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CORRESPONDENCE

Infrared Imageries of Human Body Activated by Tea Match the Hypothesis of Meridian System

Wenli Jin[1] · Yichen Tao[2] · Chen Wang[3] · Lufei Wang[3,4] · Xue Ao[2,4] · Mingjie Su[2] · Binwei Hu[2] · Yuxiao Ouyang[2] · Jiaxing Liu[3] · Hui Li[2,4]

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Abstract

Human meridian (*Jingluo*) system was hypothesized by traditional Chinese medicine (TCM) for thousands of years, suggesting 12 normal meridian channels going through respective organs, carrying fluid and energy, and laying thermal effects. Some treatments based on meridians have been proved effective. However, existence of meridians has never been confirmed, let alone the lack of measurement for meridian phenotypes. Thermal effect is one of the major phenotypes of meridian metabolism. Infrared photograph was employed to display the picture of meridians since 1970. Unfortunately, no satisfactory results have been obtained. It is possible that only when a certain meridian is activated will there be thermal effect for successful infrared photograph. In this study, 13 types of tea were selected out of the herbs to activate the hypothesized 12 meridians for imagery taking. Forty-two volunteers took part in the experiment lasted for 13 days. Different tea was tested in different day. Infrared imageries of the human bodies were taken immediately after each tea was drunk. The highest temperatures of the fingers, palms, and above the organs were derived from the imageries and analyzed. The temperatures of the organs and fingers possibly connected by 12 hypothesized meridians rose together significantly following the meridian hypothesis. Infrared imageries showed quite clear shapes of the organs activated by different kinds of tea, e.g., heart and kidneys by yellow tea, etc. Some high temperature lines also matched the hypothetic meridians. Our work displayed the probable imageries of all the 12 hypothetic meridians for the first time, and proved with data that different foods may activate different organs following the meridian hypothesis, shedding light on a possible new method of targeted drug designs. Measurements of meridian phenotypes can be developed based on this method of activation.

Keywords Traditional Chinese Medicine · Organ system · Human meridian · Herb · Alternative medicine · Body fluid

Abbreviations

HPT Hypothalamus-Pituitary-Thyroid
TCM Traditional Chinese medicine

Wenli Jin, Yichen Tao and Chen Wang have contributed equally to this work.

✉ Hui Li
LHCA@fudan.edu.cn

1 Shanghai Natural History Museum, Shanghai Science and Technology Museum, Shanghai 200041, China

2 MOE Key Laboratory of Contemporary Anthropology, Human Phenome Institute, Fudan University, Shanghai 200438, China

3 State Key Laboratory of Genetic Engineering, School of Life Sciences, Fudan University, Shanghai 200438, China

4 Fudan-Datong Institute of Chinese Origin, Shanxi Academy of Advanced Research and Innovation, Datong 037006, China

Introduction

Although traditional Chinese medicine (TCM) is always questioned as it is quite different from general medicine, some special treatments of TCM such as acupuncture were proved to be effective (Wu et al. 2017; Zhao et al. 2019; Comachio et al. 2020; He et al. 2020a, b; Yu et al. 2021; Lee and Chae 2022). The theory of TCM basically depends on the hypothetic meridian system of human body (Wan 2020; Ye et al. 2022). It is believed that there are 20 meridian channels (12 normal channels and eight extra channels) going through human body, carrying nutrition and energy. Numerous experiments have demonstrated the high electroconductivity and thermal conductivity along these channels (Fei et al. 1998; Zhu et al. 2001; Xu et al. 2005). However, the anatomic structure of the meridian channels has never been revealed or confirmed. There have been four major hypotheses about the structure of the meridians, i.e., autonomic

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nerve, body fluid channel, electromagnetic field, and connective tissue interstitium (Hua et al. 2006; Langevin and Yandow 2002). Some of these hypotheses are not mutually exclusive. Body fluid channel may just be in the connective tissue. When the heteropolar compounds flow with the fluid, it causes electrical current and raises the temperature along the meridian channel which is always felt in the human body after drinking a Chinese medicine going to a certain meridian. Recently, a fluid filled interstitial network of thick collagen bundles was revealed by confocal laser endomicroscopy (Benias et al. 2018), indicating that there was still unrecognized structure which might be that of the TCM meridians (Bai et al. 2020). This interstitial network is constructed by tissue interstitium firstly founded by a Hungarian team more than 60 years ago (Foldi et al. 1954). They proved that fluid and macromolecules could spread in interstitium, which might be the material basis of meridian.

To visualize the meridians and examine whether they drain along the lines suggested by TCM, many experiments have been performed. A remarkable study reported an observation of the migration of sodium fluorescein along meridians in the limbs of mini-pigs (Xiong et al. 2020). However, this migration can hardly extend over the acupoints, and therefore, the imagery of the whole meridian is yet to be displayed, let alone the safety of this kind of injection experiments. In 1970, Borsarello started to take infrared photos of meridians (Borsarello 1970). In the past 50 years, researchers tried many ways of body activation to take infrared imageries, e.g., acupuncture, acupressure, cooling down and rewarming the skin before taking photo, etc. (Dimitrov et al. 2021). Significant temperature difference was observed between the skin above part of the meridians and the skin away from the meridians. However, clear photos of entire meridians have never been obtained (Hu et al. 2003). Many factors may influence the results of these experiments and shield the possible effects of meridians. First of all, the temperature of the skin is influenced by too many factors, among which the microcirculation under skin is definitely pronounced. Second, some hypothetic meridians are deep in the body, and therefore, the heat is not that easy to conduct to the skin, especially when there is thick fat in between. Most important is that only when enough (theoretically heteropolar) compounds flow through the supposed meridian will the temperature of this meridian rise. However, few experiments have provided the related chemical compounds that the meridian flow required when taking infrared imageries.

In TCM, all herbs were determined to go to certain meridians according to their molecular properties (Wang et al. 2019). The 20 meridians are classified into 12 normal meridians and eight extra meridians. Parts of the aromatic compounds taken from vegetable foods can go into normal meridians. The normal meridians go through certain organs, with which the meridians are named, such as heart meridian, liver meridian, etc. The ends of the meridians are in the hands or feet. Every hand side meridian is connected with a foot meridian and forms a meridian pair. Therefore, there are six normal meridian pairs, namely, Little Lunar (foot bottoms → kidneys → heart → little fingers), Middle Lunar (big toes → liver → thymus → middle fingers), Grand Lunar (big toes → spleen → lungs → thumbs), Little Solar (ring fingers → sanjiao/HPT axis → ears → gallbladder → fourth toes), Middle Solar (index fingers → large intestine/colon → nose → stomach → second toes), Grand Solar (little fingers → duodenum → brain → urinary bladder → little toes) pairs (Fig. 1a). The previous studies did not locate the hand side meridians of Middle Lunar and Little Solar pairs to specific anatomic viscera because of the ambiguities of their TCM names, heart cover meridian and three-anxiety meridian, while quite clear shapes of thymus covering heart and thyroid of Hypothalamus-Pituitary-Thyroid (HPT) axis (Ortiga-Carvalho et al. 2016) were observed when the corresponding meridians were activated in our experiments. There have also been some misuses in previous translation of meridian system, e.g., *Xiao-Chang* in TCM does not included ileum as was defined in "*The Yellow Emperor's Canon of Medicine*", and therefore, it will be better to revise the Small Intestine Meridian into Duodenum Meridian (Table 1). According to this meridian hypothesis, as different meridian pairs go through different fingers except for Grand Solar and Little Lunar pairs, the parts of meridians in the fingers and their connections to the organs would be the easiest to observe and recognize.

Moreover, when one is not taking medicines or foods, these meridians will still open one after another spontaneously by the body itself for fluid draining, while the thermal effect of open meridian will be much weaker than that activated by medicines. The explanation of the weaker effect might be that one meridian consists of many parallel fascicular fibrils which will not be all open when not taking medicines. Twelve meridians open automatically in turn within a day, switching every two hours. Only when drinking the corresponding medicine will the meridian open beyond the schedule and have stronger thermal effects. Thus, safe medicines with strong meridian effects are essential for the experiments.

To develop measurements of the TCM phenome, especially those of meridian phenotypes related to thermal effect, in this study, we retrieved the Chinese herbs to find out a safe and common food to activate meridians efficiently. Among the herbs, Chinese tea (*Camellia sinensis*) is the most common beverage and is safe for daily drinking (Jia et al. 2015; Gilbert 2019). Quick and clear feelings of temperature rising in different areas of human body after drinking different kinds of tea were widely reported, which were explained by going to different meridians but lack of

