



# User acceptance of wearable intelligent medical devices through a modified unified theory of acceptance and use of technology

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**Background:** The acceptance of wearable intelligent medical devices and the factors influencing behavioral intention to use them have been scarcely studied. This study aimed to increase the current understanding of wearable intelligent medical devices and investigate the factors influencing their acceptance.

**Methods:** Integrating the unified theory of acceptance and use of technology and the theory of perceived risk, and based on the features of wearable intelligent medical devices, we proposed a modified unified theory of acceptance and use of technology model to identify factors influencing the acceptance of these devices. Using data collected from 2,192 respondents in China from an online survey, we used structural equation modeling to test the measurement and structural models.

**Results:** The findings suggested that facilitating conditions (path coefficient =0.942,  $P<0.001$ ) were critical to the use of wearable intelligent medical devices. Behavioral intention significantly mediated the effects of perceived risk, perceived cost, health expectation, perceived ease of use, and social influence on user behavior (path coefficient =0.210,  $P<0.001$ ). Health expectation (path coefficient =0.860,  $P<0.001$ ), perceived ease of use (path coefficient =0.289,  $P<0.001$ ), and social influence (path coefficient =0.153,  $P<0.001$ ) were found to play essential roles in predicting behavioral intention. Perceived cost (path coefficient =0.034,  $P<0.05$ ) and perceived risk (path coefficient =-0.031,  $P<0.05$ ) had no significant effect on behavioral intention. People with underlying diseases had lower health expectations and perceived costs.

**Conclusions:** The modified unified theory of acceptance and use of technology model in our research is a reliable model to evaluate the user acceptance of wearable intelligent medical devices.

**Keywords:** Unified theory of acceptance and use of technology; theory of perceived risk; technology acceptance model; wearable intelligent medical devices; acceptance

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## Introduction

With the spread of the concept of precision medicine and the urgent need for people to know their physical conditions in real-time, interest in intelligent medical products based on artificial intelligence is increasing (1,2). Recent technological advancements have facilitated individuals to monitor their fitness and health anytime, anywhere, on specific devices such as wearable intelligent medical devices (WIMDs) (3). These intelligent devices can provide a constant stream of healthcare data to help people pursue a healthier lifestyle by actively recording physiological parameters, tracking metabolic status, and sometimes even assisting in disease diagnosis and treatment (4). However, most commercially available WIMDs that have been qualified for use are usually simple and can only monitor vital signs (5). In addition, due to some other problems, such as difficulties in achieving user-friendly solutions and privacy disclosure, WIMDs now have significant limitations in medical practice. Therefore, studying the understanding and current use of these devices is essential to improve these devices and realize more medical services among people.

Most research regarding WIMDs has focused on establishing accuracy and reliability (6-8). Only a few studies have focused on WIMDs' acceptance and the factors influencing behavioral intention to use them, which may improve the overall quality of the WIMDs industry and further drive the future mobile health market (8,9). As a result, this research aimed to increase the understanding of WIMDs by investigating the factors influencing the behavioral intention of WIMDs and how those factors affect their use.

The unified theory of acceptance and use of technology (UTAUT) and the technology acceptance model (TAM) have been widely used to explain the intention to use in various fields, including intelligent healthcare systems (10-12). The theory of perceived risk (TPR) pertains primarily to searching for and choosing information about products or services and depends on the subjective uncertainty of outcomes, which can also be utilized to analyze intelligent healthcare systems (13). At present, there is no research on the UTAUT model or TAM model integrating TPR to investigate the factors influencing the acceptance of WIMDs. Thus, we present a research framework by establishing a modified model based on UTAUT, which integrates TPR and TAM, to increase the current understanding of WIMDs. We present the following article in accordance with the STROBE reporting checklist (available at <https://atm.amegroups.com/article/view/10.21037/atm-21-5510/rc>).

## Methods

### *Literature review*

This research aimed to investigate people's understanding of intelligent medical products, especially WIMDs, and investigate the antecedents of behavioral intention and use behavior. Therefore, a literature review was conducted to introduce WIMDs' development status and existing problems, as well as the basis for establishing a modified model based on the UTAUT.

