


Perceptions of traditional Chinese medicine doctors about using wearable devices and traditional Chinese medicine diagnostic instruments: A mixed-methodology study

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Abstract

Objective: This study aimed to investigate the perceptions of traditional Chinese medicine doctors about wearable devices and diagnostic instruments and explore the factors that influence them.

Methods: Data on the perceptions of the traditional Chinese medicine doctors in Hangzhou, China, about wearable devices and diagnostic instruments were collected through face-to-face semi-structured interviews. The author coded the interview responses using grounded theory. A cross-sectional survey was conducted in four traditional Chinese medicine hospitals in Hangzhou, China. The responses of 385 traditional Chinese medicine doctors were considered valid. Descriptive statistics and binary logistic regression models were used for analysis.

Results: This study categorized the perceptions of traditional Chinese medicine about wearable devices and traditional Chinese medicine diagnostic instruments under convenience, reliability, suitable population, machine usage scenario, and the integration of traditional Chinese medicine and information communication technology. Convenience encompassed portability and the convenience of carrying instruments or wearing the devices and operating them and the human–device interface. Reliability encompassed the underlying principles, accuracy, durability, and reference to diagnosis. Suitability for people encompassed age distinction and disease differentiation. Machine usage scenarios included use in daily life, educational institutions, and primary medical institutions. The combination of traditional Chinese medicine and information communication technology encompassed the integration of traditional Chinese medicine and wearable functions and diagnostic interpretation. The perceptions of traditional Chinese medicine doctors were affected by age, title, type of hospital, and specialty.

Conclusions: The use of wearable devices and traditional Chinese medicine diagnostic instruments has gradually been accepted by traditional Chinese medicine doctors. Traditional Chinese medicine doctors need to improve their knowledge and skills for information communication technology integration, and their standardized training should incorporate information communication technology and digital health.

Keywords

Wearable device, traditional Chinese medicine, grounded theory, pulse diagnosis, perceptions

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Introduction

With the continuous development of information communication technology (ICT), its use in the field of medicine and

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health is increasing. Due to advances in miniaturized electronic technology, the number of smartphones and network devices, consumer awareness of health, and the demands of traditional Chinese medicine (TCM) doctors for continuous medical data have increased. The combination of ICT and medical care has been widely used in daily life.¹ Thus, the effective integration of ICT with medical health has become important in research.

The combination of ICT and medical health has two main aspects. First, in the population health field, health data can be recorded for different groups of people through tools such as wearable devices.² Second, for the diagnosis and treatment of diseases, diagnostic instruments, such as electrocardiographs (ECGs), can monitor and detect abnormal indicators in various patients and provide diagnostic references for TCM doctors.³

With the reduction of price and the improvement of accuracy, wearable devices have been increasingly used in the daily lives of people. Wearable devices, for example, have been used to monitor posture during daily activities and explore the user experience of older adults through interviews. This study found that wearable devices can recognize motion postures with 90% accuracy.⁴ However, the comfort of wearing devices should also be considered during use. Several wearable devices can record the heart rate of older adults and monitor exercise distance. The devices allowed for the evaluation of exercise intensity and the design of an exercise plan.^{5–6} Previous studies have used various wearable devices to monitor the sleep patterns and behaviors of older adults to test their user preferences. It was found that users consider daily monitoring functions of wearable devices highly useful and are willing to allow usage of their data for health evaluation.^{7–8} Some studies have used wearable devices to monitor the health of patients after ICU discharge, and they are used to monitor data such as heart rate, pulse, and sleep quality. The results of the study showed that the continuous monitoring of heart rate by wearable devices has a specificity of 98% and can be used for health monitoring of discharged individuals.^{9–12}

Different from the use of wearable devices in daily life, diagnostic instruments are mainly used in medical institutions to provide references for diagnoses for TCM doctors. The current studies used electroencephalography (EEG) to observe patients with ischemic cardiomyopathy and found that the results of ECG can be used to evaluate patient treatments.^{13–14} Several diagnostic devices are used in the field of TCM. Digital TCM research has involved the use of digital image processing technology and machine learning methods to classify TCM tongue images. The classification accuracy of the five tongue images reached 80%, which was satisfactory for automatic diagnoses based on TCM tongue images.^{15–16} In recent years, several studies have summarized the characteristics of symptoms in TCM and found that diagnosis in TCM

can be achieved by bionics instruments.^{17–19} The application of ICT in the field of medicine and health has become normal, and several TCM doctors have begun using devices as diagnostic tools.

TCM is a holistic medical system for the diagnosis, prevention, and treatment of diseases. It has been a part of Asian culture for thousands of years. The attitudes of TCM doctors toward ICT determine whether they will use these tools for diagnosis. Specifically, several studies have found that the perspectives of TCM doctors about diagnostic tools directly affect treatment outcomes.^{20,21} Several existing studies have used information technology to build a comprehensive database of TCM drugs and devices. TCM doctors believe that the database integrates modern medicine and TCM, which allows TCM doctors to conveniently compare symptoms.^{22–24} A few studies have used machine learning to classify and predict pulse waves in a hypertensive group. These studies evaluated the risk of hypertension by observing the dynamic changes of pulse waves and provided an objective reference for the clinical application of TCM pulse diagnosis. However, the accuracy of pulse diagnostic instruments has not been recognized by some doctors.^{25,26}

Only a few studies on the application of ICT in TCM practice and perspectives of TCM doctors are available in the literature. The perspectives of TCM doctors affect their use of instruments to aid their diagnoses. The purpose of this study was to investigate the perspectives about ICT by TCM doctors through semi-structured interviews and explore the factors that influence these. We analyzed the advantages and disadvantages of existing ICT and provided theoretical support for the integration of TCM and ICT.

Methods

Participants and data collection

Qualitative exploratory study. The participants of this study are TCM doctors who work at TCM medical institutions in Hangzhou, China. After expert communication, the inclusion criteria for TCM doctors were: (a) graduation from TCM University; (b) engagement in clinical TCM diagnosis for more than 10 years; (c) having a doctor's qualification above an attending physician (TCM doctor professional qualification: chief physician, associate chief physician, and attending physician); (d) experience in teaching traditional Chinese medicine students; and (e) experience in using wearable devices and TCM diagnostic instruments. The participants of this study were recruited in December 2018.

Cross-sectional survey. Four TCM hospitals selected from Hangzhou were involved in this study. The participants were TCM doctors in hospitals in Hangzhou, including

two comprehensive TCM hospitals and two primary TCM hospitals. One hundred questionnaires were distributed in each hospital, and a total of 400 questionnaires were distributed. Wearable devices and TCM diagnostic instruments have been listed as “Hangzhou Smart Medical Tools,” and the TCM doctors who participated in this research had experience in using wearable devices and TCM diagnostic instruments. According to the “2021 Hangzhou Health Personnel Statistical Yearbook,” the number of TCM doctors in Hangzhou is 12,568. Therefore, to achieve a confidence level of 95, a 5% margin of error,

and 50% response distribution, a minimum sample size of 373 was required.