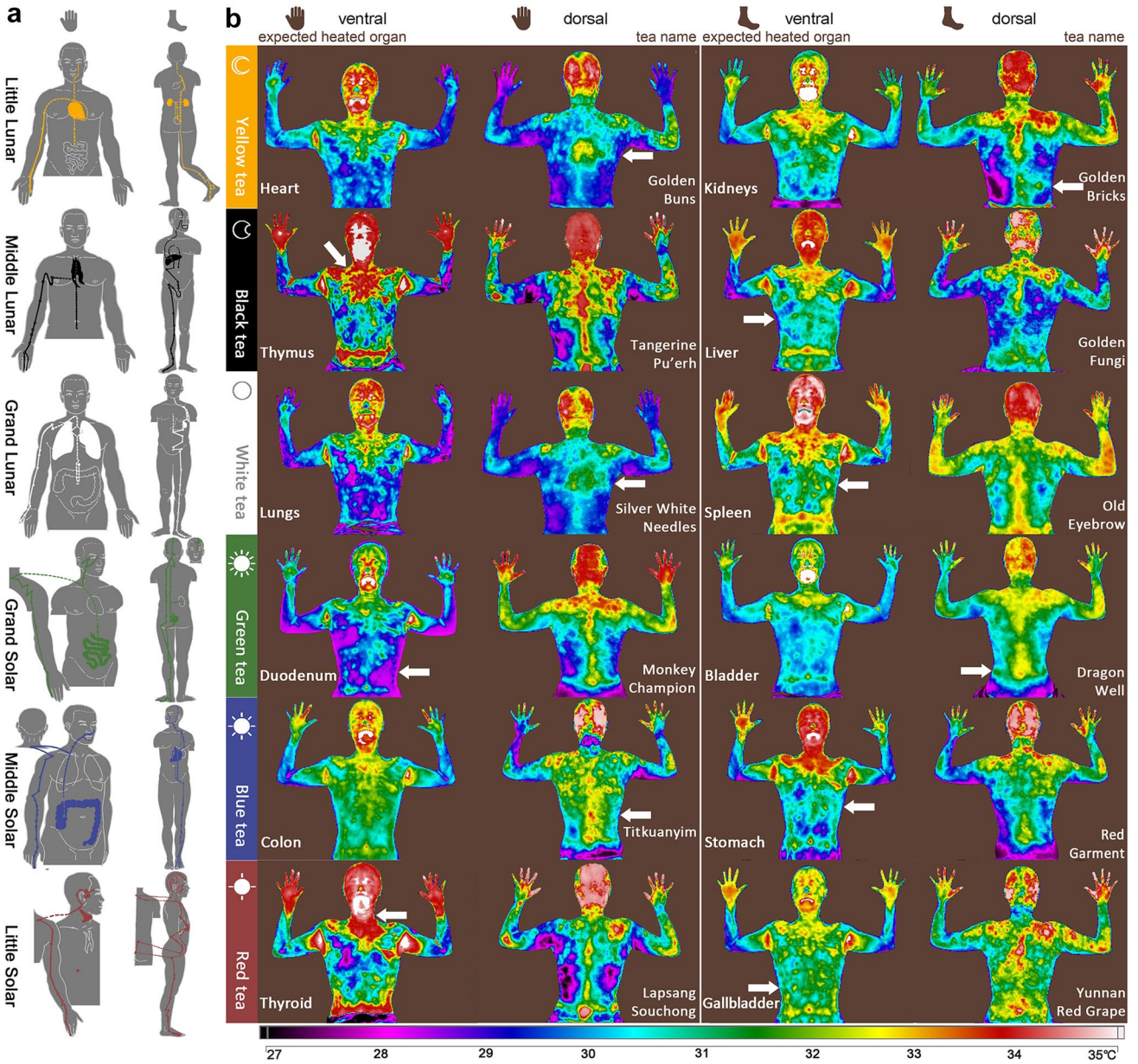

Fig. 1 Infrared imageries of volunteer M0 after drinking 12 kinds of tea draining into 12 meridians of TCM. **a** Hypothetic meridian lines of TCM. Meridian lines are bilateral. Here we displayed only one side of the lines and the related organs as a demonstration. **b** Infrared imageries after drinking 12 kinds of tea. White arrows pointed to the organs with shapes or points of high temperature

experimental evidence (Li 2021). Chinese tea is classified into six types according to six major production procedures, and are supposed to go into six meridian pairs with related medial functions, respectively. Namely, they are green tea to Grand Solar meridians, blue tea (of which oolong tea is a representative) to Middle Solar meridians, red black tea (hereafter, red tea) to Little Solar meridians, white tea to Grand Lunar meridians, dark black tea (hereafter, black tea, which are different from English black tea) to Middle Lunar meridians, and yellow tea to Little Lunar meridians. Tea is mostly safe for drinking. Therefore, we tested 512 kinds of tea from 18 provinces of China, as well as from Japan, India, Sri Lanka, New Zealand, USA, and Southeast Asian countries (Supplementary Fig. 1), and picked out 13 kinds of tea with the strongest thermal effects to examine whether there were correspondences between fingers and organs in human body as suggested by meridian hypothesis.

Table 1 A scientific revision of the nomenclature of meridians in Chinese Medicine

	Two directions	Yim/Lunar				Yaŋ/Solar			
Three energies		Meridian phase	Meridian name	Organ	Limb	Meridian phase	Meridian name	Organ	Limb
Sky	手 Hand	太阴 Grand Lunar nee: Taiyin	肺经 Lung	Lungs	Thumb	太阳 Grand Solar nee: Taiyang	小肠经 Duodenum nee: Small Intestine	Duodenum, Pallium	Little finger
	足 Foot		脾经 Spleen	Spleen	Big toe		膀胱经 Bladder	Pallium, Bladder	Little toe
Human	手 Hand	厥阴 Middle Lunar nee: Jueyin	心包经 Thymus nee: Pericardium	Thymus, Conarium	Middle finger	阳明 Middle Solar nee: Yangming	大肠经 Colon nee: Large Intestine	Nose, Colon	Second finger
	足 Foot		肝经 Liver	Prostate, Liver, Eyes	Big toe, Second toe		胃经 Stomach	Esophagus, Stomach, Lip, Facial nerve	Second toe
Earth	手 Hand	少阴 Little Lunar nee: Shaoyin	心经 Heart	Heart, Pancreas	Little finger	少阳 Little Solar nee: Shaoyang	三焦经 Three-Gland nee: Sanjiao	Hippocampus, Pituitary, Thyroid, Adrenals, Ovaries	Ring finger
	足 Foot		肾经 Kidney	Kidney, Brain medulla, Ears	Foot bottom		胆经 Gallbladder	Gallbladder	Fourth toe

Materials and Methods

Preparation of Volunteers

Volunteers from various provinces of China took part in tea testing, including 17 males and 25 females. The ages of the volunteers were between 18 and 60. They are all Han Chinese and have all graduated from junior middle school. Half of them have graduated from university. All volunteers were healthy and had no organ removals. Those individuals with clear organ stones were also excluded. The original imageries of the volunteers were not permitted to release for a guarantee of privacy, except for M0 as the corresponding author. Average of body mass index was 22.0 for males and 22.9 for females. The individuals with the body mass index higher than 26 were excluded from the experiment to avoid the pronounced shielding of heat by the fat. As the experiments required special diet and took too long time, it was difficult to collect more volunteers and carry out stricter criteria. However, in the future study of further experiments, larger sample size and stricter inclusion criteria will definitely be necessary.

Preliminary experiments were done on M0 to adjust the methods. Around 512 kinds of tea were tested during preliminary experiments in 2017 to find out 13 kinds of tea with strong and different meridian effects. All volunteers were gathered to the Lvxueya White Tea Manor in Taimu Mountain, Fuding, Fujian Province for a 13-day experiment in July, 2018. Only one kind of tea was prepared in one day for all volunteers. During the experiment, volunteers were not allowed to eat any other medicines or condiments to avoid disturbances. Vegetables, fruits, or meats cooked without salt or other condiments were provided. Males and females were separated in different buildings for experiments.

Tea Making

The selected 13 kinds of tea (Fig. 2) belong to six types defined by famous tea scientist *Chen Chuan* in 1970s (Chen 1979). The names of tea types were defined according to the major production procedures as green tea (only inactivated by heating), blue tea (shaken then heated, reaction of polyphenoloxidase), red tea (piled for fermentation then heated, reaction of amino acid dehydrogenase), white tea (inactivated by sunbathing then kept sunbathing, esterification reaction), black tea (heated then kneaded and fermented, glucosidic reaction), yellow tea (heated then wrapped for fermentation, flavonol dehydrogenation reaction). Different procedures result to different products, which make tea have different flavors and medical effects. The most famous blue tea is oolong, and therefore, most people call blue tea oolong tea by misapprehension (Chen 1979). Both red tea and black tea are called black tea outside China, or sometimes distinguished as red black tea and dark black tea. Here, the names defined by *Chen* were adopted to keep the nomenclature logical and systematic. Therefore, the English black tea is called the red tea (gallbladder meridian) in this paper. Within the same type of tea, different kinds of tea exhibit different flavors and medical effects due to the genomic diversity and variations of fermentation (Xia et al. 2017; Wei et al. 2018). In this study, all the tea samples were collected dried, and were finished products of standard

Fig. 2 Thirteen kinds of tea selected for meridian experiments. Chinese names were given for easy retrieve

quality. The information of the taxonomy and voucher specimen deposition of all kinds of tea studied was summarized in Supplementary table 1.

Green Tea

Monkey Champion (Hou Kui) with a chrysanthemum flavor was obtained from Xieyuda Tea Co., Huangshan, Anhui province, China. It was selected to activate the Hand-Grand Solar-Duodenum meridian. Green tea with similar effect on the Gut-Brain axis (Kaelberer et al. 2018; Cryan et al. 2019) include Huangshan Maofeng, Green Snails (Biluochun), etc. Dragon Well (Long Jing) with a broad been flavor was obtained from Hangzhou Xihu Longjing Tea Co., Hangzhou, Zhejiang province, and was selected for the Foot-Grand Solar-Bladder meridian. Similar effect was found from green tea including Black Buffalo (Wuniuzao), Turquoise Pearls (Guizhou Lyubaoshi), Dog Brain (Gounaogong), Baojing Huangjin, etc. Both kinds of green tea used in the experiments were newly made top grade in year 2017 (preliminary experiment) and 2018 (full experiment). Green tea was brewed in the glass pot through a copper dropping pot with hot water of around 100 °C. Five grams of dry tea were brewed in one liter water for five minutes. Water was dropped into tea through a copper pot with a hole ($\Phi = 3$ mm) in the bottom to avoid the oxidization of the polyphenols.

Blue Tea

Titkuanyim with a magnolia flavor was obtained from Xuantie Tea Co., Anxi, Fujian province, China. It was selected to activate the Hand-Middle Solar-Colon meridian. Blue tea with similar effect includes the Oriental Beauty Oolong from Xinzhu, Taiwan province. Red Garment (Dahongpao, Shengjiang Grade) with a cinnamon flavor was obtained from Ruiquan Tea Co., Wuyishan, Fujian province. It was selected to activate the Foot-Middle Solar-Stomach meridian (pylorus branch). Other kinds of rock tea from Wuyishan (Bohea Mountain) also have the similar effect. Phoenix Unique (Fenghuang Dancong) with an osmanthus flavor was obtained from Gangbhudeng Tea Co., Swatow, Guangdong province. It was selected to activate the Foot-Middle Solar-Stomach meridian (cardia branch). All kinds of the blue tea used in our experiments were newly made top grade in year 2017 and 2018. Blue tea was brewed in covered porcelain bowl with hot water of 90–95 °C. Five grams of dry tea were brewed in 300 mL water for two minutes. After the tea soup was poured out and drunk, 300 mL hot water was drawn into the tea for two more times for drinking.

