Research on the Correlation between Human Infrared Thermal Structure and Disease Risk Based on Traditional Chinese Medicine Constitution

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Abstract

Objective: To explore the correlation between human infrared thermal patterns and disease risk using infrared thermography (IRT) technology, and to investigate auxiliary methods for objective diagnosis in traditional Chinese medicine, providing new insights for clinical diagnosis and therapeutic evaluation. *Methods:* A cross-sectional study was conducted on 451 patients who met the inclusion criteria, focusing on the distribution patterns of constitution types and diseases, as well as the correlation between infrared thermal patterns and disease risk. *Results:* Among the included cases, the most prevalent constitution types were deficiency of both Yin and Yang with phlegm-dampness, and deficiency of Yang and blood; the top three diseases were chronic fatigue syndrome (CFS) with 98 cases (21.7%), chronic gastritis with 94 cases (20.8%), and gastrointestinal polyps with 31 cases (3.6%). In the study of the correlation between infrared thermal state structure and the risk of chronic fatigue syndrome (CFS), univariate analysis indicated that there were differences between the outcome event cohort and the non-outcome event cohort in terms of gender, age, T_{facial}, $T_{upper\ energizer}$, $T_{middle\ energizer}$, $T_{lower\ energizer}$, $T_{left\ dorsal\ foot}$, and $T_{right\ hypochondriac\ region}$ ($p < 0.05$). Multivariate logistic regression analysis revealed that gender, age, $T_{middle\ energizer}$, and $T_{left\ dorsal\ foot}$ were independent risk factors for CFS (with odds ratios [ORs] of 2.706, 0.956, 0.686, and 1.310, respectively, $p < 0.05$). The establishment of a receiver operating characteristic (ROC) curve assessment model found that $T_{left\ dorsal\ foot}$ had certain diagnostic value (area under the curve [AUC]: 0.564, 95% confidence interval [CI]: 0.498–0.630). *Conclusion:* There is a potential correlation between the human infrared thermal state structure and disease risk prediction. Promoting the clinical use and research popularization of infrared thermography (IRT) can provide a visual basis for disease state prediction and assessment, and is of great significance for in-depth research on constitutional types and the biophysical properties of meridians and acupoints.

Keywords

1. Introduction

Traditional Chinese Medicine (TCM) constitution refers to the comprehensive and relatively stable inherent characteristics that the human body develops in terms of morphological structure, physiological function, and psychological state during the life process, based on innate essence and acquired factors, in order to adapt to the humanistic, natural, and social environments. In TCM, the human body serves as a carrier for the continuous circulation and operation of Yin and Yang, Qi and blood, and body fluids. Constitution, as a reactive tendency reflecting the fluctuations in the abundance or deficiency of Yin and Yang, Qi and blood, and body fluids, not only represents a potential cause of diseases but also serves as a crucial diagnostic basis for predicting the progression, changes, and prognosis of diseases [1]. Different constitutions exhibit varying susceptibilities and predispositions to different diseases or even the same disease [2]. Therefore, objectively, authentically, and accurately identifying TCM constitutions, as well as intuitively, comprehensively, and systematically reflecting the connotations of TCM constitutions, are pivotal for TCM constitutions to play a role in disease diagnosis and treatment efficacy evaluation.

As a TCM diagnostic tool that achieves objectivity, visualization, and intelligence in TCM constitution identification, IRT embodies TCM diagnostic principles such as "inferring internal conditions from external manifestations", "judging abnormalities based on norms" and "detecting significant changes from subtle signs". IRT (Infrared Thermography) utilizes the "thermoelectric simulation method" to capture specific infrared wavelength signals of thermal radiation emitted by human internal organs via computers. It converts these radiation signals into distinguishable graphics and images, calculates temperature values, and thereby reflects the cold-heat bias of the body's internal organs and meridians [3]. Currently, it has been widely applied in the early diagnosis of diseases such as vascular-related diseases, rheumatic diseases, painful conditions, and tumors, as well as in the study of infrared characteristics and therapeutic effects in Traditional Chinese Medicine (TCM) [4–7]. However, there has been relatively little research on the correlation between the infrared thermal state structure of the human body based on TCM

constitutional types and disease prediction. Based on this, to explore a visual basis for predicting and assessing disease states and to provide certain clinical references for promoting the establishment of mathematical diagnostic and prognostic models for related diseases based on TCM constitutional theory, this study conducted a cross-sectional study involving 451 patients who sought medical treatment at Liuzhou Traditional Chinese Medicine Hospital (Liuzhou Zhuang Medicine Hospital) from January 1, 2023, to August 14, 2023.

2. Materials and methods

2.1. Study subjects

The study subjects were patients who visited Liuzhou Traditional Chinese Medicine Hospital (Liuzhou Zhuang Medicine Hospital) from January 1, 2023, to August 14, 2023, regardless of gender or age. A total of 451 patients with complete data available for analysis were included, comprising 168 males (37.25%) and 283 females (62.75%), with an average age of (44.75 ± 16.65) years.

