and three traditional insulation media, monkshood cake, ginger slices and garlic slices, were used. Slices of fresh cucumber and carrot of an equivalent size were used as control media. The diameter of each slice or cake was 2—3 cm and the thickness was 0.3—0.6 cm, and each was pierced by 6—8 holes evenly distributed on its surface. The third set of experiments involved infrared radiation detected from the body surface at an acupuncture point (Hegu, LI 4). All moxa materials were obtained from the Suzhou Acupuncture & Moxibustion Appliance Factory, Suzhou, China.

Human participants

Seven healthy volunteers (six males, one female) were recruited. Their ages ranged from 27 years to 42 years (mean 34.71 ± 6.34 years). The inclusion criteria were normal body temperature; no dysfunction of the autonomic nervous system such as abnormal sweating or systemic disease; no skin infection, inflammation or scarring at the test site. The sample size was determined by power estimation ($\beta = 0.8$) to detect significant differences among groups.[14] All participants were informed of the nature of the experiment and signed a consent form.

Device

A highly sensitive system for detecting the infrared radiation spectrum was obtained from the Shanghai Institute of Technical Physics of the Chinese Academy of Science, Shanghai, China. The system consists of a narrow seam, a wave cutter, an infrared spectrometer (Charls 850), an $Hg_{1-x}Cd_xTe$ infrared transducer, a lock-phase amplifier (EG&G 5300), an oscilloscope and a computer (Fig. 1).

Experimental design and methods

All experiments were performed under controlled environmental conditions: temperature $25 \pm 2\,^{\circ}C$ with minimal air flow, relative humidity 35—60%, quiet and shielded from electromagnetic fields, illuminated with two 40 W fluorescent lamps, with windows covered with heavy curtains to exclude sunlight.

Experiment 1. Detecting the infrared radiation of a burning moxa stick

In this set of experiments, a traditional moxa stick was compared to two controls, a smokeless moxa stick and a tobacco cigarette. In each experiment, the stick or cigarette was ignited and then placed on a fixed holder in which the tip of the burning end was aimed at the infrared detector. The light path was aligned to obtain the maximum signal. While wavelengths ranging from 1.5 μm to 16 μm were scanned by the infrared spectrometer, the light signal intensities in the transducer were recorded. All induced infrared radiation was scanned from low band to high and vice versa for two rounds. Each scan lasted about 2 min, and the mean of the resulting four scans was recorded for statistical analysis.

Experiment 2. Detecting infrared radiation from indirect moxibustion

Loose moxa wool was formed into circular cones 2.5 cm in diameter and 2.5 cm in height and placed

Table 1 Intensities and peak wavelengths of the infrared radiation of traditional moxibustion, moxibustion with controls, and Hegu (LI 4)

	n	Intensity of radiation (mV)	Wavelength of the peak of radiation (μm)
Traditional moxa stick	4	43300.41 ± 425.15	3.5
Smokeless moxa stick	4	31.15 ± 3.49[a]	7
555 cigarette	4	37.03 ± 3.82[a]	3.5
Moxa with monkshood	4	681.87 ± 47.52[b,c]	8
Moxa with ginger	4	520.27 ± 68.22[d,e]	7.5
Moxa with garlic	4	594.79 ± 44.71[b,c]	7.5
Moxa with cucumber	4	274.47 ± 19.61	5
Moxa with carrot	4	50.53 ± 4.68	5
LI 4 (Hegu)	28	20.40 ± 5.69	7.5

[a] Compared to the traditional moxa stick, $P = 0.000$.
[b] Compared to indirect moxibustion with cucumber, $P = 0.000$.
[c] Compared to indirect moxibustion with carrot, $P = 0.000$.
[d] Compared to indirect moxibustion with cucumber, $P = 0.004$.
[e] Compared to indirect moxibustion with carrot, $P = 0.001$.

on the traditional media (monkshood cake; ginger and garlic slices) and on slices of the control media (cucumber, carrot). After its cone had been lit, each sample was placed in a fixed holder with the detector aimed at its base to identify and record the infrared radiation emitted through the base of the media (Fig. 1). The mean of four scans was recorded for statistical analysis.

Experiment 3. Detecting infrared radiation at a human acupuncture point, LI 4

A small preliminary study had shown no significant difference in the infrared radiation spectra of an acupuncture point and a non-acupuncture point on nearby skin (data not shown). Because moxibustion is commonly practised at acupuncture points, in this study we measured the infrared radiation on human skin at LI 4, the point located between the first and second metacarpal bones at the midpoint of the second metacarpal.[11] No moxibustion was used in this experiment, as the goal was to measure the spontaneous radiation emitted by the acupuncture point.