Red Tea

Lapsang Souchong (Zhengshan Xiaozhong) with a chocolate flavor was obtained from Zhengshantang Tea Co., Wuyishan, Fujian province. It was selected to activate the Hand-Little Solar-HPT meridian, specifically the thyroid. Similar effect was found from Tanyang Gongfu, Luoyue Red, Keemun, etc. Those kinds of red tea with a longan flavor might activate the pituitary; however, pituitary is too deep in the head to examine in our experiments. Yunnan Red Grape (Pu Hong) with a grape flavor was obtained from Chamasi Tea Co., Jinggu, Yunnan. It was made of buds of old Pu'erh tea tree and was selected to activate the Foot-Little Solar-Gallbladder meridian. Other kinds of red tea with similar effect include Ceylon Tea, Dianhong, Meitan Red, etc. Both kinds of red tea used in our experiments were of top grade made in year 2016. The red tea of the third year is most effective and tasty. Red tea was brewed in black pottery with hot water of 95–100 °C. Five grams of dry tea were brewed in 300 mL water for five minutes for three times.

White Tea

Silver White Needles (Baihao Yinzhen) with a pear flavor was obtained from Lvxueya Tea Co., Fuding, Fujian province. It was selected to activate the Hand-Grand Lunar-Lung meridian. Old Eyebrows (Shou Mei) with a jujube flavor was also obtained from Lvxueya Tea Co., and was selected to activate the Foot-Grand Lunar-Spleen meridian. Similar effect was found from White Peony (Bai Mudan) and Belly Sweet (Bai Shuixian) of Fujian. Both kinds of white tea used in our experiments were of top grade made in 2009, because the lunar types of tea turn better in effect and flavor while they are stored for longer time. The white tea of the ninth year reaches a peak of quality. White tea was all boiled in metallic electric kettle and covered above 80 °C for more than a half hour. Five grams of dry tea were boiled in one liter water.

Black Tea

Tangerine Pu'erh (Chenxiang Shupu) with a dried tangerine peel flavor was obtained from Yeguo Tea Co., Jingmaishan, Lancang, Yunnan province. It was selected to activate the Hand-Middle Lunar-Thymus meridian. Similar effect was found from Liubao Tea of Guangxi province. Golden Fungi (Jimhua, Ruyi Grade) was obtained from Ziranyun Black Tea Co., Yongzhou, Hunan province. It was selected to activate the Foot-Middle Lunar-Liver meridian. Similar effect was found from Raw Pu'erh, Tuocha, Fuzhuan, etc. Both kinds of black tea used in our experiments were of top grade made in 2012. Black tea was all steamed in glass electric kettle and the soups were leaked down for around 10 minutes

until the bubbles spewed out. Five grams of dry tea were boiled in one liter water.

Yellow Tea

Golden Buns (Fan Jim Ji) with a wolfberry flavor was obtained from Bud-Chem Tea Co., Jiangkou, Guizhou. It was selected to activate the Hand-Little Lunar-Heart meridian. Similar effect was found from Goishi Tea of Kochi, Japan with an eggplant flavor. Golden Bricks (Jim Ding) was obtained from Jimding Tea Co., Zheng'an, Guizhou. It was selected to activate the Foot-Little Lunar-Kidney meridian. Similar effect was found from the De'ang Lactics (Suan Cha) of Yunnan and Junshan Jinzhuan of Hunan. Both kinds of yellow tea used in our experiments were of top grade. Golden Buns were made in 2017, and Golden Bricks were made in 2018. Yellow tea was all boiled in metallic electric kettle and covered above 70 °C for more than a half hour. Five grams of dry tea were boiled in one liter water.

The other herbs were all boiled with 40 g dry pieces in one liter water. The soups of tea and herbs were poured out into small porcelain cups and were drunk in the temperature between 50 and 60 °C.

Imageries Taking

The volunteers took off upper clothes and kept in room temperature for around 20 min before drinking tea to reduce the transverse conduction of heat on skin. The room temperature was kept around 26–28 °C. For each tea, every individual was asked to drink three times in 30 min, and imagery was taken after each time of drinking (300 mL tea soup each time). The camera was Ti450PRO Thermal Imager (Fluke Co., WA, USA). The thermal sensitivity (NTED) for the Ti450 PRO is ≤ 0.025 at 30 °C target temperature (25 mK) and accuracy is ± 2 °C or 2% at 25 °C nominal, whichever is greater. Thermal imageries were taken from both ventral and dorsal sides within two minutes after drinking each tea. The upper part of the body, including head, arms and hands, were taken in the imageries. The distance between the camera and volunteer were three meters. Different kinds of tea were drunk in different days to avoid the mutual interference.

To test the meridian clock hypothesis, infrared imageries were also taken from volunteer M0 during a three-day abrosia. The volunteer only drank pure water during abrosia. Imageries were taken about every two hours during three days.

Data Preprocessing

For each tea of one individual, the imagery showing the highest temperature was chosen for analyses. Temperature data were derived from thermal images manually. For each individual, temperature data were obtained from three parts, i.e., fingers, palms and trunci, from both ventral and dorsal sides.

On the ventral sides of the truncus, the temperatures of the skin areas above the organs including thyroid, thymus, stomach, spleen, liver, gallbladder, and duodenum were recorded. On the dorsal sides, those of heart, lungs, kidneys, colon, and urinary bladder were recorded. In each area, the maximum data were found out for analyses. As there were no significant differences between the left and right hands or between the ventral and dorsal sides of hand after data standardization, the average of the four temperatures of each finger as well as each area of palm was calculated for further analyses.

To find out the tea with effects of 12 different meridians from all the 512 kinds of tea, the temperatures of the body of individual M0 were scanned after he drank each tea, and compared the distributions of the highest temperature on the body among the tea kinds. The variations of distribution were classified into 12 patterns according to the areas above 12 organs mentioned in the above paragraph. The relationship between temperature distribution pattern and tea types were further induced.

To pick out the tea with the strongest meridian effects from all the 512 kinds of tea, temperature ranges on the body of M0 after he drank each tea were calculated. Ascending orders of the temperature range were sorted within each one of the 12 patterns. Those kinds of tea with largest ranges in each sort were selected for subsequent experiments. Two kinds of blue tea for stomach were selected as a repeat control.

Standardization and Significance Test

To make the temperature data from different area comparable, centralization and standardization were conducted on fingers, palms and trunci, respectively. Specifically, centering was done by subtracting the mean (μ_x) of the data from each area (omitting missing values). After that, scaling was done by dividing the centered data by their standard (σ_x) deviations.

$$z(X) = \frac{x_i - \mu_x}{\sigma_x}$$

Considering that the basic physical states of the volunteers and the states after drinking tea are usually different, the data after drinking each tea for a sub-regional scale were used to compare the temperature difference within the subregion. For example, after individual M_{01} drank white tea T_{01}, the temperature was measured from the ventral and dorsal sides of 10 fingers of his left and right hands. After calculating the average temperature of the dorsal–ventral side and

left–right hands, five temperature values (35.425, 35.550, 35.525, 35.450, 35.775) were obtained. The formed vector V_{tem} corresponds to finger 5 ~ 1 respectively. The scale (x, center = TRUE, scale = TRUE) function in R program was used to scale V_{tem} and get a vector V_{scale} (– 0.8663, 0.0361, – 0.1444, – 0.6858, 1.6604) with a mean of 0. V_{scale} represents the relative temperature changes of the five fingers after volunteer M_{01} drinking white tea T_{01}, where the relative change of finger one was the largest, and the temperature was higher than that of the other four fingers. Similarly, after obtaining the temperature change vectors of all volunteers drinking each tea, the results can be displayed with the boxplot as shown in Fig. 3.

T tests were performed to evaluate the statistically significance of temperature changes induced by different kinds of tea. Statistical null hypothesis (H_0) was the temperature unchanged. This step was performed using *t.test()* function (default parameter). All statistical analyses mentioned above were performed in R v3.5.3.

Correlation Coefficient Calculating

After removing missing values, the *cor()* function in *R* were used to calculate Pearson correlation coefficient. This function was used for the following formula:

$$r(X,Y) = \frac{E\left[\left(x_i - \mu_x\right)\left(y_i - \mu_y\right)\right]}{\sigma_x \sigma_y} = \frac{E\left[\left(x_i - \mu_x\right)\left(y_i - \mu_y\right)\right]}{\sqrt{\sum_{i=1}^{n}\left(x_i - \mu_x\right)^2}\sqrt{\sum_{i=1}^{n}\left(y_i - \mu_y\right)^2}}$$

where r represented the Pearson correlation coefficient (Fisher 1915, 1921).

Simultaneously, the statistically significance of r was taken into calculation using *cor.test()* function with default parameter. The test statistic was based on Pearson's product moment correlation coefficient and followed a t distribution with length(X)–2 degrees of freedom (Rahman 1968). Statistical null hypothesis (H_0) was true correlation equal to 0. Alternative hypothesis (H_1) was true correlation not equal to 0.

Figures Generation

To visually demonstrate the temperature ranges, boxplots (Fig. 3, Supplementary Figs. 2–3) and radar charts (Supplementary Fig. 4) were generated. They both exhibited the distribution of scaled temperature among three areas. The horizontal line inside the box represented the median of scaled temperature while the point of radar chart represented the mean temperature. Also, the outlier dots were kept in the boxplot.

Boxplots demonstrated the temperature ranges among three areas. The x-axis showed the sampling site inside each area, i.e., five fingers inside finger area. The y-axis showed the scaled temperature which was the measurement of temperature ranges. The colors indicate different kinds of tea.

Radar charts used polar coordinates rather than commonly used Cartesian coordinates, which is suitable for displaying outliers and commonality. Similar to boxplots, the x-axis showed the sampling site inside each area, and y-axis showed the scaled temperature. The points represented the mean temperature value.

Heatmaps were used to find out the mutual relation intra-area or inter-area. Each value inside the square is the Pearson correlation coefficient which is the commonly used measurement of the correlation level. Blue indicates the correlation coefficient less than zero, which means negative correlation. In contrast, red means positive correlation. And the value indicates correlation intensity.

All figures were generated by *ggplot2* (version 3.1.0) package in R v3.5.3.

R code for statistics and graphing in this paper is in Supplementary Code 1–2.