3. Research methodology

3.1. Research design

This study employs a cross-sectional design to investigate the Traditional Chinese Medicine (TCM) constitutional types and infrared thermal characteristics of a patient population, exploring the risk correlation between infrared thermal patterns and prevalent diseases. Information on constitutional diagnosis, clinical diagnosis, and general conditions of all patients in the group was collected, and infrared thermal detection values were recorded. After conducting a preliminary exploration of the distribution of TCM constitutional types and thermal characteristics in the population, patients diagnosed with the prevalent disease—chronic fatigue syndrome (CFS)—were marked as having an outcome event, with males uniformly assigned a value of "1". Patients not diagnosed with CFS were marked as non-outcome events, with females uniformly assigned a value of "0". The 451 observed cases were divided into two cohorts: outcome events and non-outcome events. A multivariate logistic regression model was used to screen for risk factors, and a Receiver Operating Characteristic (ROC) curve was established to

validate its predictive performance.

3.2. Infrared thermal imaging collection

The MDK-M01L cabin-type medical infrared thermal imager manufactured by Wuhan Medk Infrared Technology Co., Ltd. was used [8]. The inspection method is as follows: Conduct the examination in an environment where the room temperature is controlled at 25–27℃, the indoor humidity is ≤ 70% RH, there is no direct sunlight or intense light interference, and indoor and outdoor ventilation is isolated. Instruct the examinee to stand 1.5 meters away from the infrared camera lens in an anterior upright position. Use the infrared acquisition system to locate and measure the average body temperature of the examinee's front side, as well as the temperatures of body surface projection areas such as the face, upper energizer, middle energizer, lower energizer, palms of both hands, and dorsum of both feet. Then, instruct the examinee to adopt a posterior upright position and use the infrared acquisition system to locate and measure the temperature of the body surface projection area of the Governor Vessel on the examinee's back. Next, instruct the examinee to adopt left and right lateral positions and use the infrared acquisition system to locate and measure the temperatures of the body surface projection areas of the two hypochondriac regions on the examinee's sides (see **Figure 1**).
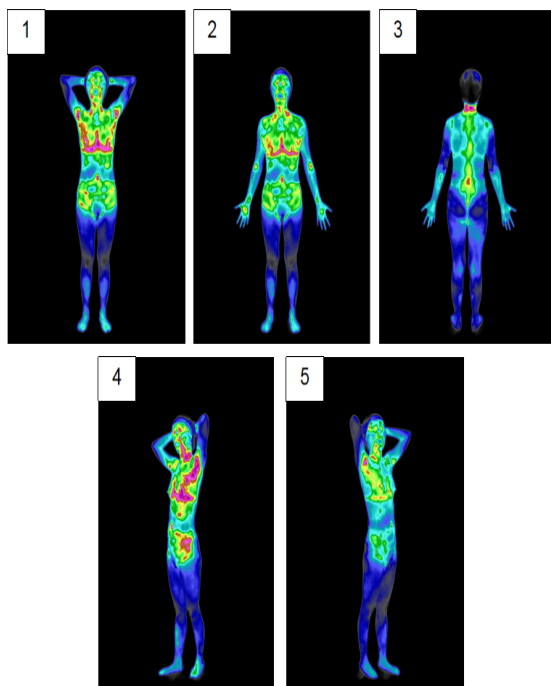

Figure 1. Standard infrared acquisition diagram.

3.3. Statistical methods

After all data are entered into an EXCEL spreadsheet, statistical processing is performed using SPSS 22.0 statistical software. Measurement data with a normal distribution are expressed as mean ± standard deviation (x̄ ± s), while measurement data with a skewed distribution are expressed as median (interquartile range) [M(IQR)]. Comparisons between groups are made using the *t*-test or Mann-Whitney U test. Count data are expressed as percentages, and comparisons between groups are made using the χ^2 test or Fisher's exact test. Multivariate Logistic regression models are used to screen for risk factors, and ROC curves are plotted. A *p*-value of 0.05 is set as the threshold for statistical significance.

4. Research findings

4.1. Distribution of TCM constitution types among the population

This study included a total of 451 subjects, encompassing 19 types of constitutional diagnoses. Among these, six single-biased constitutional types, namely Yin-Yang deficiency, Taiyin Yang deficiency, spleen and kidney Yang deficiency, Qi stagnation, Qi deficiency, and blood deficiency, accounted for 37.9%. Meanwhile, mixed constitutions, which involve two or more of the aforementioned types, constituted 62.1%. Among the single constitutions, the one with the highest clinical diagnosis rate was Yin-Yang deficiency (98 cases, 21.7%), followed by Taiyin Yang deficiency (39 cases, 8.6%). Among the mixed constitutions, the highest clinical diagnosis rate was for Yin-Yang deficiency combined with phlegm-dampness (88 cases, 19.5%), followed by Yang deficiency and blood deficiency (48 cases, 10.6%) (refer **Table 1** and **Figure 2**).