### *WIMDs*

Intelligent medical products are based on artificial intelligence and machine learning, which can be applied in clinical practice to improve the existing medical model (14). WIMDs are intelligent medical products that should be worn directly on the body to monitor health status and diagnose and treat diseases (4). There are five main features of WIMDs (15): (I) wireless mobility; (II) interactivity and intelligence; (III) sustainability and durability; (IV) simple operation and miniaturization; and (V) wearability and portability. WIMDs can promote the development of precision medicine and facilitate the emergence of connected healthcare (16,17).

In clinical practice, intelligent medical product applications involve at least three subjects: social groups, doctors, and manufacturers. To realize the purpose of this research, our research subject was social groups. With the gradual aging of society and the extension of average life expectancy, the proportion of the population experiencing chronic diseases is expected to increase, which will require younger generations and society to expend more energy and financial resources to care for the elderly. Furthermore, a fast-paced lifestyle and work responsibilities negatively impact work-life balance for an increasing number of young and middle-aged people, resulting in some physical and psychological problems. WIMDs can help alleviate these problems by helping the elderly achieve a high-quality, independent life and helping young people maintain as regular a lifestyle as possible despite increased responsibilities. In this context, the market demand for WIMDs is increasing.

A series of studies have confirmed the feasibility and accuracy of wearable devices (18-22). However, little research has focused on acceptance of WIMDs and the factors influencing behavioral intention and use behavior. For example, Tsai and Lin (23) found that perceived usefulness indirectly affected behavioral intention through attitude in

older adults using an extended TAM; however, their research did not recruit younger adults. In addition, although some studies have used UTAUT to build comprehensive models (including health awareness and TPR) to investigate the factors affecting the intention to use WIMDs, the sample sizes of these studies were small (<500) (24,25). Therefore, in light of these studies, we expanded the sample size and integrated TPR and TAM to construct a comprehensive modified UTAUT model to research the acceptance of WIMDs and the factors influencing behavioral intention.

### *Theories of TAM*

The theory of technology acceptance is an analysis model of the research population's acceptance of new things and their influencing factors, given the development of science and technology and the continuous emergence of innovative products. The classic theories include TAM, the theory of planned behavior, and UTAUT (26). These theories have been widely used to explain intention to use in intelligent healthcare systems, including the acceptance of wearable devices and intelligent health monitoring systems (10,27-29). However, UTAUT was developed by redefining representative technology acceptance theories without considering risk factors.

### *TPR*

Perceived risk is the construction of a perceived situation that can be defined in various ways (26). TPR is mainly applied to the process of consumers' purchase and use of products, including financial, performance, physical, psychological, social, and convenience risks (13). However, its application in intelligent medical devices has rarely been studied. As is well known, all medical practices, including WIMDs, have risks, including health, financial, and privacy risks (27-29). Therefore, TPR can compensate for the deficit of UTAUT. Combined models of UTAUT integrating TPR and TAM provide a better explanation for the acceptance of the WIMDs than that of the TAM or UTAUT model alone.

### *Research model and hypotheses*

Based on WIMDs' features, we propose a research model that identifies several factors influencing their acceptance, integrating the theoretical background of the UTAUT model, TPR, and TAM (*Figure 1*).

The basic assumption is that WIMDs' acceptance is

reflected in the behavior of use, which is jointly determined by behavioral intention and facilitating conditions. Behavioral intention is influenced by five motivational factors: perceived risk, perceived cost, health expectation, perceived ease of use, and social influence. On the one hand, different people have different health conditions, which is a feature of WIMDs. On the other hand, people with various health conditions have different health expectations and perceived costs related to their health conditions.

### *Modified UTAUT model*

To test the dependent variable of use behavior, the modified UTAUT model was applied to test the relationships between behavioral intention and facilitating conditions. Furthermore, we separately tested the dependent variable of behavioral intention by removing the facilitating conditions.