Results

Infrared thermor was employed to take imageries of naked upper bodies of volunteers after drinking each tea. Warm water with the same temperature (around 55 °C) of the tea was drunk as a negative control for most of the volunteers (Supplementary Table 2). In preliminary experiments, the body of male volunteer M0 was scanned to adjust the conditions for taking photos of the highest effects, including doses, soup temperature, air bath, period diet, scanning speed, and all the others mentioned in the Method section. Temperature distributions (around 27 ~ 35 °C) after drinking 12 kinds of tea were obviously different in M0 (Fig. 1b, Supplementary Table 2). For all the 512 kinds of tea, the temperature distributions can roughly be classified into 12 major patterns according to different body areas that reached to the highest temperature. After drinking each tea, the temperatures of the body areas rose in different levels, and some areas even got cooler. For example, the bladder or duodenum got warmer after drinking most of the green tea. The colon or stomach got warmer after drinking most of the blue tea. The pituitary, thyroid, adrenals, or gallbladder got warmer after drinking most of the red tea. The heart or kidney got warmer after drinking most of the yellow tea. The thymus or liver got warmer after drinking most of the black tea. The lungs or spleen got warmer after drinking most of the white tea. However, although the highest temperature mainly appeared in 12 body areas respectively, temperatures in other areas varied dramatically among the tea kinds of different

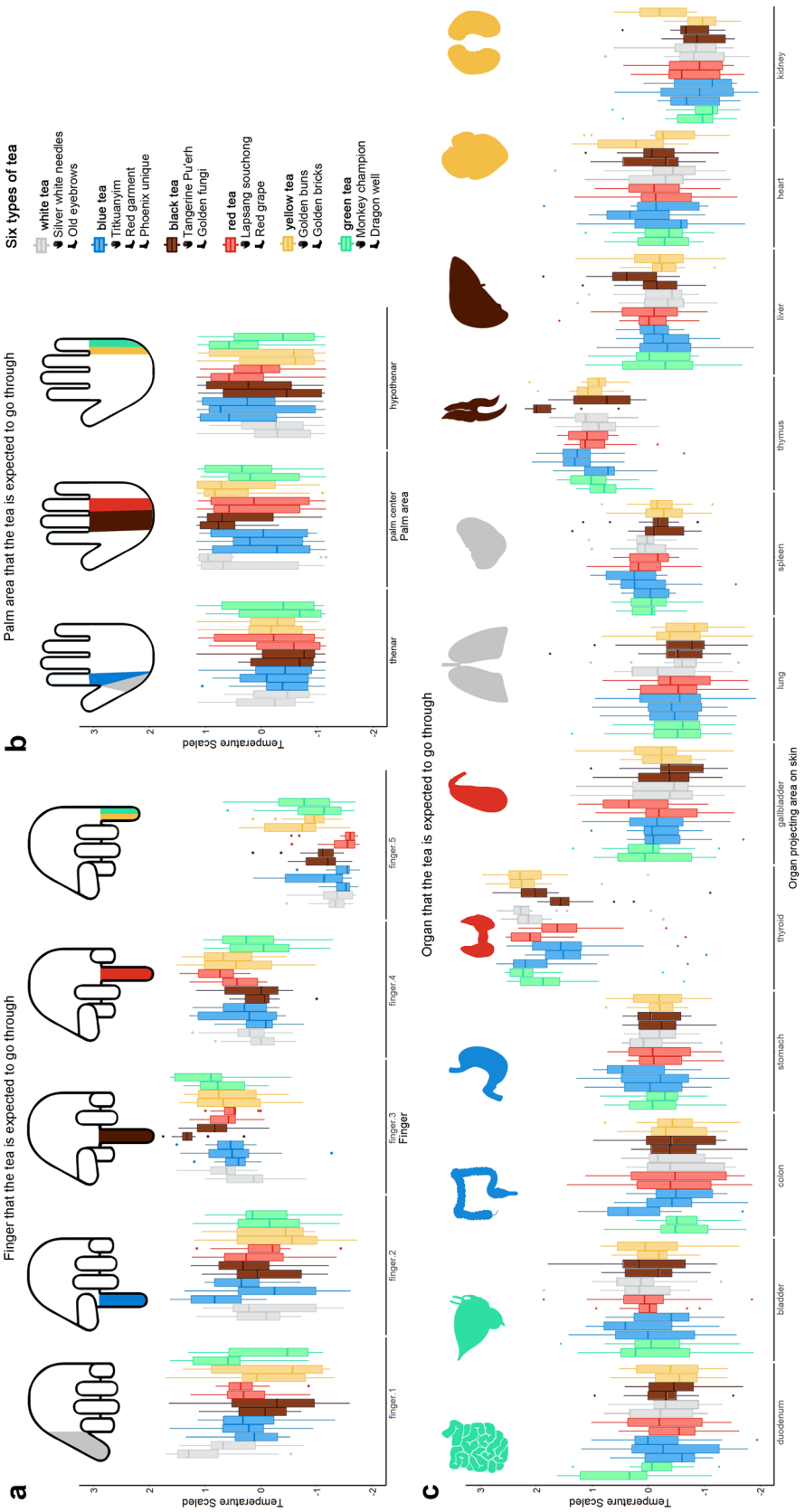

Fig. 3 The scaled temperatures derived from surface areas of the body after drinking different kinds of tea. **a** The fingers. Fingers 1 ~ 5 stand for thumb, index finger, middle finger, ring finger, and little finger, respectively. **b** The palm areas. **c** The skin above the organs. The bars with the same color were displayed in order of hand side tea to foot side tea from the left. Tea names were listed in the legend. Medians and 95% CI were marked on the bar. The figures above the bars indicated the areas activated by the tea distinguished with colors according to the meridian hypothesis. Data were displayed in Supplementary Table 3. Significance test results were displayed in Supplementary Table 4

quality, which scattered the temperature data out of any clusters in those commonly used clustering analyses, such as Principal Component Analysis and Multi-dimensional Scaling. Moreover, the temperature range among body areas varied widely among the kinds of tea (Supplementary Fig. 1). After drinking warm water of 55 °C, there will be a temperature range of around 3.2 °C on the body. The volunteers of this experiment were selected with a limitation of body mass index (< 26), or the temperature range will be much smaller either after drinking warm water or tea. Some kinds of tea caused few variations in temperature rise among body areas, even fewer than warm water. Therefore, the kinds of tea with highest temperature ranges (at least > 5 °C) among body areas from each of the 12 patterns were selected for the subsequent experiments.

After drinking these 12 types of tea with strongest thermal effects, noteworthily, shapes of different organs were clearly projected as the temperature rose, e.g., heart, kidney, thymus, lungs, spleen, stomach, thyroid, gallbladder, respectively. The shapes of liver, duodenum, colon, and urinary bladder were not quite clear, but hot points within the areas of these organs were found. This proved that different kinds of tea may lay effects on different organs. The correspondence between tea and organs matches the hypothesis very well. Interestingly, only the shape of the right kidney was shown in the imagery. The left kidney of volunteer M0 might be blocked by a kidney stone of 10 mm in diameter. After he drank the yellow tea going to Little Lunar kidney meridian for a month, shape of both kidneys appeared and the kidney stone disappeared confirmed by type-B ultrasonic check (Fig. 4a). The fingers were also heated clearly after drinking tea, especially those kinds of tea corresponding to hand side meridians. The highest temperature appeared in different fingers, for example, middle fingers for black tea, thumbs for white tea, index fingers for blue tea, etc., which also matched the hypothesis. Some parts of the body were always heated. For example, lips and esophagus were heated because of touching the warm tea soups directly. Navel, armpits, shoulders, etc. always showed high temperatures because of thinner skin or concentrated arteries. Some high temperature lines matched the meridian lines quite well, such as the thymus meridian line on the dorsal side. The area of the hypothetic four bladder meridian lines on the center of the back was much hotter than the ventral side after drinking the green tea for bladder. However, most of the lines were not quite clearly shown, maybe because they are thin and deep in the body. A special example of experiment showed quite clear heart meridian (Fig. 4e) after drinking an extremely old yellow tea with an age around 137 years, but this tea sample was not enough for all volunteers. Several herbs were also tested for meridian activity, however, weak (Fig. 4d), partial (Fig. 4b) or mixed (Fig. 4f–h) meridians were observed. These imageries of preliminary experiments suggested that the correspondence between the tea types and the temperature rises of the fingers and the organs exists. Therefore, the experiments of 13 kinds of picked tea on more volunteers (17 males and 25 females) were performed.

The highest temperature data were derived from every finger, three areas of palms, and every skin area above the 12 organs. The data of the hands were taken from both ventral and dorsal sides. Generally, the temperatures of thumbs are higher than other fingers, and those of the little fingers are the lowest. Therefore, the data were scaled for further analyses. Average of ventral, dorsal, right, and left data of each kind of finger was used in the following analyses as there were no significant differences among the four data after standardization (Supplementary Fig. 2). For each area of the body, the scaled temperatures after drinking different kinds of tea were compared. The male samples showed a very clear correspondence between tea and the hot areas (Fig. 3, Supplementary Table 3) while the female samples showed much weaker signals (Supplementary Figs. 3–4), which might due to the shielding of more subcutaneous fat of the female volunteers (Fuente-Martín et al. 2013). Among the males, different fingers reached highest temperatures after drinking different tea, e.g., thumbs after white tea, index fingers after blue tea, middle fingers after black tea, ring fingers after red tea, and little fingers after yellow and green tea. For each type of tea, both hand side meridian tea and foot side meridian tea were examined. Most of the hand side tea caused the highest temperatures on the corresponding fingers except for red tea and green tea of which foot side tea caused the higher temperatures. The gaps between the highest temperature and the temperatures of the other fingers after drinking each tea were mostly significant (Table 2, Supplementary Table 4). This result matches the meridian hypothesis well.

To examine whether the meridian lines behind the fingers were always heated as were seen in sample M0, the data of palms were derived. Among the male samples, significant higher temperature was observed in palm center after drinking hand side black tea than most of the other kinds of tea. Significant differences were also found between hand side green tea and foot side white tea or hand side yellow tea in hypothenar area. In thenar area, no significance was found (Table 2, Fig. 3b). Among the female samples, there were significant higher temperatures in ulnar side of hand after drinking red or green tea (Supplementary Fig. 3, Supplementary Table 4). This indicates a less match between observed temperature rise and the meridian hypothesis in the palm than in the fingers.