The survey period for this study was March 2022. This study protocol passed the ethical review and was approved by Waseda University (No. 2018-278) and Hangzhou Normal University (No. 2021-1147).

Study design

Interview guide. The interview phase took place in January 2019. According to the recommendation of experts, the researchers selected 20 interviewees who met the criteria, of which 10 were willing to participate. To suit the interviewees who wished to fully evaluate the use of ICTs in the field of TCM, this study used semi-structured face-to-face interviews to collect data. Each interview began with the following question: How do you feel about wearable devices and TCM diagnostic instruments? The following areas probed included: (a) the trustworthiness of wearable devices and TCM diagnostic instruments; (b) the role of wearable devices and TCM diagnostic instruments in different populations; (c) the role of wearable devices and TCM diagnostic instruments in the diagnosis of TCM; and (d) suggestions for wearable devices and TCM diagnostic instruments.

If the interviewee did not spontaneously touch these areas, the interviewer asked questions appropriately. The author of this article conducted a semi-structured interview at the interviewee’s office. Signed informed consent was obtained from all participating TCM doctors. Each interview lasted approximately 40 min. After communicating with the interviewees, the interviewer explained the study theme and goals, signed the informed consent form, and collected specific information such as the age, professional title, and the number of years in practice. During the interview, the interviewees were allowed to use the recording equipment, and all interviews were recorded.

Questionnaire survey. The survey period for this study was March 2022. The collected data mainly covered the following: (a) basic information including the gender, title, age, and specialty of the doctor; (b) reliability of wearable devices and TCM diagnostic instruments based on indicators including accuracy and underlying principles; (c) convenience in using wearable devices and TCM diagnostic instruments, spanning ease of use and degree of comfort; (d) benefits of using wearable devices and TCM diagnostic instruments, indicated by efficient diagnosis and misdiagnosis rate (before and after using wearable devices and TCM diagnostic instruments), among others.

The questionnaire consisted of three items: reliability, convenience, and benefits of wearable devices and TCM diagnostic instruments. A five-point Likert scale with scores ranging from 1 (strongly disagree) to 5 (strongly agree). The scores for the separate items were summed

Table 1. Results of factor analysis after rotation.

Categories	Items	1	2	3
Reliability	Reliability in accuracy (TCM diagnostic instruments)	0.833		
	Reliability in accuracy (wearable devices)	0.830		
	Reliability in principles (TCM diagnostic instruments)	0.789		
	Reliability in principles (wearable devices)	0.744		
Convenience	Ease of use (TCM diagnostic instruments)		0.693	
	Ease of use (wearable devices)		0.665	
	Degree of comfort (TCM diagnostic instruments)		0.654	
	Degree of comfort (wearable devices)		0.552	
Benefits evaluation	Efficiency diagnosis (TCM diagnostic instruments)			0.747
	Efficiency diagnosis (wearable devices)			0.668
	Misdiagnosis rate (TCM diagnostic instruments)			0.534
	Misdiagnosis rate (wearable devices)			0.506

and divided by the total number of items. The formula was $\text{Score} = \sum (a + \beta + \dots + \delta) / n$.

Exploratory factor analysis was conducted to assess the 12 items retained in the item analysis. The results demonstrated a KMO test statistic of the evaluation questionnaire of 0.859. The factor analysis results after rotation are shown in Table 1. The reliability of the questionnaire was checked using Cronbach's alpha, and the reliability coefficient was 0.844.

Statistical analysis

Interview data analysis. This study used grounded theory to analyze interview data.²⁷ Grounded theory enables researchers to develop a theory to explain the phenomena. In other words, grounded theory is best suited for discovering new things. As the research progressed, the initial exploratory problems of the researchers were improved until they understood the subject of the research.²⁸ Data analysis was performed using qualitative methods in the field of health care. This applies to health care research.^{29,30} Interview data were uploaded via digital media and transcribed using standard operating procedures to ensure participant confidentiality. The data were transcribed verbatim and uploaded to the NVivo 10 software for separation and encoding of the summarized data.

The data analysis was performed in five steps: Step 1: Editing: researchers read the interview data verbatim and fully understand the interview content; Step 2: Open coding: researchers coded the data line-by-line and conceptually grouped the content; Step 3: Intermediate coding: researchers focused on the grouping concept, reclassifying and defining them; Step 4: Axial coding: researchers used axis coding to develop categories and concepts and classify them into higher-level headlines; Step 5: Formation theory: researchers integrated the final theme choice into the final grounded theory.³¹

Survey data analysis. Descriptive analysis was used to describe the characteristics of the TCM doctors. Reliability, convenience, and benefits were quantified and expressed as means (M) and standard deviations (SDs). The statistical analyses were performed using a student's t -test or one-way analysis of variance (ANOVA), according to the characteristics of the data. Pearson correlation coefficient (r) was used to assess the associations between variables. The strength of correlations was described as weak ($|r| < 0.3$), moderate ($0.3 < |r| < 0.5$), or strong ($|r| > 0.70$). The titles of the TCM doctors were classified as primary (including attending TCM doctor and resident TCM doctor) and senior (including chief TCM doctor and associate chief TCM doctor). The ages were divided into two ranges using the median value: <40 years and ≥ 40 years. To evaluate the reliability, convenience, and benefits of wearable devices and TCM diagnostic instruments,

scores of > 3 were classified as high, while scores of ≤ 3 were classified as low. Binary logistic regression was used to assess the effects of individual characteristics on the perceptions of TCM doctors about the reliability, convenience, and benefits of wearable devices and TCM diagnostic instruments. The analyses were conducted using Python version 3.9.0.

Results

Participants

The interviewees included eight males and two females, aged from 35 to 76 years, and capable of clearly expressing their opinions about the primary research questions. The qualifications of the participants were higher; nine of them had qualifications above the associate chief physician level, and the average number of years of medical practice was 23.7 years. All TCM doctors had experience in using wearable devices and TCM diagnostic instruments. The most used wearable devices were wristbands, and the most used diagnostic instruments were pulse diagnostic instruments (Table 2).

Categories

During the axial coding process, five categories were used to describe the perceptions of TCM doctors about the use of wearable devices and TCM diagnostic instruments (Table 3).

Category 1: Proprioceptive effect. TCM doctors described the experience of using wearable devices and TCM diagnostic instruments. For example, devices and instruments were easy to carry, comfortable to wear, and convenient to operate.

Some TCM doctors had used wearable devices over long periods and had accepted them: "I have been wearing healthy bracelet for more than 3 months. I feel comfortable and it do not affect my daily work" (Doctor 2).

Some TCM doctors reported that wearable devices were not used as watches, and their willingness to continue to wear the devices depended on the level of comfort: "I brought the bracelet for no more than 2 months. It was not for functional reasons, because the rubber material felt uncomfortable" (Doctor 5).