4.2. Disease distribution among individuals with biased constitutions

This study examined the primary Western medical diagnoses of the 451 subjects, identifying over 100 diagnostic types. Among these, 15 disease types had a clinical diagnosis rate exceeding 1%. The top three were CFS with 98 cases (21.7%), chronic gastritis with 94 cases (20.8%), and gastrointestinal polyps with 31 cases (3.6%) (see **Figure 3**).

Table 1. Composition of biased constitution types

No.	Constitution category	Constitution type	No. of cases	Percentage (%)
1	Single constitution	Yin-Yang Deficiency	98	21.7%
2		Taiyin-Yang Deficiency	39	8.6%
3		Spleen-Kidney Yang Deficiency	22	4.9%
4		Qi Stagnation	6	1.3%
5		Qi Deficiency	3	0.7%
6		Blood Deficiency	3	0.7%
7	Combined constitution	Yin-Yang Deficiency with Phlegm-Dampness	88	19.5%
8		Yang Deficiency with Blood Deficiency	48	10.6%
9		Yang Deficiency with Qi Stagnation	43	9.5%
10		Yin-Yang Deficiency with Qi Stagnation	43	9.5%
11		Yang Deficiency with Phlegm-Dampness	30	6.7%
12		Yang and Blood Deficiency with Qi Stagnation	14	3.1%
13		Yang and Blood Deficiency with Phlegm-Dampness	5	1.1%
14		Qi Stagnation with Blood Deficiency	3	0.7%
15		Qi Deficiency with Blood Deficiency	2	0.4%
16		Yang Deficiency, Qi Stagnation, and Phlegm-Dampness	1	0.2%
17		Yang Deficiency, Phlegm-Dampness, and Qi Stagnation	1	0.2%
18		Yin-Yang Deficiency with Blood Deficiency and Phlegm-Dampness	1	0.2%
		Total	451	100%
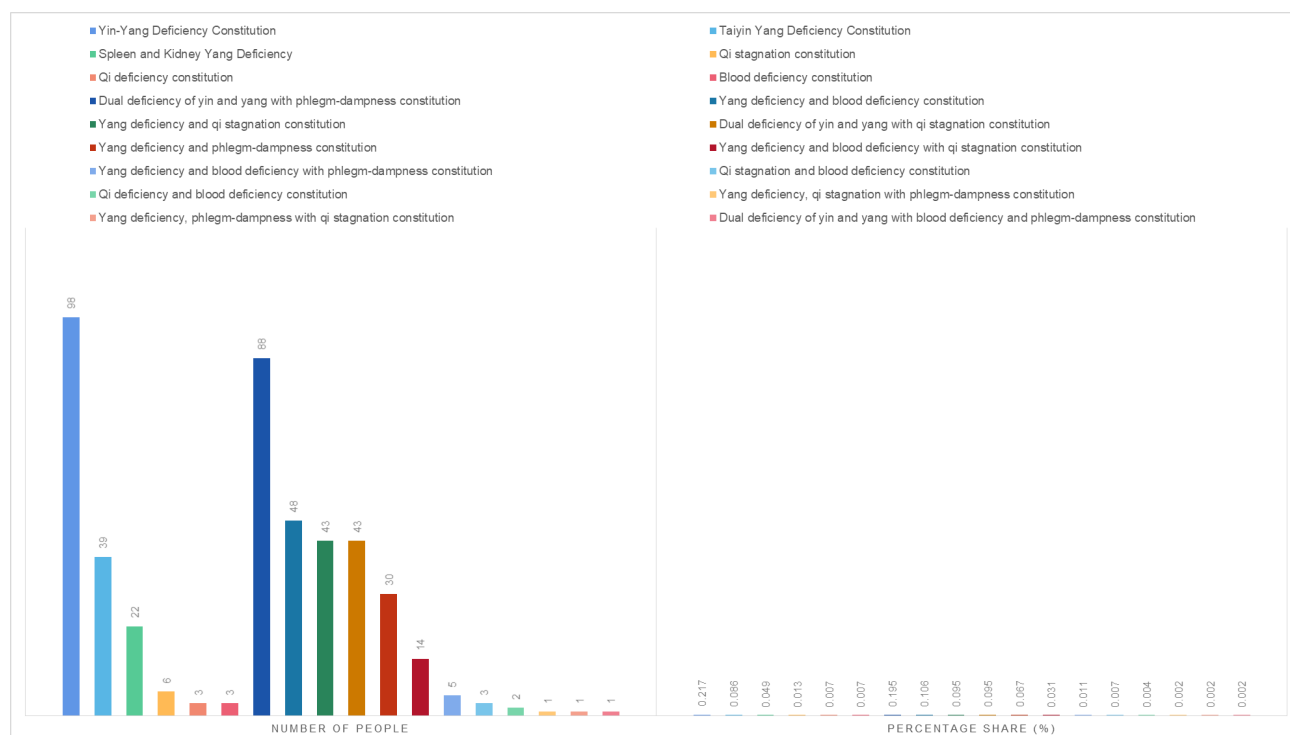
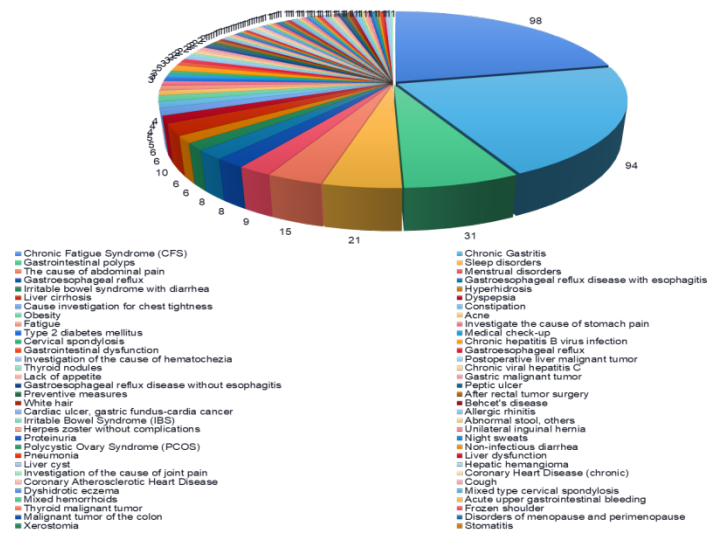**Figure 2.** Distribution of biased constitution types.