Obviously, the temperatures above different organs rose after drinking different kinds of tea among male samples, although such heating effect will sometimes be blocked by kidney stones, gall stones, splenic cyst, hepatic adipose infiltration, etc. All the temperatures above the organs increased after drinking the hypothetic corresponding kinds of tea,

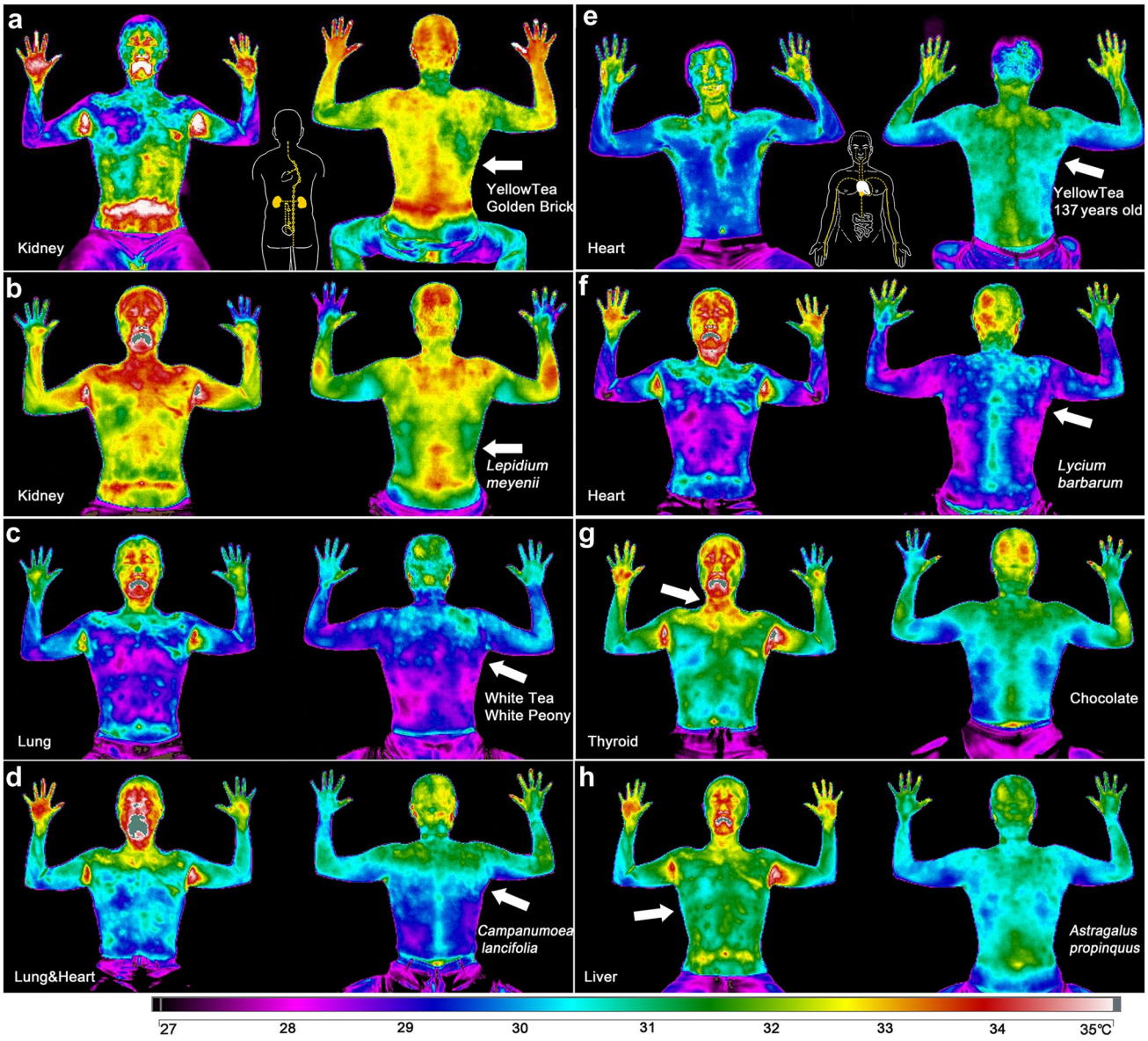

Fig. 4 Infrared imageries of meridians activated by more tea and herbs. **a** The possible kidney meridian of M0 after drinking kidney yellow tea for one month. The red cross in the center of the back matches the route of the kidney meridian. The left kidney was blocked by a kidney stone for the first time drinking the kidney meridian yellow tea, Golden Bricks (Fig. 1), while this imagery with both kidneys shown was taken after drinking the yellow tea every evening for one month and the kidney stone was dissolved. **b** Kidney meridian after drinking soup of *Lepidium meyenii*. Half of the kidney meridian was activated (a T-shape). **c** Lung meridian after drinking white peony tea. **d** Both shape of Lung and Heart meridians after drinking soup of *Campanumoea lancifolia*. **e** Heart meridian after drinking a 137-year-old yellow tea. A shape of question mark appeared in the center of the chest, which is the iconic shape of the heart meridian. The broken lines extended from the heart to the little fingers as well as eyes were also clearly shown. **f** Heart meridian after drinking soup of *Lycium barbarum*. **g** Thyroid (HPT) meridian after drinking chocolate soup. **h** Liver meridian after drinking soup of *Astragalus propinquus*

except for those above bladder and spleen (Fig. 3c, Table 2). The highest significances were observed for data of thymus, kidney, colon, liver, and duodenum following the hypothesis. No significance was found for stomach. For lung, significance was found only between hypothetic lung meridian white tea and kidney meridian yellow tea. Also, the temperature above gallbladder was clearly higher after drinking the hypothetic gallbladder meridian red tea than after liver meridian black tea. Above thyroid, data of the hypothetic HPT (three-gland) meridian red tea was significantly high, while those of stomach meridian blue tea, thymus meridian black tea, and gallbladder meridian red tea were significantly low (Supplementary Table 4). Therefore, we concluded

Table 2 The top significance p value of temperature variation in each surface area of the body after drinking different kinds of tea

Tea	White tea Silver Needles	White tea Old Eyebrows	Black tea Tangerine Pu'erh	Black tea Golden Fungi	Yellow tea Golden Buns	Yellow tea Golden Bricks	Green tea Monkey Champion	Green tea Dragon Well	Blue tea Titkuanyim	Blue tea Red Garment	Blue tea Phoenix Unique	Red tea Lapsang Souchong	Red tea Red Grape
Hypothetic meridian Channel	Grand Lunar Lung Channel	Grand Lunar Spleen Channel	Middle Lunar Thymus Channel	Middle Lunar Liver Channel	Little Lunar Heart Channel	Little Lunar Kidney Channel	Grand Solar Duodenum Channel	Grand Solar Bladder Channel	Middle Solar Colon Channel	Middle Solar Stomach Channel Cardia Branch	Middle Solar Stomach Channel Pylorus Branch	Little Solar HPT Channel	Little Solar Gall Channel
Finger 1	0.0001***	0.0236*	0.0221*	0.0285*	0.0618	0.0417*	0.0158*	0.0158*	0.1585	0.1168	0.1461	0.1089	0.0710
Finger 2	0.1408	0.0936	0.0325*	0.0701	0.0173*	0.0164*	0.0375*	0.0344*	0.0002**	0.0960	0.0164*	0.1210	0.0340*
Finger 3	0.0017**	0.1552	0.0000***	0.0024**	0.1148	0.0330*	0.0272	0.0017**	0.0211*	0.0658	0.0386*	0.0198*	0.0304*
Finger 4	0.0039**	0.0754	0.0015**	0.0696	0.0768	0.0015**	0.0102*	0.0470*	0.0048**	0.0713	0.0472*	0.0034**	0.0000***
Finger 5	0.0049**	0.0084**	0.0027**	0.0043**	0.0001***	0.0002***	0.0199*	0.0012**	0.0002***	0.0124*	0.0004***	0.0004***	0.0004***
Thenar	0.0605	0.3368	0.1370	0.1544	0.2462	0.1389	0.3121	0.2579	0.3782	0.2007	0.4341	0.2186	0.1370
Palm center	0.3364	0.0705	0.0074**	0.1863	0.0827	0.1878	0.1113	0.1974	0.0925	0.0705	0.1263	0.2222	0.1205
Hypothenar	0.0768	0.0569	0.0932	0.2134	0.0583	0.0727	0.0383*	0.0945	0.0569	0.1882	0.0954	0.0729	0.2390
Lung	0.0446*	0.3740	0.2035	0.4572	0.2702	0.1150	0.1529	0.2100	0.1969	0.1150	0.2634	0.1988	0.2833
Spleen	0.1019	0.0409*	0.0223*	0.0366*	0.0035**	0.0069**	0.0730	0.0450*	0.0436*	0.1892	0.0035**	0.0494*	0.0544
Thymus	0.0368*	0.1441	0.0000***	0.0654	0.0323*	0.0832	0.0070**	0.1526	0.0397*	0.0070**	0.0928	0.1072	0.1755
Liver	0.3058	0.3350	0.3949	0.0057**	0.2611	0.4698	0.5000	0.3490	0.3237	0.1846	0.3949	0.2078	0.2208
Heart	0.1850	0.0778	0.3144	0.2557	0.0196*	0.0571	0.0844	0.0853	0.1270	0.0571	0.2052	0.1369	0.2223
Kidney	0.5217	0.2561	0.3359	0.1937	0.1937	0.0000***	0.4605	0.2862	0.4850	0.6580	0.2914	0.3551	0.3513
Duodenum	0.2145	0.2991	0.3792	0.1492	0.1255	0.2785	0.0083**	0.0929	0.3196	0.4143	0.3585	0.1444	0.4687
Bladder	0.1036	0.1165	0.3477	0.3074	0.1731	0.3140	0.2423	0.3319	0.4260	0.1444	0.1036	0.2740	0.2934
Colon	0.5351	0.3168	0.3800	0.3681	0.2589	0.3846	0.3586	0.2632	0.0029**	0.5462	0.2589	0.3145	0.5561
Stomach	0.3887	0.4427	0.4863	0.5352	0.5230	0.6413	0.7529	0.3887	0.5542	0.2233	0.0656	0.4319	0.6657
Thyroid	0.1839	0.0054**	0.0002***	0.1211	0.0002***	0.0047**	0.0691	0.0073**	0.1398	0.0022**	0.0127*	0.0345*	0.0049**
Gallbladder	0.3707	0.3255	0.1638	0.0822	0.1872	0.2704	0.2006	0.0822	0.1717	0.2238	0.2796	0.1779	0.0329*

The data in the boxes are expected to be significant according to the TCM meridian hypothesis. The significant value makers are as follows, $*p<0.05$, $**p<0.01$, $***p<0.001$. The data outside the boxes are the top p values of the corresponding tea comparing to those of other tea, excluding the expected significant tea. Most of the significance values match the hypothesis, except for white tea and blue tea in thenar area, red tea in palm center, yellow tea in hypothenar area, green tea above bladder, and blue tea above stomach

that different kinds of tea will activate different organs after drinking, following the meridian hypothesis.