When using wearable devices for the first time, some TCM doctors reported that they were concerned about operability: "The screen of this bracelet is too small. I can't see the contents of the screen. So I have not continued to use the bracelet" (Doctor 6).

Compared with the perceptions about wearable devices, the perceptions about TCM diagnostic instruments were consistent. TCM doctors thought that TCM diagnostic instruments were easy to operate: "The pulse diagnosis

Table 2. TCM doctors' information.

ID	Gender	Age	Title	Working years	Wearable device	TCM diagnostic instrument
Doctor 1	Male	55	Chief	32	Smart wristband	Pulse diagnosis instrument
Doctor 2	Male	49	Associate chief	15	Smart wristband	Pulse diagnosis instrument; Meridian diagnosis instrument
Doctor 3	Female	59	Chief	35	Smart wristband	Pulse diagnosis instrument
Doctor 4	Male	36	Associate chief	11	Smart wristband	Pulse diagnosis instrument; Meridian diagnosis instrument
Doctor 5	Male	39	Associate chief	12	Smart wristband	Pulse diagnosis instrument
Doctor 6	Male	76	Chief	54	Smart wristband	Pulse diagnosis instrument
Doctor 7	Male	42	Associate chief	15	Smart wristband; Smart watch	Pulse diagnosis instrument
Doctor 8	Male	67	Chief	37	Smart wristband	Pulse diagnosis instrument
Doctor 9	Male	41	Associate chief	16	Smart wristband; Smart watch	Pulse diagnosis instrument
Doctor 10	Female	35	Attending	10	Smart wristband	Pulse diagnosis instrument

instrument is connected to the computer. I can use the keyboard to directly input information, so the result can be output quickly' (Doctor 2)"; "The operation of the pulse diagnosis instrument is convenient, and it has a large screen to confirm the result" (Doctor 8).

Category 2: Sense of trust. TCM doctors described the trust in wearable devices and TCM diagnostic instruments. The areas of concern included the understanding of machine principles, accuracy of evaluation, durability of the instrument, and reference to diagnosis.

TCM doctors have a simple, but not comprehensive, understanding of the principles of wearable devices and TCM diagnostic instruments: "The principle should be bionics, light perception and gravity sensors. This can mimic pulse diagnosis, and can also record data such as steps and heart rate. But I can't say the detailed principle" (Doctor 1).

TCM doctors believe that the sustainability of wearable device monitoring data affects accuracy: "I think the record accuracy of steps and heart rate are relatively high. Because these data are easy to monitor and can be monitored continuously for a long time. But blood pressure is easily affected by external factors, I think the accuracy is low" (Doctor 3).

TCM doctors also have doubts about the accuracy of TCM diagnostic instruments and think it is unlikely they will replace conventional clinical diagnosis: "Pulse diagnosis has three steps, but pulse diagnosis instrument only achieve the first step. Although the accuracy is high, it is just a single pulse. TCM doctors compare the three different pulses to diagnosis. Pulse diagnosis instrument cannot achieve this function" (Doctor 4).

TCM doctors have concerns about the durability of wearable devices and TCM diagnostic instruments: "Some patients have feedback that durability is not good. There are also sophisticated components in the devices. They are still easy to break" (Doctor 8).

TCM doctors reported that wearable devices and TCM diagnostic instruments are not very helpful for diagnosis: "It doesn't help much for my diagnosis. The diagnosis of TCM requires current data. For example, to diagnose the current physical condition, I must diagnosis pulse immediately. The wearable device records historical data, and the accuracy of the pulse diagnosis instrument is not high" (Doctor 9).

Category 3: Suitable population. TCM doctors described the indications for wearable devices and TCM diagnostic

Table 3. Coding and categorization of TCM doctor data.

Selective coding	Axial coding-TCM doctors
Proprioceptive effect <ul style="list-style-type: none"> • Carrying convenience • Comfortable feeling • Convenient operation • Interface humanity 	1. Digital technology has facilitated the miniaturization and weight reduction of diagnostic instruments. 2. The design and materials of the wearable device are designed with humanity in mind. 3. Wearable devices and TCM diagnostic instruments are designed with different operation modes according to different groups of people.
Sense of trust <ul style="list-style-type: none"> • Principle of the machine • Instrument accuracy • Instrument durability • Reference to diagnosis 	4. TCM diagnostic instruments used motion capture technology to imitate TCM diagnostic procedures. 5. The accuracy of wearable devices and TCM diagnostic instruments is affected by the user and the environment. 6. Advances in ICT and materials have extended the durability of wearable devices and TCM diagnostic instruments. 7. The results of wearable devices and TCM diagnostic instruments serve as a reference for TCM doctors' diagnosis.
Suitable population <ul style="list-style-type: none"> • Age distinction • Disease differentiation 	8. There are differences in the application of wearable devices in different age groups. 9. TCM diagnostic instruments are suitable for the diagnosis of non-communicable chronic diseases.
Machine usage scenario <ul style="list-style-type: none"> • Daily life • Educational institution • Primary medical institutions 	10. Wearable devices are suitable for health monitoring in daily life. 11. Wearable devices and TCM diagnostic instruments have been offered as courses in TCM universities. 12. TCM diagnostic instruments can be used as auxiliary diagnosis for triage in primary medical institutions.
Combination of TCM and ICT <ul style="list-style-type: none"> • Integration of TCM and wearable functions • Interpretation of the diagnosis results 	13. The miniaturization and light weight of TCM diagnostic instruments are helpful for the application of TCM diagnosis in daily life. 14. Quantitative TCM diagnostic data is more helpful to explain the disease mechanism of patients.

instruments; for example, the age group of the population and the symptoms of the population.

TCM doctors found that wearable devices are more suitable for older adults: "I feel that wearable devices are more suitable for the elderly. Because it is difficult for the elderly to describe their own health. The data recorded by wearable devices can help the elderly understand their health" (Doctor 1); "Some wearable devices also have an anti-fall warning function, which is the most suitable function for the elderly" (Doctor 7).

TCM doctors stated that wearable devices were suitable for the chronic patient population and useful for the detection of abnormal conditions: "I think wearable devices are necessary for chronic patients. For example, for young hypertensive patients, we ask them to take blood pressure every day and monitor blood pressure in real time. Regardless of age, I recommend using wearable device" (Doctor 5).

One TCM doctor suggested that the TCM diagnostic instrument is suitable for people interested in TCM: "Just those who want to know their physical condition, there is

no need to use pulse diagnosis instrument. Because the results of the pulse diagnosis instrument can only be used for reference and cannot be used for diagnosis. People who know TCM knowledge can use it because they can judge result of right or wrong" (Doctor 6).

Category 4: Machine usage scenario. TCM doctors described the usage scenarios of wearable devices and TCM diagnostic instruments; for example, the places and stages to be used.