Figure 3. Disease distribution map of individuals with biased constitutions.

4.3. Correlation study between human infrared thermal patterns and disease prediction

(1) One-way analysis of variance

Variables such as gender, age, and the average temperatures of the face, left armpit, right armpit, upper energizer, middle energizer, lower energizer, left palm, right palm, left dorsum of the foot, right dorsum of the foot, Governor Vessel, left hypochondrium, and right hypochondrium were included in the research model. Compared with cases where no outcome event occurred, statistically significant differences ($p < 0.05$) were observed in variables such as gender ($p = 0.013$, CI%: 0.33-0.42), age ($p = 0.000$, CI%: 43.27–46.22), T_{face} ($p = 0.028$, CI%: 31.18–31.38), $T_{upper\ energizer}$ ($p = 0.049$, CI%: 31.38–31.63), $T_{middle\ energizer}$ ($p = 0.002$, CI%: 31.23–31.46), $T_{lower\ energizer}$ ($p = 0.007$, CI%: 31.30–31.53), $T_{left\ dorsum\ of\ the\ foot}$ ($p = 0.021$, CI%: 30.23–30.45), and $T_{right\ hypochondrium}$ ($p = 0.018$, CI%: 29.28–29.67) in cases where an outcome event did occur (see **Table 2**).

(2) Multivariate logistic regression analysis

The variables with statistical differences mentioned above were included as independent variables, and the occurrence of the outcome event was used as the dependent variable in a multivariate logistic regression model. The study found that among the 98 cases with outcome events, 72 were female (73.47%); among the 353 cases without outcome events, 211 were female (59.77%). This suggests that the risk of developing CFS in females is approximately 2.7 times that of males, and the risk of developing CFS increases with age (**Table 3**).

(3) ROC curve

An ROC curve graph was constructed based on four independent risk factors: gender, age, $T_{middle\ jiao}$, and $T_{left\ dorsum\ of\ foot}$. The ROC curve analysis indicated that the areas under the curve for gender, age, $T_{middle\ jiao}$, and $T_{left\ dorsum\ of\ foot}$ were 0.432 (95% CI: 0.369–0.494), 0.292 (95% CI: 0.241–0.344), 0.402 (95% CI: 0.339–0.465), and 0.564 (95% CI: 0.498–0.630), respectively.

5. Discussion

### 5.1. The disease prediction value and modern clinical application of IRT

As a new technology in modern functional imaging examination, Infrared Thermography (IRT) enables non-invasive, radiation-free, intervention-free, pollution-free, and side-effect-free monitoring under natural human conditions. Without the need for external emission sources or the ingestion of contrast agents or other marker drugs, it can sensitively detect abnormal changes in the temperature field caused by metabolic disorders before