Moreover, it was worth verifying whether the whole meridian would be heated at the same time after drinking a certain tea. If so, the temperatures of the fingers and above the organs would be significantly correlated. Thus, a correlation analysis was performed on all the temperature data of body areas (Fig. 5). Among males, the only significant positive correlation was between index finger and colon. There was no negative correlation between the hypothetic connected finger and organ. This result meant that the temperature of a meridian did not increase in the same time after drinking a tea. A possible explanation is that as bioactive molecules in a tea drain along the meridian, temperatures of different parts will increase in succession when the molecules arrive at that part. In one photo, there would usually be only one part in the highest temperature, either the organ or the corresponding finger.

Interestingly, significant negative correlations appeared within areas of truncus, palm, or fingers. The strongest negative correlations were between spleen and lung, duodenum and lung, liver and colon, gallbladder and colon, thyroid and liver, heart and gallbladder, heart and duodenum, hypothenar and palm center, thumb and index finger, thumb and middle finger, etc. This indicated the mutual exclusion among the meridians. In addition, the strongest positive correlation was between heart and lung. Duodenum, spleen, liver, and gallbladder were also strongly correlated. This might be caused by the heat conduction between adjoining organs. Similar but less strong correlations were found among females (Supplementary Fig. 5).

The meridian channels are not only activated by medicines or vegetable foods but are also activated spontaneously in a sequence hypothesized by TCM every day. To examine this meridian clock hypothesis, individual M0 performed a three-day abrosia test by avoiding any interferences of food. Interestingly, in the infrared imageries of the three days, the temperature distribution pattern changed obviously every two hours (Fig. 6). One can clearly see the shape of gallbladder around 12 am and that of liver around 2 am. The shapes of kidney, duodenum, thyroid, etc. in the corresponding time also appeared. In the imagery of stomach time, quite clear

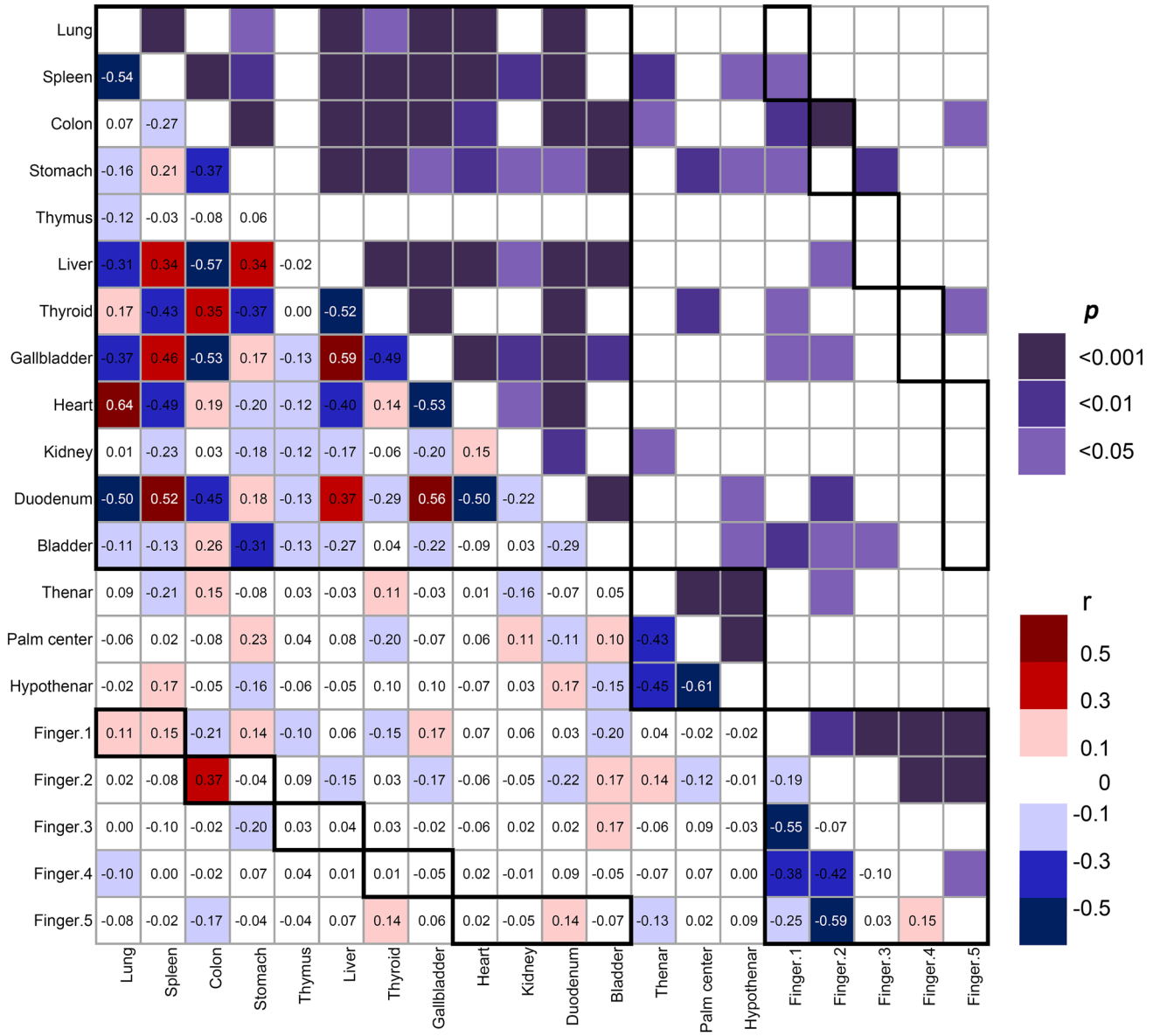

Fig. 5 Correlations among temperature data of body areas after drinking tea. Significances were displayed in the right upper part. The bold boxes in the left lower part indicated the hypothetic correlations between fingers and organs. Bold boxes in the center indicated the correlations within the body parts

lines went across the ventral side of the body, which matched the stomach channel quite well. This observation of temperature distribution changing within one day may indicate that the meridian clock hypothesis is true, although many more investigations and experiments are definitely required.

Discussion

In this study, we demonstrated that the connection between fingers and organs suggested by TCM meridian hypothesis exist, as correspondences of temperature increasing in both fingers and organs to the kinds of tea consumed were revealed. Beyond our expectation, the whole region of certain organ through which the meridian distributed will be activated and get warmer after drinking a tea, so will the acupoints of the meridian. That means the possible meridian activity causing thermal effect appears in both meridians and organs, maybe regulated by the same biophysical and biochemical mechanism (Zhu et al. 2021). We hypothesize that the biochemical mechanism of meridian activity may be the systematical distribution of the transmembrane channel proteins. The channel proteins of the cells might be quite similar in the same meridian and the organs passed through by the meridian, while

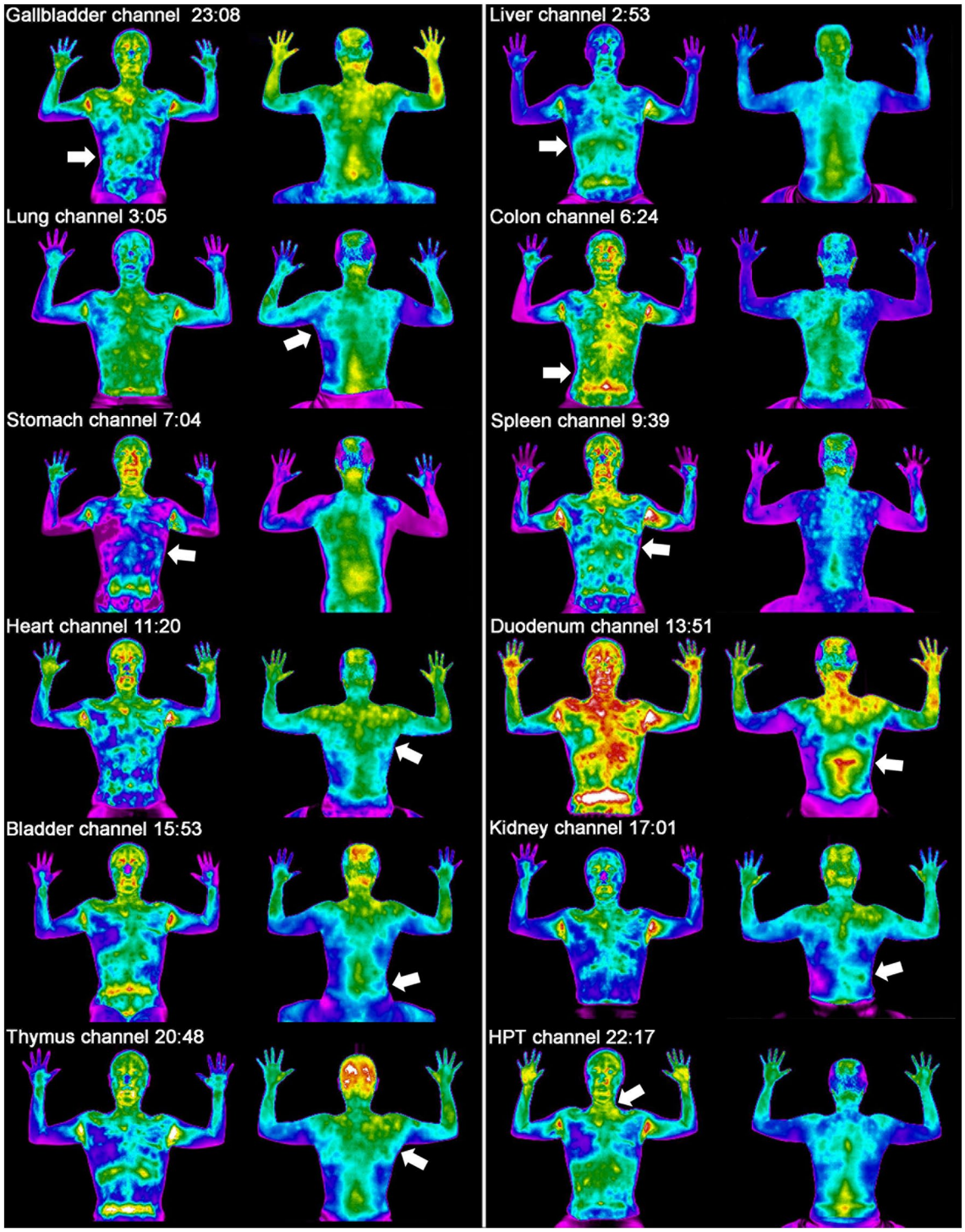

Fig. 6 Infrared imageries of M0 during abrosia supported the meridian clock hypothesis. The meridian clock hypothesis suggests that the meridians will open spontaneously in order every day. Every two hours, only one channel is open or dominated if the person does not eat anything. This set of imagery was the temperature distribution on the body in the third day of abrosia. The pattern changed every two hours, partially matching the meridian channel hypothesized to open at the corresponding time, e.g., from 23:00 to 1:00, the gallbladder was hot; from 1:00 to 3:00, the liver was hot