Some TCM doctors believed that wearable devices should be used in daily life: "Wearable devices are suitable used in daily life. I think the most important function of wearable device is to detect abnormalities and data records, which are useful for our diagnosis" (Doctor 3).

Some TCM doctors reported that TCM diagnostic instruments should be mainly used at the TCM education stage: "The pulse diagnosis instrument is best suited for teaching. It is impossible for students to follow the teacher every day, and the pulse diagnosis instrument can be used as a practice object for comparison." (Doctor 4);

“Nowadays, students rarely have the opportunity to diagnose the disease, and the pulse diagnosis instrument solves this problem. It allows students to have a basic understanding of the pulse” (Doctor 10).

Some TCM doctors have suggested that TCM diagnostic instruments can be used in primary medical institutions: “The patient is actually very curious about the pulse diagnosis, but it is impossible for us to explain the patient one by one. TCM diagnosis instrument can be placed in primary medical institutions for patients to use” (Doctor 1).

Category 5: Combination of TCM and ICT. TCM doctors described the integration of TCM and ICT using wearable devices and TCM diagnostic instruments; for example, the improvement of wearable devices and TCM diagnostic instruments in the future.

Some TCM doctors recommend that the use of wearable devices and TCM diagnostic instruments need to be more convenient: “As a TCM clinical doctor, I consider to reveal the symptoms of patients more quickly. If the pulse diagnosis instrument can give results more quickly and accurately, it will help us to eliminate common interference items and improve our diagnostic efficiency” (Doctor 3).

Several TCM doctors reported that the existing instruments could not explain results: “If the pulse diagnosis instrument cannot explain the pathology, it will have little effect on the diagnosis for TCM doctor” (Doctor 4); “Wearable devices only have the ability to record data and lack the ability to analyse data” (Doctor 9).

Some TCM doctors believed that the integration of wearable devices and TCM diagnostic instruments was feasible: “If the pulse diagnosis instrument can be worn, it is very valuable for our diagnosis. We can compare the pulse with other physiological indicators to make the correct diagnosis” (Doctor 6); “TCM is an empirical medicine, and it is also necessary to consider the impact of the patient’s emotions on health. If the instrument can judge the patient’s emotions, it can be used as a reference for TCM diagnosis” (Doctor 7).

A total of 385 TCM doctors participated in this survey, which met the requirement of sample size. They included 231 men and 154 women, 81 chief TCM doctors (21.1%), 120 associate chief TCM doctors (31.2%), 98 attending TCM doctors (25.4%), and 86 resident TCM doctors (22.3%). Their mean age was 40.9 ± 11.2 years, and their age distribution was as follows: 70 (18.2%) were 20–29 years old, 119 (30.9%) were 30–39 years old, 114 (29.6%) were 40–49 years old, 46 (11.9%) were 50–59 years old, and 36 (9.4%) were 60 years and older. Regarding specialty, 160 practiced surgery, and 225 practiced internal medicine. The scores of reliability, convenience, and benefits are detailed in Table 4.

Univariate analysis (Table 5) showed that the reliability of wearable devices differed with age and title. Younger TCM doctors and TCM doctors with low titles had higher

mean scores for the reliability of wearable devices. Gender, age, type of hospital, and job title were significantly different across the using somatosensory of wearable devices. Specifically, male TCM doctors were significantly more likely to experience a greater sense of convenience than female TCM doctors. Compared with doctors from primary TCM hospitals, those from comprehensive TCM hospitals had higher scores for convenience. Younger TCM doctors and TCM doctors with low titles had higher mean scores of convenience for wearable devices. Age and job title significantly affected the evaluation of the benefits of wearable devices. Compared with older TCM doctors and TCM doctors with high titles, younger TCM doctors and TCM doctors with low titles felt that wearable devices improved diagnostic efficiency and reduced the misdiagnosis rate.

The results showed that the scores of the reliability of TCM diagnostic instruments differed with gender, age, specialty, and title. Female TCM doctors and TCM doctors who specialized in surgery had higher mean scores for the reliability of TCM diagnostic instruments. Older TCM doctors and TCM doctors with high titles had lower mean scores for the reliability of TCM diagnostic instruments. The convenience of using TCM diagnostic instruments differed with gender, age, and job title. Compared with male TCM doctors, the females had higher scores for convenience in using TCM diagnostic instruments; younger TCM doctors and TCM doctors with low titles also had higher mean. The perceptions of the benefits of TCM diagnostic instruments also differed with age, specialty, and job title. Compared with internal medicine specialists, TCM surgeons tended to believe that TCM diagnostic instruments improved the accuracy and efficiency of diagnosis. Younger TCM doctors and TCM doctors with low titles felt that TCM diagnostic instruments improved diagnostic efficiency and reduced the misdiagnosis rate.

The correlation analyses showed significant positive relationships between reliability, convenience, and usefulness of wearable devices (Table 6). Reliability was strongly correlated with the convenience of use ($r=0.82$) and usefulness ($r=0.7$). Convenience was strongly correlated with usefulness ($r=0.75$). The pairwise Pearson’s correlation scores were measured. Significant positive relationships among reliability, convenience, and usefulness of TCM diagnostic instruments were also found. Reliability was strongly correlated with convenience ($r=0.68$) and usefulness ($r=0.62$), convenience was moderately correlated with usefulness ($r=0.49$).

Regarding the reliability of wearable devices, binary logistic regression analysis showed that the TCM doctors aged <40 years scored 4.1 times higher than the TCM doctors aged ≥ 40 years. The doctors from comprehensive TCM hospitals scored 3.2 times higher than the doctors from primary TCM hospitals. TCM doctors with low titles scored 10.1 times higher than the TCM doctors with

Table 4. Scores of reliability, convenience, and benefits evaluation.

Item	Reliability		Convenience		Benefits evaluation	
	Reliability in accuracy	Reliability in principles	Ease of use	Degree of comfort	Efficiency diagnosis	Misdiagnosis rate
Wearable devices	2.5 ± 0.9	3.0 ± 0.9	3.4 ± 0.9	3.9 ± 0.8	3.2 ± 0.7	3.2 ± 0.6
TCM diagnostic instruments	2.8 ± 0.9	3.5 ± 0.5	2.8 ± 0.6	2.6 ± 0.6	3.4 ± 0.7	3.5 ± 0.7

high titles. Regarding the convenience of wearable devices, the doctors from comprehensive TCM hospitals scored 3.7 times higher than the doctors from primary TCM hospitals. Internal TCM doctors scored 1.9 times higher than the TCM surgeons. Regarding the usefulness of wearable devices, the TCM doctors aged <40 years scored 9.1 times higher than the TCM doctors aged ≥40 years. The doctors from comprehensive TCM hospitals scored 3.5 times higher than the doctors from primary TCM hospitals (Table 7).