Table 2. One-way analysis of clinical characteristics in patients

Clinical feature	Total (N = 451)	Outcome event (N = 98)	Non-outcome event (N = 353)	*p*-value
Gender				0.013
Female	283 (62.8%)	72 (73.5%)	211 (59.8%)	
Male	168 (37.2%)	26 (26.5%)	142 (40.2%)	
Age (years)				0.000
< 18	13.50 ± 3.80 (32)	15.00 ± 1.41 (6)	13.00 ± 4.09 (25)	
18–65	43.64 ± 11.89 (367)	37.33 ± 10.50 (91)	45.65 ± 11.62 (277)	
≥ 65	70.88 ± 5.09 (52)	73.00 ± 0.00 (1)	71.76 ± 4.91 (51)	
Temperature (°C)				
T_{Face}	31.29 ± 1.09	31.07 ± 1.09	31.34 ± 1.08	0.028
$T_{Left\ Axilla}$	29.01 ± 2.15	29.03 ± 2.26	29.01 ± 2.13	0.948
$T_{Right\ Axilla}$	29.19 ± 2.18	29.15 ± 2.23	29.07 ± 2.17	0.820
$T_{Upper\ Jiao}$	31.51 ± 1.30	31.28 ± 1.31	31.57 ± 1.28	0.049
$T_{Middle\ Jiao}$	31.34 ± 1.27	31.99 ± 1.31	31.44 ± 1.24	0.002
$T_{Lower\ Jiao}$	31.41 ± 1.23	31.12 ± 1.20	31.50 ± 1.23	0.007
$T_{Left\ Palm}$	28.04 ± 2.55	28.01 ± 2.60	28.04 ± 2.53	0.904
$T_{Right\ Palm}$	27.98 ± 2.37	27.97 ± 2.52	27.98 ± 2.32	0.965
$T_{Left\ Dorsal\ Foot}$	30.34 ± 1.28	30.60 ± 1.26	30.26 ± 1.27	0.021
$T_{Right\ Dorsal\ Foot}$	30.27 ± 1.27	31.38 ± 1.40	30.24 ± 1.24	0.351
$T_{Governor\ Vessel}$	30.83 ± 1.67	31.57 ± 1.58	30.90 ± 1.62	0.078
$T_{Left\ Hypochondrium}$	29.48 ± 2.10	29.13 ± 2.21	29.57 ± 2.09	0.065
$T_{Right\ Hypochondrium}$	31.28 ± 1.35	31.00 ± 1.23	31.36 ± 1.37	0.018

Table 3. Multivariate logistic regression analysis

Variable	OR	95% CI	*p*-value
Gender	2.706	1.563–4.685	0.000
Age	0.956	0.940–0.971	0.000
$T_{Middle\ Jiao}$	0.686	0.566–0.831	0.000
$T_{Left\ Dorsal\ Foot}$	1.310	1.069–1.605	0.009
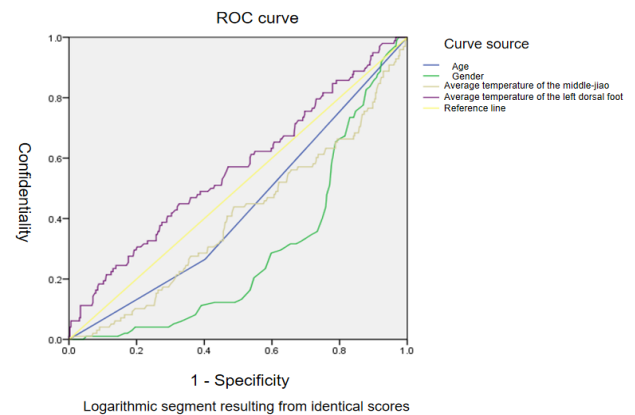
Figure 4. ROC Curve Graph for Gender, Age, $T_{middle\ jiao}$, and $T_{left\ dorsum\ of\ foot}$.

obvious symptoms or signs appear in the body. Thus, it can be used for health assessment, early disease auxiliary detection, and functional evaluation of therapeutic effects, and has become a research hotspot in recent years for early disease monitoring and prevention [4]. Wang Jiali et al. discovered that after cold stimulation, patients with phlegm-dampness constitution metabolic syndrome (MS) exhibited a lower average surface temperature in the supraclavicular region (SCR) compared to healthy individuals [9]. The thermal deviation in the SCR of phlegm-dampness MS patients was not significant, and the elevated temperature difference was lower than that of healthy individuals and non-phlegm-dampness MS patients. Utilizing IRT to study the infrared manifestations in the SCR of phlegm-dampness MS patients can provide objective evidence and new targets for the early detection and precise treatment of phlegm-dampness MS. Yang Qian et al. found that female patients with Hashimoto's thyroiditis (HT) exhibited higher thermal values in the left and right lobes of the thyroid gland and lower thermal values in the uterus, Governor Vessel, and Shenque area. This characteristic also provides new clinical theoretical evidence for HT-induced infertility. Meanwhile, the thermal values in the left and right lobes of the thyroid gland can serve as one of the indicators for early diagnosis and screening of HT, affirming the clinical significance of IRT as an auxiliary diagnostic tool to improve the diagnostic efficacy of HT. Meanwhile, when assessing the risk of foot lesions, Infrared Thermography (IRT) can provide useful clinical information by detecting characteristic changes in the temperature of the lower extremities and plantar regions. It can sensitively identify metabolic differences caused by early peripheral nerve and vascular lesions associated with diabetic foot (DF), offering additional reference information for early warning and diagnosis of DF ulcers [10]. It is worth mentioning that in the fields of basic traditional Chinese medicine (TCM) theory and TCM diagnostic research, the advent of IRT has provided objective, visual, and intelligent diagnostic evidence for TCM clinical differentiation of common and frequently occurring diseases such as stomachache, coronary heart disease, and ischemic encephalopathy [11–13].