quite different among different meridians. That may explain why different kinds of tea and other herbs can activate different meridians and organs. There are various compounds in tea, especially when fermented through different procedures (Drew 2019). Six types of tea contain quite different organic molecules (Wan 2003; Wei et al. 2018), namely, polyphenols, aromatic acids, aromatic amides, aromatic esters, saponins, flavones, etc. These compounds might be keys to open the transmembrane channels of the cells along different meridians, which will be most important to examine. This research is making exciting progress in our team recently.

To explain how these compounds are transported into meridians, we hypothesized a Three-Pole-Relay mode including digestive system, circulatory system, and meridian system (Fig. 7). As was revealed by Fei et al. (1998), acupoints in meridians connected not only interstitium of meridians but also concentrated blood capillaries, nerve endings, lymphatic capillaries, etc. (Li et al. 2021c). Thus, the acupoints could be the hubs transporting compounds from circulatory system to meridian system. When people consume the key compounds for meridian, these compounds are initially be absorbed by the digestive system and are then transported into blood capillaries distributed along digestive tract as we all know. By that time, most of the compounds are distributed out of cells, and will immediately be sent to anywhere of the body. When they are sent into the acupoints where the blood capillaries are mostly concentrated, they will get in touch with the meridian cells, probably telocytes (Shi et al. 2020), which will correspond with the proper compounds. Therefore, different compounds opened different meridians, and are sent to the corresponding organs effectively along with the body fluid (Li et al. 2021a), and are finally transported into the cells of the organs which makes the temperature of the organs rise quickly. There is also a biochemical mechanism for the tropism of meridians (Li et al. 2021b). This might be the mechanism of the endotherm body to keep the intracellular environment and nourish different organs with different compound they need.

The compounds contained by the six types of tea also exhibit obvious different medical functions. For example, white tea has been used for respiratory and immune system disorders for very long history (Lin 2017). Raw (cool-fermented) Pu'erh, a typical black tea, can attenuate hypercholesterolemia (Huang et al. 2019). Our recent experiments proved that two kinds of yellow tea are effective in treating diabetes and kidney stone (Sang et al. 2022; Wang et al. 2022). The different functions can be ascribed not only to the different major molecules they contain, but may also to the different meridians leading to different organs they drain into. There may be unrecognized compounds in the herbs like tea determining the meridian attributes. To find these compounds would be a charming prospect of targeted drug designs, when the detailed structure and mechanism of meridians is revealed.

Conclusion

Meridian system is the fundamental theory based on which the TCM carries out the treatment programs, such as acupuncture, herb compound, etc. East Asians have believed for a very long history that the meridian system carrying

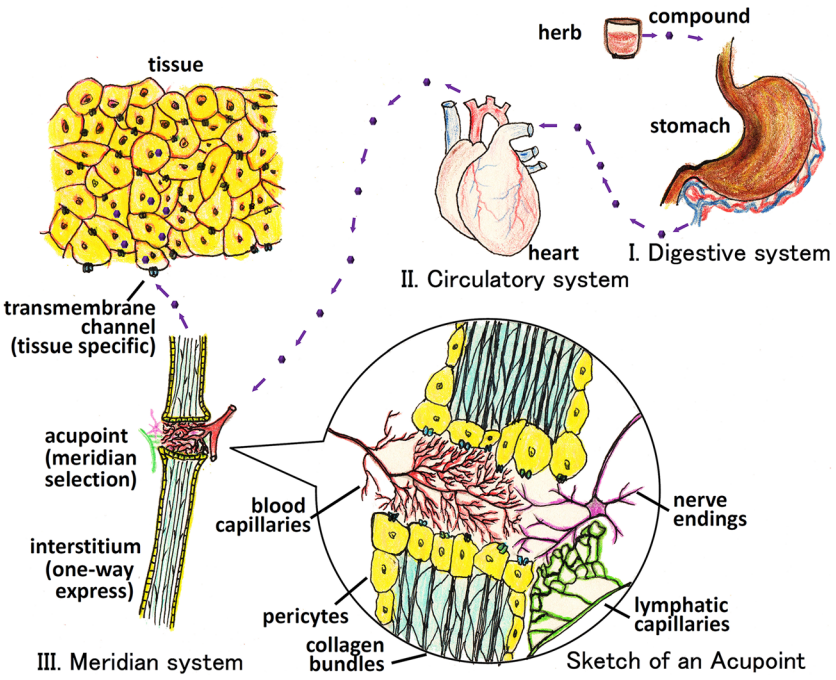

Fig. 7 A Three-Pole-Relay mode of compound transportation into meridians and tissue cells

the body fluid to be the tenth body system besides the well-known nine systems, and a most important and efficient system for health keeping. After fifty years ever since French scientist Borsarello tried to take infrared imageries of the mysterious meridians, we have probably made progress in visualization of a set of human meridian system, which is also the first step to measure the relevant phenotypes of meridian hypothesized in TCM.

We demonstrated that only when the corresponding medicines were consumed would the meridians probably be activated, and thus were the thermal signals caught. We found out 12 types of tea corresponding to 12 hypothetic meridians. The infrared imageries matched the pattern of meridian after drinking the corresponding tea. Therefore, these types of tea may serve as good catalysts for meridians in the future studies on TCM phenome. The chemical contents of the tea and their mechanism of activating meridians are also most important for the further research.

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Authors' Contributions HL and WJ designed the research; HL, WJ, CW, XA, MS, BH, and YO performed the experiments; YT, HL, CW, LW, and JL analyzed the data; and HL, WJ and YT wrote the paper.

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Availability of Data and Materials All data needed to evaluate the conclusions in the paper are present in the paper or the supplementary materials.

Data availability Data of this paper were all displayed in the supplements.

Declarations

Conflict of Interest No competing interests declared.

Ethical Approval Our research was proved by Ethic Committee of Fudan University School of Life Sciences (Approval Number: BE1945).

Consent to Participate All volunteers signed the informed consents.

Consent for Publication All authors proved the paper for publication.

References

Bai X, Wu R, Zhang Y, Liang C, Shi Y, Zhang Y, Ding B, Tarique I, Yang P, Chen Q (2020) Tissue micro-channels formed by collagen fibers and their internal components: cellular evidence of proposed meridian conduits in vertebrate skin. Microsc Microanal 26(5):1069–1075. https://doi.org/10.1017/S1431927620024381

Benias PC, Wells RG, Sackey-Aboagye B, Klavan H, Reidy J, Buonocore D, Miranda M, Kornacki S, Wayne M, Carr-Locke DL, Theise ND (2018) Structure and distribution of an unrecognized interstitium in human tissues. Sci Rep 8(1):4947. https://doi.org/10.1038/s41598-018-23062-6

Borsarello JF (1970) La cartographie isotherme est-elle un moyen de mettreen evidence les meridiens de l'acupuncture chinoise? Meridiens 11(12):91–96

Chen C (1979) Theory and practice of tea classification. Chaye Tongbao Z1:48–56. https://doi.org/10.16015/j.cnki.jteabusiness.1979.z1.010

Comachio J, Oliveira CC, Silva IFR, Magalhães MO, Marques AP (2020) Effectiveness of manual and electrical acupuncture for chronic non-specific low back pain: a randomized controlled trial. J Acupunct Meridian Stud 13(3):87–93. https://doi.org/10.1016/j.jams.2020.03.064

Cryan JF, O'Riordan KJ, Cowan CSM, Sandhu KV, Bastiaanssen TFS, Boehme M, Codagnone MG, Cussotto S, Fulling C, Golubeva AV, Guzzetta KE, Jaggar M, Long-Smith CM, Lyte JM, Martin JA, Molinero-Perez A, Moloney G, Morelli E, Morillas E, O'Connor R, Cruz-Pereira JS, Peterson VL, Rea K, Ritz NL, Sherwin E, Spichak S, Teichman EM, van de Wouw M, Ventura-Silva AP, Wallace-Fitzsimons SE, Hyland N, Clarke G, Dinan TG (2019) The microbiota-gut-brain axis. Physiol Rev 99(4):1877–2013. https://doi.org/10.1152/physrev.00018.2018

Dimitrov N, Tomov N, Atanasova D, Iliev S, Tomova T, Sivrev D, Goranova Z (2021) Visible meridian phenomena after acupuncture: a series of case reports. J Acupunct Meridian Stud 14(2):50–57. https://doi.org/10.51507/j.jams.2021.14.2.50

Drew L (2019) Making tea. Nature 566:S2–S4. https://doi.org/10.1038/d41586-019-00395-4

Fei L, Cheng HS, Cai DH, Yang SX, Xu JR, Chen EY, Dang RS, Ding GH, Shen XY, Tang Y, Yao W (1998) Experimental exploration and research prospect of physical bases and functional characteristics of meridians. Chin Sci Bull 43: 1233–1252. https://doi.org/10.1007/BF02884134