Regarding the reliability of TCM diagnostic instruments, binary logistic regression analysis showed that the TCM doctors with low titles scored 3.9 times higher than the TCM doctors with high titles. Regarding the convenience of the use of TCM diagnostic instruments, the females scored twice higher as the males. The TCM doctors with low titles scored 12.8 times higher than the TCM doctors with high titles. Regarding the usefulness of TCM diagnostic instruments, the TCM doctors aged <40 years scored 2.6 times higher than the TCM doctors aged ≥40 years. The internal TCM doctors scored 0.5 times higher than the TCM surgeons (Table 7).

Discussion

The perceptions of TCM doctors about wearable devices and TCM diagnostic instruments were categorized into convenience, reliability, suitable population, machine usage scenario, and integration of TCM and ICT (Table 8).

Convenience encompassed the convenience of carrying, comfort, convenience of operation, and human–device interface. Carrying convenience is one of the main reasons users buy wearable devices.³² However, TCM diagnostic instruments have not been miniaturized, which affects the evaluation of TCM doctors. Furthermore, comfort is the foundation for the long-term use of wearable devices by patients. Health monitoring sensors should be worn by people throughout the day (including during sleep) to allow continuous collation of health data. Health data relevant to healthcare are ubiquitous, extensive, and extremely valuable.³³ At the operational level, TCM doctors pointed out that wearable devices had somewhat

delayed feedback and were difficult to use. This problem has been attributed to the miniaturization of wearable devices; smartphones are, therefore, needed to carry out the operations of devices. Regarding the human interface, TCM diagnostic instruments have display screens and can directly provide feedback image data such as pulse images, which can be easily interpreted by TCM doctors. Human–computer interaction is the reason why instruments are highly evaluated, and both doctors and patients hope to obtain valid comprehensive data quickly.³⁴

The sense of trust is based on machine principles, instrument accuracy, instrument durability, and reference to diagnosis. TCM doctors generally do not understand the principles of the instruments because most of them may not have studied ICT before. However, TCM doctors stated that the lack of understanding of the principles does not affect their use and evaluation of instruments.³⁵ They are most concerned about the accuracy of instruments, which directly affects their judgment of the diagnostic results. Although the accuracy of instruments can reach more than 80%, the results are mainly focused on the accuracy of single indicators. During diagnosis and treatment, TCM doctors need to combine various indicators such as pulse and tongue. Current devices are not able to provide comprehensive diagnoses of symptoms yet.^{36,37} In addition, TCM doctors have put forward higher requirements for the durability of instruments. Regarding the use of wearable devices for data recording of diabetics, durable devices can provide TCM doctors with more diagnostic references.³⁸ Based on the accuracy of the data and the durability of the device, TCM doctors may use the data as a diagnostic reference standard.

For the populations indicated for the use of these devices, TCM doctors are willing to use age and chronic disease as a standard to discriminate against patients. Most young people use wearable devices now, and TCM doctors recommend that wearable devices are more suitable for older adults. The judgment of older adults about their health is mainly based on subjective feelings, and wearable devices can objectively analyze their health data and help them monitor health indicators.³⁹ TCM diagnostic instruments are also very suitable for older adults. Older adults

Table 5. The univariate analysis of reliability, convenience, and benefits evaluation.

Items	Score of wearable devices			Score of TCM diagnostic instruments		
	Reliability	Convenience	Benefits evaluation	Reliability	Convenience	Benefits evaluation
Gender						
Male	2.8 ± 0.8	3.6 ± 0.8	3.2 ± 0.5	3.1 ± 0.5	2.6 ± 0.5	3.4 ± 0.6
Female	2.7 ± 0.9	3.5 ± 0.8	3.2 ± 0.6	3.2 ± 0.6	2.7 ± 0.6	3.4 ± 0.5
Age						
<30	3.7 ± 0.3	4.3 ± 0.4	3.6 ± 0.3	3.2 ± 0.5	2.7 ± 0.5	3.5 ± 0.5
30-39	3.2 ± 0.5	4.1 ± 0.6	3.5 ± 0.4	3.4 ± 0.5	2.8 ± 0.6	3.6 ± 0.4
40-49	2.6 ± 0.4	3.6 ± 0.6	3.2 ± 0.5	3.1 ± 0.4	2.7 ± 0.4	3.5 ± 0.5
50-59	1.5 ± 0.5	2.2 ± 0.6	2.4 ± 0.5	3.0 ± 0.6	2.5 ± 0.6	3.2 ± 0.7
≥60	1.5 ± 0.3	2.7 ± 0.4	2.6 ± 0.4	2.6 ± 0.5	2.2 ± 0.5	3.0 ± 0.6
Type of hospital						
Comprehensive	2.9 ± 0.8	3.8 ± 0.7	3.4 ± 0.5	3.2 ± 0.5	2.7 ± 0.5	3.5 ± 0.5
Primary	2.6 ± 0.8	3.4 ± 0.9	3.1 ± 0.5	3.1 ± 0.5	2.6 ± 0.5	3.4 ± 0.6
Specialty						
Internal	2.6 ± 0.8	3.5 ± 0.9	3.2 ± 0.5	3.1 ± 0.6	2.6 ± 0.5	3.3 ± 0.6
Surgeon	2.9 ± 0.8	3.8 ± 0.8	3.2 ± 0.6	3.3 ± 0.5	2.8 ± 0.5	3.5 ± 0.5
Title						
Resident	3.5 ± 0.5	4.2 ± 0.4	3.5 ± 0.3	3.2 ± 0.5	2.7 ± 0.5	3.4 ± 0.5
Attending	3.2 ± 0.5	4.2 ± 0.6	3.5 ± 0.3	3.4 ± 0.4	2.8 ± 0.5	3.7 ± 0.4

(continued)

Table 5. Continued.

Items	Score of wearable devices			Score of TCM diagnostic instruments		
	Reliability	Convenience	Benefits evaluation	Reliability	Convenience	Benefits evaluation
Associate chief	2.5 ± 0.5	3.6 ± 0.6	3.3 ± 0.5	3.1 ± 0.4	2.7 ± 0.4	3.4 ± 0.5
Chief	1.6 ± 0.4	2.4 ± 0.6	2.5 ± 0.5	2.8 ± 0.6	2.4 ± 0.5	3.1 ± 0.7

Table 6. Correlation analyses of reliability, convenience, and benefits evaluation.