5.2. Unique advantages of IRT in the field of traditional Chinese medicine research

As stated in "Su Wen: Great Treatise on Correspondence Between Yin and Yang and the Images of the Natural World", "Water and fire are the manifestations of Yin and Yang". It also says, "Excess of Yang leads to heat, excess of Yin leads to cold, deficiency of Yin leads to heat, and deficiency of Yang leads to cold". Changes in cold and heat reflect the balance of Yin and Yang Qi in the body's organs and meridians. Based on the principle of infrared radiation, IRT can capture the instantaneous infrared thermal radiation temperature of the human body and convert it into a visualized image of the body's surface temperature distribution, intuitively reflecting the body's cold-heat Yin-Yang status. It also aids in syndrome differentiation by combining the infrared thermal image characteristics of different locations, such as disease sites, organ regions, and meridian pathways [14]. Currently, the application of Infrared Thermography (IRT) in Traditional Chinese Medicine (TCM) has centered around three major research hotspots: meridian acupoint studies combined with acupuncture and Tuina therapy, auxiliary diagnosis of diseases and syndromes, and TCM constitution research [9]. Particularly in the field of TCM constitution identification, IRT offers unique advantages in terms of objectivity, visualization, dynamism, and intelligence. Li Hongjuan first utilized IRT to analyze the thermal characteristics of nine different constitutional groups, discovering that the relative temperature variations in specific areas such as the Du meridian, Ren meridian, Shenque (CV8), upper energizer, middle energizer, lower energizer, lungs, heart, and liver among different constitutional groups aligned with the typical characteristics outlined in TCM constitution theory, visually demonstrating the characteristic changes in population constitutions [15]. Xie Jiding et al. employed IRT to investigate the effects of Baduanjin exercise on Body Mass Index (BMI) and abdominal temperature, revealing that Baduanjin could elevate abdominal temperature, activate specific acupoints, and promote metabolism and blood circulation [16]. Liu Feng et al. also proposed that the adequacy of Zang-fu Qi could be preliminarily inferred from the infrared characteristics of the projected skin areas of the Zang-fu organs and their corresponding front-mu acupoint [17]. This underscores

the objective reference value of IRT in clinical constitution research and application. With the continuous advancement of modern technology, infrared thermal imaging technology has become closely integrated with the development of "Internet Plus" and artificial intelligence. Li Xin designed an algorithm based on a Convolutional Neural Network (CNN) to automatically extract and classify temperature features from segmented infrared images of cervical spine regions [18]. By introducing an attention mechanism, the algorithm's performance was further enhanced, enabling effective differentiation of cervical spine conditions and promoting the intelligent application of Infrared Thermography (IRT) in clinical diagnosis and treatment. Research on the spectral and quality detection of traditional Chinese medicine (TCM) samples, based on IRT and an Internet sharing model, has demonstrated that intelligent IRT applications represent a crucial avenue for rapid TCM quality detection [19]. Although the current scope and depth of IRT research in the field of TCM remain insufficient, its ability to reflect differences in body surface temperature under various conditions and interventions highlights its advantages for studying TCM concepts with clear body surface localization. Furthermore, its convenience, speed, and lack of side effects in clinical applications have led to widespread use in objective TCM clinical diagnosis and efficacy evaluation.

5.3. Evaluation of CFS risk based on IRT

Among the 451 observed cases in this study, 98 experienced outcome events, with incidence rates of 5.8% in males and 15.9% in females, consistent with previous literature reports on chronic fatigue syndrome (CFS) incidence [20,21]. The 98 CFS patients were predominantly female, with a peak age range of 18–65 years. In terms of constitutional diagnosis, 30.6% (30 cases) were classified as having a deficiency of both Yin and Yang, while 21.4% (21 cases) exhibited a deficiency of both Yin and Yang combined with phlegm-dampness. Multifactor logistic regression analysis suggests that gender and $T_{\text{left dorsum of foot}}$ in infrared thermal state structure are positively correlated with the onset of fatigue syndrome, while age and $T_{\text{middle jiao}}$ region of infrared thermal state structure are negatively correlated. Chronic Fatigue Syndrome (CFS) falls into the categories of "consumptive disease" and "depression syndrome" in traditional Chinese medicine, caused by pathogenic factors impairing the body's vital energy, improper balance between work and rest, and emotional disturbances, leading to deficiencies in Qi, blood, Yin, and Yang of the internal organs, as well as disharmony in the Qi mechanisms of the five organs, primarily involving the heart, liver, and spleen, along with imbalances in Qi and blood [22]. Women are prone to worry, and their hormonal levels are more susceptible to fluctuations than men, leading to emotions such as anxiety and depression [23]. Moreover, as women age, their likelihood of developing the condition increases significantly compared to before. Studies have shown that the incidence of depression in perimenopausal women reaches as high as 47.02%, which aligns with the patterns of onset observed in this study [24]. To further explore the best predictive factors for CFS, this study utilized ROC curve analysis. The results indicate that the AUC of the ROC curve for $T_{\text{left dorsum of foot}}$ is 0.564 (95% CI: 0.498–0.630), with an optimal predictive value of 30.82, a sensitivity of 0.449, and a specificity of 0.674. The foot, as a holographic organ of the human body, has corresponding reflex zones for all internal organs and tissues [25]. The meridians that pass through the dorsal foot include the Stomach Meridian of Foot-Yangming, Gallbladder Meridian of Foot-Shaoyang, and Liver Meridian of Foot-Jueyin, and this area encompasses five shu points and source points such as Qiuxu, Jiexi, Chongyang, Zulinqi, Xiangu, Taichong, Neiting, and Xingjian. Among them, Taichong (LR3) is the Shu-Stream and Source point of the Liver meridian, corresponding to the characteristics of the "Kan Trigram". The Liver stores blood and belongs to Yin, while its function of regulating the flow of Qi is Yang. The Source point of the Liver meridian also embodies the principle of Yin in substance and Yang in function, demonstrating the effect of Yin in essence and Yang in action [26]. In animal experimental studies, the use of Hegu (LI4) and Taichong (LR3) as the Four Gate points for treating chronic fatigue syndrome (CFS) has been shown to be effective by downregulating serum TNF-α and lipopolysaccharide levels in rats, thereby inhibiting inflammatory responses [27]. The combined use of acupoints on the Stomach and Spleen meridians can significantly alleviate psychological and physical fatigue in CFS rats and enhance their antioxidant capacity [28]. Therefore, for CFS, which is