Fisher RA (1915) Frequency distribution of the values of the correlation coefficient in samples from an indefinitely large population. Biometrika 10(4):507–521. https://doi.org/10.1093/biomet/10.4.507

Fisher RA (1921) On the probable error of a coefficient of correlation deduced from a small sample. Metron 1:3–32

Foldi M, Yusznyak I, Szabo G, Magyar Z (1954) Studies on the function of lymph capillaries; the spread of the fluid and macromolecules in interstitium. Acta Med Acad Sci Hung 6(3–4):229–254

Fuente-Martín E, Argente-Arizón P, Ros P, Argente J, Chowen JA (2013) Sex differences in adipose tissue: It is not only a question of quantity and distribution. Adipocyte 2(3):128–134. https://doi.org/10.4161/adip.24075

Gilbert N (2019) Drink tea and be merry. Nature 566:S8–S9. https://doi.org/10.1038/d41586-019-00398-1

He Y, Guo X, May BH, Zhang AL, Liu Y, Lu C, Mao JJ, Xue CC, Zhang H (2020a) Clinical evidence for association of acupuncture and acupressure with improved cancer pain: a systematic review and meta-analysis. JAMA Oncol 6(2):271–278. https://doi.org/10.1001/jamaoncol.2019.5233

He Z, Yang Y, Wen Q, Yin T, Li Z, Ma P, Zheng H, Yang Y, Jiang Y, Fang J, Lan L, Zeng F (2020b) Acupuncture for chronic stable angina pectoris based on the theory of meridian-viscera association: study protocol for a multicenter randomized controlled trial. Trials 21(1):915. https://doi.org/10.1186/s13063-020-04836-8

Hu X, Xu J, Wang P, Xu XY, Gao LY, Wu BH (2003) Preliminary exploration on the mechanism underlying the formation of

infrared radiant track along meridian courses over human body surface. J Infrared Millim Waves 22:175–180. https://doi.org/10.3321/j.issn:1001-9014.2003.03.003

Hua P, Lü H, Yuan L, Tang L (2006) Four main schools of thought and analysis in studies of channels and collaterals. Chin Acupunct Moxibustion 26:407–413

Huang F, Zheng X, Ma X, Jiang R, Zhou W, Zhou S, Zhang Y, Lei S, Wang S, Kuang J et al (2019) Theabrownin from Pu-erh tea attenuates hypercholesterolemia via modulation of gut microbiota and bile acid metabolism. Nat Commun 10(1):4971. https://doi.org/10.1038/s41467-019-12896-x

Jia W, Fan TP, Wang X, Xie GX (2015) The Polypharmacokinetics of Herbal Medicines Science (The Art and Science of Traditional Medicine) 350(871):S76–S79

Kaelberer MM, Buchanan KL, Klein ME, Barth BB, Montoya MM, Shen X, Bohórquez DV (2018) A gut-brain neural circuit for nutrient sensory transduction. Science 361(6408):1219. https://doi.org/10.1126/science.aat5236

Langevin HM, Yandow JA (2002) Relationship of acupuncture points and meridians to connective tissue planes. Anat Rec 269(6):257–265. https://doi.org/10.1002/ar.10185

Lee IS, Chae Y (2022) Exploring acupuncture actions in the body and brain. J Acupunct Meridian Stud 15(3):157–162. https://doi.org/10.51507/j.jams.2022.15.3.157

Li Z (2021) Exegeses of Yīm Yáŋ canon of tea. Fudan Univ Press, Shanghai

Li HY, Wang F, Chen M, Zheng ZJ, Yin YJ, Hu J, Li H, Sammer A, Feigl G, Maurer N, Ma C, Ji FS (2021a) An acupoint-originated human interstitial fluid circulatory network. Chin Med J (engl) 134(19):2365–2369. https://doi.org/10.1097/CM9.0000000000001796

Li M, Chen Y, Cai Z, Teng J, Feng Q, Chen Y, Wang L, Li C, Tang BQ, Bai X (2021b) Exploring the biochemical basis of the meridian tropism theory for the Qi-Invigorating traditional Chinese medicine herb Panax ginseng. J Evid Based Integr Med 26:2515690x20983249. https://doi.org/10.1177/2515690X20983249

Li Q, Zhao T, Wang X, Qiu C, Zhou B, Wang H, Wang B (2021c) Study on potential of meridian acupoints of traditional Chinese medicine. J Healthc Eng 2021:5599272. https://doi.org/10.1155/2021/5599272

Lin ZC (2017) White Tea. China Wenshi Press, Beijing

Ortiga-Carvalho TM, Chiamolera M, Pazos-Moura C, Wondisford FE (2016) Hypothalamus-pituitary-thyroid axis. Compr Physiol 6:1387–1428. https://doi.org/10.1002/cphy.c150027

Rahman NA (1968) A course in theoretical statistics. Charles Griffin and Company, London

Sang S, Wang L, Liang T, Su M, Li H (2022) Potential role of tea drinking in preventing hyperuricaemia in rats: biochemical and molecular evidence. Chin Med 17:108. https://doi.org/10.1186/s13020-022-00664-x

Shi Y, Wu R, Zhang Y, Bai X, Tarique I, Liang C, Yang P, Chen Q (2020) Telocytes in different organs of vertebrates: potential essence cells of the meridian in Chinese traditional medicine. Microsc Microanal 26:575–588. https://doi.org/10.1017/S1431927620001518

Wan XC (2003) Tea biochemistry. China Agriculture Press, Beijing

Wan XH (2020) Mathematical analysis of the meridian system in traditional Chinese medicine. Digit Chin Med 3(3):141–147. https://doi.org/10.1016/j.dcmed.2020.09.001

Wang Y, Jafari M, Tang Y, Tang J (2019) Predicting meridian in Chinese traditional medicine using machine learning approaches. PLoS Comput Biol 15:e1007249. https://doi.org/10.1371/journal.pcbi.1007249

Wang C, Liu J, Sang S, Ao X, Su M, Hu B, Li H (2022) Effects of tea treatments against high-fat-diet-induced disorder by regulating lipid metabolism and the gut. Comput Math Methods Med 2022:9336080. https://doi.org/10.1155/2022/9336080

Wei C, Yang H, Wang S, Zhao J, Liu C, Gao L, Xia E, Lu Y, Tai Y, She G, Sun J, Cao H, Tong W, Gao Q, Li Y, Deng W, Jiang X, Wang W, Chen Q, Zhang S, Li H, Wu J, Wang P, Li P, Shi C, Zheng F, Jian J, Huang B, Shan D, Shi M, Fang C, Yue Y, Li F, Li D, Wei S, Han B, Jiang C, Yin Y, Xia T, Zhang Z, Bennetzen JL, Zhao S, Wan X (2018) Draft genome sequence of Camellia sinensis var. sinensis provides insights into the evolution of the tea genome and tea quality. Proc Natl Acad Sci USA 115(18):E4151–E4158. https://doi.org/10.1073/pnas.1719622115

Wu XK, Stener-Victorin E, Kuang HY, Ma HL, Gao JS, Xie LZ, Hou LH, Hu ZX, Shao XG, Ge J, Zhang JF, Xue HY, Xu XF, Liang RN, Ma HX, Yang HW, Li WL, Huang DM, Sun Y, Hao CF, Du SM, Yang ZW, Wang X, Yan Y, Chen XH, Fu P, Ding CF, Gao YQ, Zhou ZM, Wang CC, Wu TX, Liu JP, Ng EHY, Legro RS, Zhang H, PCOSAct Study Group (2017) Effect of acupuncture and clomiphene in Chinese women with polycystic ovary syndrome: a randomized clinical trial. JAMA 317:2502–2514. https://doi.org/10.1001/jama.2017.7217

Xia EH, Zhang HB, Sheng J, Li K, Zhang QJ, Kim C, Zhang Y, Liu Y, Zhu T, Li W, Huang H, Tong Y, Nan H, Shi C, Shi C, Jiang JJ, Mao SY, Jiao JY, Zhang D, Zhao Y, Zhao YJ, Zhang LP, Liu YL, Liu BY, Yu Y, Shao SF, Ni DJ, Eichler EE, Gao LZ (2017) The tea tree genome provides insights into tea flavor and independent evolution of caffeine biosynthesis. Mol Plant 10(6):866–877. https://doi.org/10.1016/j.molp.2017.04.002

Xiong F, Song X, Jia SY, Wang GJ, Li HY, Gu X, Wang Z, Zhang WB (2020) Preliminary observation of the migration of sodium fluorescein along meridians in the limbs of mini-pigs. Sci China C 50:1453–1463. https://doi.org/10.1360/SSV-2020-0144

Xu J, Hu X, Wang P, Ye L, Yang J (2005) Comparison of the thermal conductivity of the related tissues along the meridian and the non-meridian. Chin Acupunct Moxibustion 25:477–482

Ye X, Ren YL, Chen YH, Chen J, Tang XJ, Zhang ZM (2022) A "4D" systemic view on meridian essence: substantial, functional, chronological and cultural attributes. J Integr Med 20(2):96–103. https://doi.org/10.1016/j.joim.2021.11.006

Yu B, Li M, Huang H, Ma S, Huang K, Zhong Z, Yu S, Zhang L (2021) Acupuncture treatment of diabetic peripheral neuropathy: an overview of systematic reviews. J Clin Pharm Ther 46:585–598. https://doi.org/10.1111/jcpt.13351

Zhao L, Li D, Zheng H, Chang X, Cui J, Wang R, Shi J, Fan H, Li Y, Sun X, Zhang F, Wu X, Liang F (2019) Acupuncture as adjunctive therapy for chronic stable angina: a randomized clinical trial. JAMA Intern Med 179:1388–1397. https://doi.org/10.1001/jamainternmed.2019.2407

Zhu B, Rong PJ, Li YQ, Ben H, Xu WD, Gao XY (2001) Propagated sensation and myoelectric response along the channels. Sci China C Life Sci 31:465–470. https://doi.org/10.3969/j.issn.1674-7232.2001.05.012

Zhu Y, Huang JP, Zhong JM, Li WT, Xu NG, Liu JH (2021) Biological mechanism of specific relationship between Gan (Liver) Meridian of Foot-Jueyin and genitals. Chin J Integr Med 27(5):384–387. https://doi.org/10.1007/s11655-020-3483-y