In order to acclimatise the participants, we had them sit quietly in the laboratory for 30 min before the experiment. They adopted a natural sitting position with the forearm placed on a table. Only right LI 4 was examined. The participant gently put their hand in a holder, and the detector was aimed at point LI 4. The scanning data from two rounds (four scans) were recorded for statistical analysis.

Statistical analysis

The independent samples *t*-test was used to compare the data from traditional moxibustion with that of controls. $P \leq 0.05$ was considered significant in all cases. A diagram of the infrared radiation spectrum was produced using *Excel*. The operator of the infrared radiation device was blinded to the group assignments.

Results

Moxa stick infrared radiation spectrum

The results for infrared radiation from traditional moxibustion, controls, and human acupuncture point LI 4 are summarised in Table 1. The infrared radiation intensity of the traditional moxa stick was 43300.41 mV, and the peak was 3.5 μm. The intensities of the smokeless moxa stick and 555 cigarette controls were 31.15 mV and 37.03 mV, respectively, both significantly lower than that of the traditional moxa stick ($P = 0.000$). The peaks of these controls were 7 μm and 3.5 μm, respectively (Fig.2).

Indirect moxibustion infrared radiation spectrums

The infrared radiation intensity of indirect moxibustion with monkshood cake, ginger, and garlic each peaked around 7.5 μm, and their radiation intensities were 681.87 mV, 520.27 mV and 594.79 mV, respectively ($P > 0.05$). The patterns of their spectra were similar (Fig. 3), but in the indirect moxibustion with the control media (cucumber, carrot), infrared radiation intensities were 274.47 mV and 50.53 mV, respectively, both significantly lower than those of the three traditional media ($P < 0.005$); and their spectral patterns were clearly different from those of the traditional media (Fig. 3).

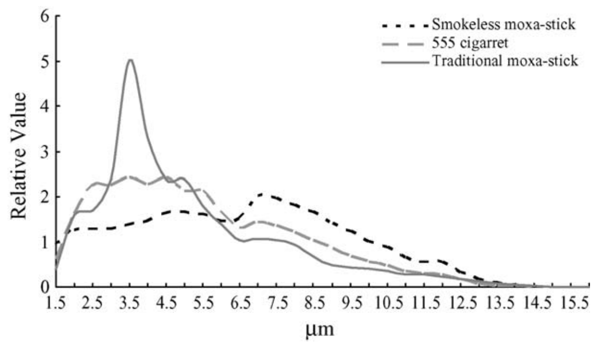

Figure 2 Unified infrared radiation spectra of a traditional moxa stick, a smokeless moxa stick, and a 555 cigarette. In order to show the differences in infrared radiation intensities among these three moxibustion materials within the same figure, we adopted the formula $e_j = x_j \times n / \sum_{i=1}^{n} x_i$, $j = 1, 2, 3, \ldots$ to unify the data.

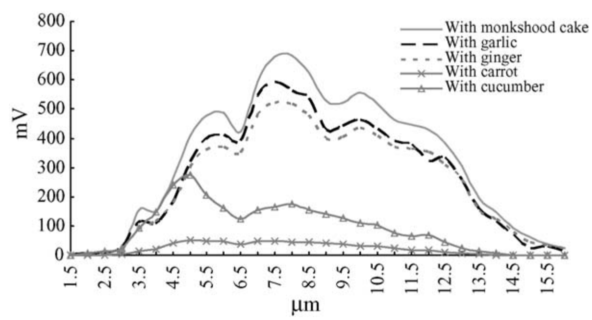

Figure 3 Comparison of the infrared radiation spectra of traditional and substitute indirect moxibustion media. The data were unified for this figure. Similar infrared radiation patterns can be seen among the three traditional media, while the patterns of the carrot and cucumber controls are clearly different.

Acupuncture point LI 4 infrared radiation spectrum

The spontaneous infrared radiation data from LI 4 in seven participants (7 × 4) are shown in Table 1. The spectral range was 1.5—16 μm, mainly distributed between 4.5 μm and 13.5 μm. The radiation peaked around 7.5 μm, and the radiation intensity was 20.40 mV (Fig. 4).