primarily characterized by deficiency with intermingled excess and deficiency as its basic pathogenesis, the clinical selection and combination of acupoints on the Liver and Stomach meridians on the dorsal foot hold greater significance in terms of nourishing the acquired constitution, promoting the generation of Qi and blood, and regulating the flow of Qi.

In summary, the infrared thermal patterns on the dorsal foot and middle-jiao regions in CFS patients are correlated with the onset of CFS. In this study, the infrared skin temperature of the left dorsal foot ($T_{left\ dorsum\ of\ foot}$) emerged as the best predictor for the occurrence of CFS, with relevant experimental results further confirming the association between the human infrared thermal patterns and disease risk prediction.

However, as this study is a single-center retrospective cross-sectional study, it cannot avoid selection bias and temporal bias in the study subjects. Moreover, the number of detection sites is still insufficient, and the sensitivity of individual sites is not high. Therefore, a large number of multi-center, large-sample, and long-time-zone randomized controlled trials are still needed to construct a comprehensive evaluation model of composite sites, promote the clinical use and research popularization of IRT, reveal the potential physiological regulatory functions of Zang-fu organs and meridians in traditional Chinese medicine constitution, and provide important experimental evidence for in-depth research on constitution and the biophysical properties of meridians and acupoints.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Wang Q, 2008, Three Discussions on TCM Constitution. Journal of Beijing University of Traditional Chinese Medicine, 2008(10): 653–655.

[2] Wang J, Qin J, Xie Z, et al., 2023, Application of TCM Constitution Theory in the Prevention and Treatment of Dementia Under the Background of Great Health. Journal of Beijing University of Traditional Chinese Medicine, 46(02): 154–158.

[3] Liao J, Wang T, Li Z, et al., 2021, Research Progress on the Application of Infrared Thermal Imaging Technology in Disease Diagnosis and TCM Syndrome Differentiation. Chinese Journal of Basic Medicine in Traditional Chinese Medicine, 27(04): 698–702.

[4] Li L, Wu S, Yang T, 2016, Diagnostic Value of Infrared Thermography in Vascular Diseases. Laser Journal, 37(4): 144–147.

[5] Ma B, Ye S, Wang Q, et al., 2021, Study on the Thermodynamic Distribution Characteristics of Different TCM Syndromes in Knee Osteoarthritis Based on Infrared Thermography. Shanghai Journal of Traditional Chinese Medicine, 55(12): 17–22.

[6]   Zhou Y, Zhou X, Shui D, et al., 2019, Discussion on the Diagnostic Value of Infrared Thermal Image Mathematical Mean in Breast Diseases. Infrared, 40(2): 30–35.

[7]   Zhang X, Qiu X, Jiang S, et al., 2016, Discussion on the Relationship Between Infrared Thermography Manifestations and TCM Syndrome Types in Patients with Lumbar Disc Herniation. Guiding Journal of Traditional Chinese Medicine and Pharmacy, 22(3): 55–57.

[8]   Zhou X, Xie S, Zhang D, et al., 2015, Application and Mechanism Discussion of Meridian Infrared Imaging Technology in Patients with Jueyin Cold Transformation Syndrome. Lishizhen Medicine and Materia Medica Research, 26(11): 2703–2705.

[9]   Wang J, Wang Z, Liu Y, et al., 2023, Exploring the Relationship Between Brown Adipose Tissue and Phlegm-Dampness Metabolic Syndrome Based on Infrared Thermal Imaging Technology. China Journal of Chinese Materia Medica, 48(03): 823–828.