### *Behavioral intention*

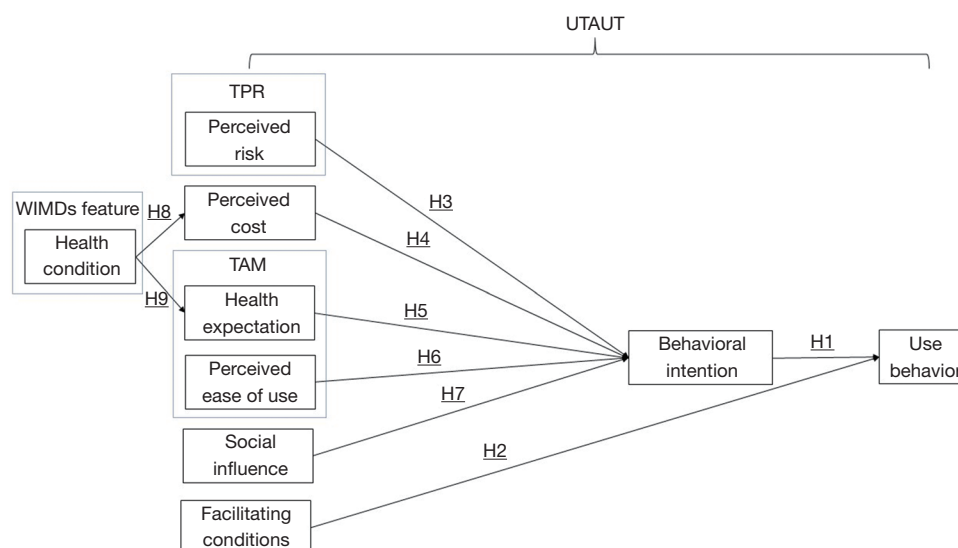
According to Venkatesh and Davis, behavioral intention refers to "the degree to which a person has formulated conscious plans to perform or not perform some specified future behavior" (30). Further research has indicated that intention to use is the main indicator of an information system (31). The intention to use WIMDs is also a form of information system adoption. Thus, we propose the following research hypothesis:

- ❖ H1: behavioral intention toward wearable fitness technology will be positively related to WIMD use.

### *Facilitating conditions*

Facilitating conditions refer to the degree to which an individual believes that a technical infrastructure exists to support technology use (32). In promoting and using WIMDs, real-time data transmission requires network devices' support, and a timely feedback platform is needed when the devices fail; these are necessary technical infrastructure (7). With the technological advancement of WIMDs and the expansion of demand for their functions, more advanced information transmission and medical chip technology have recently been introduced in the WIMD adoption literature, representing a significant development direction of future technology infrastructure (4). Thus, we propose the following research hypothesis:

- ❖ H2: facilitating conditions have a positive effect on WIMD use.



**Figure 1** Modified conceptual model. H1, behavioral intention toward wearable fitness technology will be positively related to WIMDs use; H2, facilitating conditions have a positive effect on WIMDs use; H3, perceived risk has a negative effect on the intention to use WIMDs; H4, perceived cost has a negative effect on the intention to use WIMDs; H5, health expectation has a positive effect on the intention to use WIMDs; H6, perceived ease of use has a positive effect on the intention to use WIMDs; H7, social influence has a positive effect on the intention to use WIMDs; H8, a health condition has a negative effect on the perceived cost of WIMDs; H9, a health condition has a negative effect on the health expectation of WIMDs. UTAUT, unified theory of acceptance and use of technology; TPR, theory of perceived risk; TAM, technology acceptance model; WIMDs, wearable intelligent medical devices.

### Perceived risk

Online medical advice based on WIMDs is riskier and more uncertain than traditional medicine. Two important reasons why patients do not accept online medical advice are the security of online visits and personal information privacy concerns (8,33). Online patients cannot decipher if the doctor is real and can provide practical advice. Patients also feel insecure when registering personal information and paying fees, such as transmitting identification and credit card numbers via the internet (33). All of the above findings indicate that perceived risk negatively influences behavioral intention. Thus, perceived risk is a measure that determines intention prior to use. Accordingly, we propose the following research hypothesis:

- ❖ H3: perceived risk has a negative effect on the intention to use WIMDs.