	Wearable devices			TCM diagnostic instruments			
	Reliability	Convenience	Benefits evaluation	Reliability	Convenience	Benefits evaluation	
Reliability	1			Reliability	1		
Convenience	0.82**	1		Convenience	0.68**	1	
Benefits evaluation	0.70**	0.75**	1	Benefits evaluation	0.62**	0.49**	1

** $p < 0.01$.

have high trust in TCM, and instruments such as pulse diagnosis instruments can objectively describe the pulse, which can improve the understanding of the older adults and cooperation during their TCM consultation.⁴⁰ Likewise, TCM doctors believe that wearable devices and TCM diagnostic instruments are suitable for patients with chronic diseases. These patients can monitor their health by monitoring their daily health data. When outliers occur, they can compare outliers to normal values and seek medical attention.⁴¹

Regarding machine usage scenarios, TCM doctors recommend that wearable devices are suitable for use in daily life, and TCM diagnostic instruments can be used in educational institutions and primary medical institutions. By monitoring heart rate and pulse, wearable devices provide users with objective health indicators to help them prevent lifestyle diseases.⁴² Taking pulse diagnosis instruments as an example, TCM diagnostic instruments can be used in universities and are mainly used to guide students in pulse diagnosis.^{43,44} During the teaching, the teacher can use a pulse diagnosis instrument to simulate different pulse images and display them, so that students have an intuitive understanding of the pulse. TCM doctors pointed out that TCM diagnostic instruments can be placed in primary medical institutions for the promotion of TCM. In addition, in primary medical institutions without TCM doctors, TCM diagnostic instruments can provide patients with simple diagnostic results.^{45,46}

TCM diagnostic instruments are still relatively large and cannot carry portable functions. Therefore, TCM doctors are expected to appreciate the miniaturization of TCM diagnostic instruments to allow them to monitor TCM health indicators in daily life. TCM doctors also hope for continual improvement of the accuracy of these equipment. The correct interpretation of the results of TCM diagnoses can help TCM doctors become more efficient.^{47,48} Existing wearable devices and TCM diagnostic devices lack explanations and data to support the diagnostic results, and TCM doctors expect them.

The application of wearable devices and TCM diagnostic instruments in the field of TCM is in its infancy. The TCM doctors in this study indicated that wearable devices and TCM diagnostic instruments are acceptable, but there were significant differences related to age, title, hospital type, and specialty.

The results showed that younger TCM doctors and TCM doctors with low titles had higher mean scores for reliability, convenience, and usefulness of wearable devices. TCM doctors with low titles scored 10.1 times more than TCM doctors with high titles for the reliability of wearable devices. This result was significantly higher than the age difference and hospital type difference. Although wearable devices have been suggested for TCM auxiliary diagnosis, older TCM doctors and TCM doctors with higher titles rely more on personal experience to make judgments.⁴⁹ In promoting electronic medical records and hospital information systems in the past, older TCM doctors and TCM doctors with higher professional titles demonstrated similar attitudes.⁵⁰ This behavior can be explained by the fact that older TCM doctors and TCM doctors with higher titles have higher learning costs due to the introduction of new things, which makes it more difficult for them to adopt ICT.⁵¹ Therefore, it is important to strengthen the digital training of older TCM doctors and TCM doctors with high titles.⁵² Compared with the doctors from primary TCM hospitals, the doctors from comprehensive TCM hospitals had higher scores for convenience. In China, comprehensive TCM hospitals receive the most government investment. The instruments in comprehensive TCM hospitals are more advanced than those in primary hospitals, and their convenience of use is also significantly better.⁵³ Regarding efficiency, wearable devices can help young TCM doctors obtain historical information about patients in advance, which may assist in making a diagnosis; this may explain the finding that the TCM doctors aged <40 years scored 9.1 times higher than the TCM doctors aged ≥ 40 years.⁵⁴

Table 7. The binary logistic regression analysis of reliability, convenience, and benefits evaluation.

Items	Score of wearable devices			Score of TCM diagnostic instruments		
	Reliability OR (95%CI)	Convenience OR (95%CI)	Benefits evaluation OR (95%CI)	Reliability OR (95%CI)	Convenience OR (95%CI)	Benefits evaluation OR (95%CI)
Gender	0.12	0.33	0.3	0.19	0.04	0.38
Female	1.0	1.0	1.0	1.0	1.0	1.0
Male	1.5 (0.8-2.9)	1.3 (0.7-2.3)	1.4 (0.8-2.1)	0.7 (0.5-1.1)	0.5 (0.3-0.9)	0.8 (0.5-1.2)
Age	0.02	0.77	< 0.01	0.67	< 0.01	< 0.01
≥40	1.0	1.0	1.0	1.0	1.0	1.0
<40	4.1 (1.2-14.2)	1.2 (0.3-4.4)	9.1 (2.5-33.3)	0.7 (0.3-2.4)	12.8 (3.3-29.9)	2.6 (1.7-4.1)
Type of hospital	< 0.01	< 0.01	< 0.01	0.72	0.78	0.58
Comprehensive	1.0	1.0	1.0	1.0	1.0	1.0
Primary	3.2 (1.7-5.8)	3.7 (2.1-6.7)	3.5 (2.1-6.1)	1.1 (0.7-1.6)	0.9 (0.4-1.7)	
Specialty	0.51	0.04	0.91	0.81	0.08	0.01
Internal	1.0	1.0	1.0	1.0	1.0	1.0
Surgeon	0.8 (0.4-1.4)	1.9 (1.1-3.6)	0.9 (0.5-1.6)	1.1 (0.6-1.5)	0.5 (0.3-1.1)	0.5 (0.3-0.8)
Title	< 0.01	< 0.01	0.58	0.02	< 0.01	0.63
High	1.0	1.0	1.0	1.0	1.0	1.0
Low	10.1 (3.2-38.1)	4.5 (1.1-20.7)	1.4 (0.3-5.3)	3.9 (1.2-12.5)	0.2 (0.1-0.5)	0.7 (0.2-2.1)

Table 8. Framework of ethical principles.

Moral principle/ concept	Definition	Intrinsic concepts	Effects on diagnosis
1. Proprioceptive effect	The experience of using wearable devices and TCM diagnostic instrument.	<ul style="list-style-type: none"> • Carrying convenience • Comfortable feeling • Convenient operation • Interface humanity 	Support <ul style="list-style-type: none"> • Health data record • Patient's willingness to wear • Inhibit • Health data privacy
2. Sense of trust	The trustworthy in using wearable devices and TCM diagnostic instruments.	<ul style="list-style-type: none"> • Principle of the machine • Accuracy of evaluation • Durability of the instrument • Reference to diagnosis 	Support <ul style="list-style-type: none"> • Auxiliary diagnosis • Inhibit • Palpation experience
3. Suitable population	The applicable objects for wearable devices and TCM diagnostic instruments.	<ul style="list-style-type: none"> • Age group of the population • Symptoms of the population 	Support <ul style="list-style-type: none"> • Personalized diagnosis • Inhibit • Emergency diagnosis
4. Machine usage scenario	The use scenarios of wearable devices and TCM diagnostic instrument.	<ul style="list-style-type: none"> • Daily life • Stages to be used 	Support <ul style="list-style-type: none"> • Daily health monitoring • Cultivation of TCM graduate
5. Combination of TCM and ICT	The degree of integration of TCM and ICT.	<ul style="list-style-type: none"> • Integration of TCM and wearable functions • Interpretation of the diagnosis results 	Support <ul style="list-style-type: none"> • Daily collection of TCM data • Patient notification of diagnosis

ICT: information communication technology; TCM: traditional Chinese medicine.