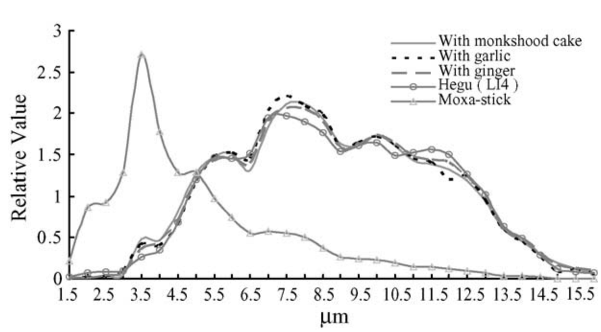

Figure 4 Unified infrared radiation spectra of an acupuncture point, Hegu (LI 4), direct moxibustion with a traditional moxibustion stick, and indirect moxibustion with three traditional media.

Discussion

To the best of our knowledge, this study is the first to attempt to explore the scientific basis of traditional moxibustion. In the long history of moxibustion practice, many substitute materials have been tried and recorded.[11] However, the moxa wool made from *A. vulgaris* remains the most commonly used material and is believed to produce the greatest therapeutic effect, and monkshood, ginger, and garlic are still the most commonly used media for indirect moxibustion.[11] No scientific evidence has yet been offered for using these materials. Our data from the highly sensitive, newly developed, infrared radiation spectrum-detecting system show that the intensity of the traditional moxa stick is extremely strong, reaching 43300.41 mV in comparison to the controls (only 31.15 mV from the smokeless moxa stick and 37.03 mV from the 555 cigarette). The lesser thermal action produced by these substitutes may explain why such materials are not commonly used in the clinic. On the other hand, the radiation peak in the spectrum of the traditional moxa stick is 3.5 μm, very different from the 7.5 μm of the acupuncture point (Fig. 4). Hence the therapeutic effect of the moxa stick may not due to sympathetic vibration, but rather to its potent infrared radiation (Fig. 4).

The infrared radiation produced by the three traditional indirect moxibustion media was significantly stronger than that of the controls (Table 1; Fig. 2). The spectral pattern of the three traditional media was very similar to that of acupoint LI 4 in that the radiation peaked at almost the same wavelength, around 7.5 μm (Table 1; Fig. 4). This similarity to the wavelength of the human acupuncture point may be the key to the therapeutic effect of traditional indirect moxibustion. Not only are the infrared radiation intensities produced by the controls low, but also their spectral patterns are also completely different from that at the acupuncture point.

It has been posited that the moxibustion effect is associated both with thermal action and the pharmacological action of the materials used.[23] However, there has been a debate about possible mechanisms in recent years. For example, some researchers suggest that the therapeutic effect of moxibustion is mainly the result of temperature-dependent thermal action rather than the properties of the herbal materials,[12,24] while others have shown that non-thermal factors such as infrared irradiation may also have important therapeutic effects.[25] When the wavelength range of a source of infrared irradiation is similar to that of the infrared radiation emitted from the human body, body metabolism can be affected. This is because water molecules, and indeed all the body's organic and biological molecules, can easily absorb infrared radiation, causing the molecules to vibrate and the energy level to change.[26] It has been hypothesised that moxibustion induces a sympathetic vibration of the molecules that corrects metabolic dysfunction and pathological conditions.[27] Our data show the involvement of thermal action and sympathetic vibration. It is possible, however, that all three actions, thermal, sympathetic vibration and pharmacological, account for the therapeutic effects of moxibustion.

Our small preliminary study showed no significant difference in the infrared radiation spectra of an acupuncture point and a non-acupuncture point on nearby skin (data not shown). We chose acupoint LI 4 to detect human infrared radiation because moxibustion is commonly used on acupuncture points. We believe that a study to determine the point specificity of the infrared radiation spectrum requires a more comprehensive design and larger sample size, which was beyond the present scope but is a reasonable next step for future research.

In conclusion, based on the analysis of infrared radiation, the therapeutic effect produced by a traditional moxa stick may be the result of potent thermal action, and the effects of indirect moxibustion with traditional media may result both from thermal action and sympathetic vibration. None of the substitute materials used as controls in the study possessed characteristics found by infrared analysis of the traditional materials. This suggests that the selection of an appropriate moxibustion material may be important to optimal therapeutic effect.

Further studies to determine correlations between the therapeutic effects of moxibustion and the materials used are warranted. The newly developed technology used here provides a powerful tool to explore the mechanisms of acupuncture/moxibustion, as it detects infrared radiation that may reflect physiological information, pathological changes, and the effects of treatment interventions such as moxibustion. The control materials we used may be ideal for conducting future randomised, double-blind, controlled clinical trials to determine the effect of moxibustion, and the present findings could serve as the basis for such studies.

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