### Perceived cost

Perceived cost in this research refers to the additional payout that is believed necessary prior to using WIMDS, including the perceived time and perceived fee (7,26). First,

because WIMDs transmit information in real-time, people pay more attention to what is happening to their bodies and spend more time communicating with healthcare professionals (34,35). In addition, it takes time to learn how to use WIMDS. Second, WIMDs require both a wearable product and a subscription to a related service, which results in ongoing costs. Although studies have shown that health plans for health promotion, early detection, and prevention reduce costs in the long term, costs can negatively impact behavioral intention before use. Thus, we propose the following research hypothesis:

- ❖ H4: perceived cost has a negative effect on the intention to use WIMDs.

### Health expectation

Health expectation is similar to health consciousness but is more subjective. It includes the degree to which health concerns are integrated into people's daily activities and the extent to which they control their health (24,25). People with a higher health expectation care more about their health and are thus more motivated to improve or maintain their health. Thus, we propose the following research

hypothesis:

- ❖ H5: health expectation has a positive effect on the intention to use WIMDs.

### *Perceived ease of use*

Perceived ease of use is defined as how a person believes that using technology will take minimal effort (36). Improvements in perceived ease of use may enhance productivity, performance, and effectiveness (i.e., usefulness) (13). Prior research has provided evidence of the significant effect of perceived ease of use on behavioral intention, either directly or indirectly, on perceived usefulness (13). WIMDs require users to learn how to use the internet and WIMDs' operating system, which is generally very difficult for the elderly and requires assistance from family and friends (7). Therefore, in this research, we speculate that wearable devices' ease of use severely impacts intention to use them, especially in the elderly population. Thus, we propose the following research hypothesis:

- ❖ H6: perceived ease of use has a positive effect on the intention to use WIMDs.

### *Social influence*

Social influence refers to how others' perceptions influence a user's decision-making (24,25). "Others" include family members, close friends, influential people such as employers or peers, professionals such as physicians, and technical specialists (37). Taylor and Todd (38) indicated that peer influence from friends and classmates and superior influence from professors indirectly influenced behavioral intention through the mediator of subjective norms. Given that WIMD use is likely affected by the influence of superiors or other influential people, we propose the following research hypothesis:

- ❖ H7: social influence has a positive effect on the intention to use WIMDs.

### *Feature of WIMDs*

Because health conditions are a prominent feature of people who use WIMDs, this research is interested in WIMDs' effects on the two primary constructs: perceived cost and health expectation.

People with various health conditions pay more attention to healthy living differently than healthy people do. Research shows that those with a more substantial subjective health complaint are more concerned about

modern health (39). People with high-risk diseases, such as high blood pressure and diabetes, focus more on their health conditions (40). Another study reported that patients who had undergone coronary artery bypass surgery had higher depression and anxiety levels and may pay more attention to their health conditions (41). Concerns about health conditions will likely urge people to increase their investment in their health, and the need to maintain it through external measures will also be stronger. Thus, we propose the following hypotheses:

- ❖ H8: health conditions have a negative effect on the perceived cost of WIMDs;
- ❖ H9: health conditions have a negative effect on the health expectation of WIMDs.

### *Questionnaire development*

As shown in [Appendix 1](#), we used a questionnaire survey with four sections to test our theoretical model. The first section included demographic questions about the respondents. The second section assessed the state of understanding and adoption of intelligent medical products. The third section contained questions for various constructs presented in the research model, measured using multiple entries, as shown in [Table S1](#). A 5-point Likert scale was used, with answer options ranging from strongly disagree (1) to strongly agree (5). The fourth section requested respondents' subjective feelings and suggestions for the functionality of intelligent medical products. To validate the questionnaire's effectiveness, a pilot study was conducted at Capital Medical University, for which five professors and five postgraduate students were recruited. The respondents were chosen because of their technical competencies and thorough understanding of medicine. Questionnaires collected from the pilot research helped improve its effectiveness with some specific adjustments.

### *Data collection*

The target respondents of this study were the entire population. We sent online surveys to WeChat Moments via <https://www.wjx.cn/>. Data were collected from September to December 2020; overall, 2,192 valid surveys were returned.