In the same vein, the findings showed that younger TCM doctors and TCM doctors with low titles had higher mean scores for reliability, convenience, and usefulness of TCM diagnostic instruments. The reason for this should be similar to that regarding the use of wearable devices. Due to the TCM cultural emphasis on the inheritance theory of experience, older TCM doctors believe that only their diagnoses can help them gain medical experience.⁵⁵ Therefore, their scores for the reliability of TCM diagnostic instruments were low. By imitating the diagnosis and treatment principles of TCM, TCM diagnostic instruments can reduce the physical work burden through the use of modalities like pulse diagnosis and massage.⁵⁶ TCM diagnostic instruments reduce the workload of TCM doctors and have been recognized by female TCM doctors. Compared with internal TCM doctors, the surgeon tended to believe that TCM diagnostic instruments increased the accuracy and efficiency of diagnosis. TCM surgeons mainly treat patients through orthopedic repair. Pulse diagnosis, which is less used by TCM surgeons, can be performed by TCM diagnostic instruments.⁵⁷

This study had limitations. First, the TCM diagnostic instruments used by TCM doctors were almost exclusively pulse diagnosis instruments. Thus, their perceptions were

mainly based on the pulse diagnosis instruments. Second, the patient interviews and evaluations were limited and a comprehensive perspective of these devices could not be obtained.

Conclusion

The data from wearable devices and TCM diagnostic instruments have been used as a reference for TCM diagnoses. The perceptions of TCM doctors about wearable devices and TCM diagnostic instruments can be categorized into convenience, reliability, suitable population, machine usage scenario, and integration of TCM and ICT. Instruments should have high accuracy and allow continual monitoring to be approved by doctors. TCM doctors believe that different places and people should use different wearable devices and TCM diagnostic instruments. They also pointed out that the miniaturization of instruments and the interpretation of diagnostic results are urgently needed. In the future, through the use of wearable devices and TCM diagnostic instruments, TCM doctors can monitor the health data of users at the medical health level and help users understand their daily health. TCM doctors indicated that wearable devices and TCM diagnostic instruments

were acceptable. Age and title influenced the reliability, convenience, and usefulness scores of wearable devices and TCM diagnostic instruments. However, there are still large differences in the levels of acceptance of wearable devices and TCM diagnostic instruments among TCM doctors with high and low titles. Therefore, it is necessary to improve the digital training of TCM physicians while developing digital technology to increase their acceptance and adoption of wearable devices and TCM diagnostic instruments.

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References

1. Heikenfeld J, Jajack A, Rogers J, et al. Wearable sensors: modalities, challenges, and prospects. *Lab Chip* 2018; 18: 217–248.
2. Dias D and Paulo Silva Cunha J. Wearable health devices-vital sign monitoring, systems and technologies. *Sensors (Basel)* 2018; 18: 2414.
3. Toyosu Y, Inui S, Wang Z, et al. High-resolution body-surface electrocardiograph system and survey of possible applications. *Springerplus* 2015; 4: 535.
4. Cajamarca G, Rodríguez I, Herskovic V, et al. Straightenup + : monitoring of posture during daily activities for older persons using wearable sensors. *Sensors (Basel)* 2018; 18: 3409.
5. Dooley EE, Golaszewski NM and Bartholomew JB. Estimating accuracy at exercise intensities: a comparative study of self-monitoring heart rate and physical activity wearable devices. *JMIR Mhealth Uhealth* 2017; 5: e34.
6. Coutts AJ and Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 2010; 13: 133–135.
7. Jia Y, Wang W, Wen D, et al. Perceived user preferences and usability evaluation of mainstream wearable devices for health monitoring. *PeerJ* 2018; 6: e5350.
8. Tobin SY, Williams PG, Baron KG, et al. Challenges and opportunities for applying wearable technology to sleep. *Sleep Med Clin* 2021; 16: 607–618.
9. Kroll RR, McKenzie ED, Boyd JG, et al. Use of wearable devices for post-discharge monitoring of ICU patients: a feasibility study. *J Intensive Care* 2017; 5: 64.
10. Zhou S, Ogihara A, Nishimura S, et al. Analyzing the changes of health condition and social capital of elderly people using wearable devices. *Health Inf Sci Syst* 2018; 6: 4.
11. Nuutila OP, Korhonen E, Laukkanen J, et al. Validity of the wrist-worn polar vantage V2 to measure heart rate and heart rate variability at rest *Sensors (Basel)* 2021; 22: 137. Published 2021 Dec 26.
12. Pipek LZ, Nascimento RFV, Acencio MMP, et al. Comparison of SpO2 and heart rate values on apple watch and conventional commercial oximeters devices in patients with lung disease. *Sci Rep* 2021; 11: 18901. Published 2021 Sep 23.
13. Hu Y, Jiang S, Lu S, et al. Echocardiography and electrocardiography variables correlate with the New York heart association classification: an observational study of ischemic cardiomyopathy patients. *Medicine (Baltimore)* 2017; 96: e7071.
14. Yin XJ, Wei W, Han T, et al. Value of amplitude-integrated electroencephalograph in early diagnosis and prognosis prediction of neonatal hypoxic-ischemic encephalopathy. *Int J Clin Exp Med* 2014; 7: 1099–1104.
15. Qi Z, Tu LP, Chen JB, et al. The classification of tongue colors with standardized acquisition and ICC profile correction in traditional Chinese medicine. *Biomed Res Int* 2016; 2016: 3510807.
16. Li J, Chen Q, Hu X, et al. Establishment of noninvasive diabetes risk prediction model based on tongue features and machine learning techniques. *Int J Med Inform* 2021; 149: 104429.
17. Zhao C, Li GZ, Wang C, et al. Advances in patient classification for traditional Chinese medicine: a machine learning perspective. *Evid Based Complement Alternat Med* 2015; 2015: 376716.
18. Tang Y, Li Z, Yang D, et al. Research of insomnia on traditional Chinese medicine diagnosis and treatment based on machine learning. *Chin Med* 2021; 16: 2.
19. Wang Y, Shi X, Li L, et al. The impact of artificial intelligence on traditional Chinese medicine. *Am J Chin Med* 2021; 49: 1297–1314.
20. Fan X, Meng F, Wang D, et al. Perceptions of traditional Chinese medicine for chronic disease care and prevention: a cross-sectional study of Chinese hospital-based health care professionals. *BMC Complement Altern Med* 2018; 18: 209.
21. Lin YC, Huang WT, Ou SC, et al. Neural network analysis of Chinese herbal medicine prescriptions for patients with colorectal cancer. *Complement Ther Med* 2019; 42: 279–285.