[10] Chen Z, Gao M, Zhang W, et al., 2021, A Brief Discussion on Strategies for Early Diagnosis of Diabetic Foot Using Infrared Thermal Imaging Technology. China Journal of Traditional Chinese Medicine and Pharmacy, 36(02): 963–967.

[11] Zhao T, Wen Y, Zong J, et al., 2020, Research on Infrared Thermal Imaging Characteristics of Spleen–Stomach Deficiency-Cold Syndrome in Epigastric Pain. Journal of Basic Chinese Medicine, 26(11): 1654–1658.

[12] Gao M, Shi Y, Xiao Y, et al., 2020, Overview of the Application of Infrared Thermal Imaging Technology in the Early Diagnosis of Coronary Heart Disease. China Journal of Traditional Chinese Medicine and Pharmacy, 35(09): 4561–4564.

[13] Cheng C, Gao Y, Xue Y, et al., 2014, Application of Far-Infrared Thermal Imaging in Ischemic Cerebrovascular Disease. Chinese Journal of Medical Imaging, 22(03): 210–212 + 216.

[14] Zhang Y, Wang Y, Li N, et al., 2023, Visual Analysis of the Application of Infrared Thermal Imaging Technology in the Field of Traditional Chinese Medicine Based on CiteSpace. World Journal of Integrated Traditional and Western Medicine, 18(05): 887–892.

[15] Li H, Xu J, Guo H, et al., 2009, Research on the Thermal Characteristics of Nine Types of Traditional Chinese Medicine Constitutions. Journal of Basic Chinese Medicine, 15(10): 790–791.

[16] Xie J, Tian S, Zheng X, et al., 2023, Exploring the Effect of Baduanjin on Body Mass Index Based on Infrared Thermal Imaging Technology and Acupoint Theory. Journal of Beijing University of Traditional Chinese Medicine: 1–11.

[17] Liu F, Liu Z, Zhang W, 2022, Detection by Infrared Thermal Imaging and Observation of Clinical Efficacy of the Xing-Qi-Shen Hypoglycemic and Qi-Circulating Method Based on Traditional Chinese Medicine Qi-Circulating Techniques. China Journal of Traditional Chinese Medicine and Pharmacy, 37(12): 7387–7391.

[18] Li X, 2020, Research and Application of an Auxiliary Diagnosis and Treatment System for Cervical Spondylosis Based on Infrared Thermal Imaging, thesis, Zhejiang University.

[19] Ni L, Luan S, Zhang L, 2016, Exploration of Rapid Determination of the Quality of Traditional Chinese Medicines by Near-Infrared Spectroscopy Based on Internet Sharing Mode. China Journal of Chinese Materia Medica, 41(19): 3520–3527.

[20] Wu Q, Gao J, Bai D, et al., 2020, Meta-Analysis of the Prevalence of Fatigue Syndrome in the Chinese Population. Youjiang Medical Journal, 48(10): 727–735.

[21] Peng X, Zhou X, Xiong Z, et al., 2020, Epidemiological Investigation of Fatigue Syndrome in Guangxi. Applied Preventive Medicine, 26(05): 409–411.

[22] Wang C, Tang X, Li C, et al., 2023, Multicenter Randomized Controlled Clinical Trial of Astragalus Injection Combined with Buzhong Yiqi Acupuncture for the Treatment of Chronic Fatigue Syndrome in Qi-Deficiency Constitution. Chinese Journal of Experimental Traditional Medical Formulae: 1–7.

[23] Yu S, Zhu Y, 2022, Investigation and Analysis of Postoperative Fatigue Syndrome in Patients Undergoing Painless

Gastrointestinal Endoscopy in Outpatient Settings. Clinical Education of General Practice, 20(06): 493–496.

[24] Liu X, Chen G, Ping J, et al., 2022, Investigation of Depression in Perimenopausal Women and Analysis of Related Factors Influencing the Occurrence of Depression. Maternal and Child Health Care of China, 37(09): 1558–1561.

[25] Lei L, Pang J, Lun S, 2005, Foot Massage in the Treatment of 205 Cases of Chronic Fatigue Syndrome. Journal of Guangxi Traditional Chinese Medical University, 2005(04): 22–23.

[26] Ai H, Wang Z, Bolin, et al., 2016, Preliminary Exploration of Acupuncture Point Selection Ideas for Chronic Fatigue Syndrome Based on the Theory of the Kan Trigram. Sichuan Journal of Traditional Chinese Medicine, 34(09): 30–32.

[27] Xie Y, Ji B, Zhang Q, et al., 2021, Effects of Electroacupuncture on Serum Inflammatory Factors and Intestinal Flora in Rats with Chronic Fatigue Syndrome of Liver Stagnation and Spleen Deficiency Type. Chinese Journal of Information on Traditional Chinese Medicine, 28(11): 63–68.

[28] Zhai H, Zhang B, Yuan X, 2016, Effects of Acupuncture at Different Acupoint Groups on Behavior and Antioxidant Capacity in Mice with Chronic Fatigue Syndrome. China Modern Medicine, 23(25): 12–15.