22. Wu Y, Zhang F, Yang K, et al. Symmap: an integrative database of traditional Chinese medicine enhanced by symptom mapping. *Nucleic Acids Res* 2019; 47: D1110–D1117.
23. Chen PJ, Wu HK, Hsu PC, et al. Effects of five daily activities on harmonic analysis of the radial pulse. *Evid Based Complement Alternat Med* 2020; 2020: 6095674.
24. Fu Y, Zhao S and Zhu R. A wearable multifunctional pulse monitor using thermosensation-based flexible sensors. *IEEE Trans Biomed Eng* 2019; 66: 1412–1421.
25. Luo ZY, Cui J, Hu XJ, et al. A study of machine-learning classifiers for hypertension based on radial pulse wave. *Biomed Res Int* 2018; 2018: 2964816.
26. Jin C, Xia C, Zhang S, et al. A wearable combined wrist pulse measurement system using airbags for pressurization. *Sensors (Basel)* 2019; 19: 386.
27. Tie Y C, Birks M and Francis K. Grounded theory research: a design framework for novice researchers. *Sage Open Med* 2019; 7: 2050312118822927.
28. Sigler BE. Investigating the perceptions of care coordinators on using behavior theory-based Mobile health technology with Medicaid populations: a grounded theory study. *JMIR Mhealth Uhealth* 2017; 5: e36.
29. Singh S and Estefan A. Selecting a grounded theory approach for nursing research. *Glob Qual Nurs Res* 2018; 5: 2333393618799571.
30. Rees N, Porter A, Rapport F, et al. Paramedics' perceptions of the care they provide to people who self-harm: a qualitative study using evolved grounded theory methodology. *PLoS One* 2018; 13: e0205813.
31. Stadtmann MP, Maercker A, Binder J, et al. Mastering life together – symptom management, views, and experiences of relatives of persons with PTSD: a grounded theory study. *J Patient Rep Outcomes* 2018; 2: 50.
32. Qureshi F and Krishnan S. Wearable hardware design for the internet of medical things (IoMT). *Sensors (Basel)* 2018; 18: 3812.
33. Rodríguez-Martín D, Pérez-López C, Samà A, et al. A Waist-worn inertial measurement unit for long-term monitoring of Parkinson's disease patients. *Sensors (Basel)* 2017; 17: 827.
34. Wang Q, Markopoulos P, Yu B, et al. Timmermans A. Interactive wearable systems for upper body rehabilitation: a systematic review. *J Neuroeng Rehabil* 2017; 14: 20.
35. Vesnic-Alujevic L, Breitegger M and Guimarães Pereira Â. 'Do-It-Yourself' healthcare? Quality of health and healthcare through wearable sensors. *Sci Eng Ethics* 2018; 24: 887–904.
36. Yang G, Deng J, Pang G, et al. An IoT-enabled stroke rehabilitation system based on smart wearable armband and machine learning. *IEEE J Transl Eng Health Med* 2018; 6: 2100510.
37. Li Q, Zhang X, Wang X, et al. Detection method and system of the human body characteristic Index based on TCM. *J Healthc Eng* 2021; 2021: 5549842.
38. Mader JK, Lilly LC, Aberer F, et al. Improved glycaemic control and treatment satisfaction with a simple wearable 3-day insulin delivery device among people with type 2 diabetes. *Diabet Med* 2018; 35: 1448–1456.
39. Jang IY, Kim HR, Lee E, et al. Impact of a wearable device-based walking program in rural older adults on physical activity and health outcomes: cohort study. *JMIR Mhealth Uhealth* 2018; 6: e11335.
40. Liu GP, Li GZ, Wang YL, et al. Modelling of inquiry diagnosis for coronary heart disease in traditional Chinese medicine by using multi-label learning. *BMC Complement Altern Med* 2010; 10: 37.
41. Aliverti A. Wearable technology: role in respiratory health and disease. *Breathe (Sheff)* 2017; 13: e27–e36.
42. Nakanishi M, Izumi S, Nagayoshi S, et al. Estimating metabolic equivalents for activities in daily life using acceleration and heart rate in wearable devices. *Biomed Eng Online* 2018; 17: 100.
43. Lin B. Modernization of traditional Chinese medicine pulse diagnosis. *World Chinese Medicine* 2017; 12: 1706–1710.
44. Kim YJ. Observational application comparing problem-based learning with the conventional teaching method for clinical acupuncture education. *Evid Based Complement Alternat Med* 2019; 2019: 2102304.
45. Huan L. Exploration of the occupational quality cultivation program of TCM doctors. *J Chengdu University of Tradit Chin Medi (Educational Science Edition)* 2017; 19: 5–9.
46. Zheng Y, Qin Y, Lyu Y, et al. Community promotion and application of Wuqinxi combined with brief behavioral therapy for insomnia: a study protocol. *Medicine (Baltimore)* 2021; 100: e28046.
47. He Y. Application of qualitative research methods to describe the process of communication between Chinese medicine doctors and patients. *J Beijing University of Tradit Chin Med* 2010; 33: 732–736.
48. Matos LC, Machado JP, Monteiro FJ, et al. Can traditional Chinese medicine diagnosis be parameterized and standardized? A narrative review. *Healthcare (Basel)* 2021; 9: 177.
49. Harmsworth K and Lewith GT. Attitudes to traditional Chinese medicine amongst western trained doctors in the people's republic of China. *Soc Sci Med* 2001; 52: 149–153.
50. Fan B, Li Y, Wen G, et al. Personalized body constitution inquiry based on machine learning. *J Healthc Eng* 2020; 2020: 8834465.
51. Barutçu S. Mhealth apps design using quality function deployment. *Int J Health Care Qual Assur* 2019; 32: 698–708.
52. Sarradon-Eck A, Bouchez T, Auroy L, et al. Attitudes of general practitioners toward prescription of Mobile health apps: qualitative study. *JMIR Mhealth Uhealth* 2021; 9: e21795.
53. Ding L, Miao X, Lu J, et al. Comparing the performance of different instruments for diagnosing frailty and predicting adverse outcomes among elderly patients with gastric cancer. *J Nutr Health Aging* 2021; 25: 1241–1247.
54. Li P, Luo Y, Yu X, et al. Patients' perceptions of barriers and facilitators to the adoption of E-hospitals: cross-sectional study in western China. *J Med Internet Res* 2020; 22: e17221.
55. Sang T, Zhou H, Li M, et al. Investigation of the differences between the medical personnel's and general population's view on the doctor-patient relationship in China by a cross-sectional survey. *Global Health* 2020; 16: 99.
56. Chen J, Huang H, Hao W, et al. A machine learning method correlating pulse pressure wave data with pregnancy. *Int J Numer Method Biomed Eng* 2020; 36: e3272.
57. Tang AC, Chung JW and Wong TK. Digitalizing traditional Chinese medicine pulse diagnosis with artificial neural network. *Telemed J E Health* 2012; 18: 446–453.