### *Statistical analysis*

H1–H7 were tested collectively using structural equation

modeling implemented via partial least squares. These techniques allow the assessment of relationships among theoretical constructs in a structural model. The structural model estimates the path coefficients, which indicate the relationships between the dependent and independent variables. Before testing the research model, SPSS 25.0 (IBM Corporation) for Windows was used to determine descriptive statistics on demographic variables, including characteristics such as gender, age, and educational background. In the last step, *t*-tests were conducted to compare mean differences in the constructs, including perceived cost and health expectation between people with different health conditions, to test H8 and H9, and differences were considered statistically significant at two-sided *P* values <0.05.

### Ethics

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). It was approved by the Ethics Committee of Beijing TongRen Hospital, Capital Medical University (No. TRECKY2019-049), and all respondents provided informed consent online. Personal data were anonymized prior to analysis.

## Results

### Sample description

A total of 2,192 distributed questionnaires were selected for data analysis. As shown in *Table 1*, 62.0% of the respondents were men. Respondents' median age was 26 (interquartile range, 22–31) years. Most respondents had less than a bachelor's degree (93.1%). Regarding regional background, 78.1% lived in Eastern China, and 76.7% lived in urban areas. Most respondents' monthly income was less than 20,000 yuan (67.0%). In terms of health conditions, 84.7% had no underlying disease, and 82.9% had never undergone surgery.

As shown in *Table 2*, according to the analysis of respondents' current use status of intelligent medical products, only 188 (8.6%) understood and used intelligent medical products, among which WIMDs were the most widely used (49.5%). Of the respondents who used intelligent medical products, 47.3% primarily acquired them on their initiative, and 27.7% acquired them based on friends' recommendations. More than half of the users (51.6%) believed that the current intelligent medical products are relatively easy to use and that their functions

can meet their current needs.

### Structural model for hypotheses testing

Statistical analysis indicated that the data followed normality characteristics. The skewness value for all variables was in the range of +1 to -1, indicating that the data distribution was normal. Moreover, all of the determinants' kurtosis results were in the range of +2.58 to -2.58, indicating that the data distribution was normal.

Once data normality was confirmed, the model's internal reliability, convergent validity, and discriminant validity were determined. To measure the data's internal reliability, Cronbach's  $\alpha$  was evaluated against the standard threshold of 0.7, the criterion for acceptable internal consistency of data (42,43).

Convergent validity was calculated using average variance extracted (AVE), composite reliability (CR), and item loadings, such that a minimum of 0.50 of AVE exists for construct validity. As clearly depicted in *Table 3*, the calculated values of Cronbach's  $\alpha$  ranged from 0.942 to 0.973, and CR varied in the range of 0.943–0.967. As the calculated indices were all above the recommended thresholds, the strong internal reliability of the data was confirmed (44). The individual item loadings of the constructs ranged between 0.760 and 0.940, whereas AVE values ranged from 0.846 to 0.923, both exceeding the recommended levels. Hence, the required criterion for convergent validity was fulfilled.

A cross-loading matrix along with the square root of AVE was determined to measure the discriminant validity of the data. For discriminant validity, the square root of AVE of a determinant must surpass the correlation it exhibits with other constructs (45). The results presented in *Table 4* confirmed the data's discriminant validity.

*Figure 2* illustrates the resulting path coefficients of the proposed research model. A summary of the hypotheses testing results of the standardized path coefficients and path significance was provided in *Table 5*. As shown in *Table 5*, the positive influence of behavioral intention, facilitating conditions, health expectation, perceived ease of use, and social influence was supported by hypothesis testing. The negative influence of perceived risk was also validated by hypothesis testing. However, the proposed negative effect of perceived cost was rejected by hypothesis testing.

After removing the facilitating conditions, which were the most critical to use behavior, the above results were also confirmed in *Figure 3*.

**Table 1** Demographics characteristics of respondents (N=2,192)

Variable	Category	Frequency	Percent (%)
Gender	Male	1,360	62.0
	Female	832	38.0
Age	<20 years	299	13.6
	20–30 years	1,222	55.7
	30–40 years	405	18.5
	40–50 years	118	5.4
	50–60 years	71	3.2
	≥60 years	77	3.5
Education	Less than diploma's	833	38.0
	Diploma's	566	25.8
	Bachelor's	641	28.3
	Master's or above	152	6.9
Occupation	Professional	467	21.3
	Service personnel	327	14.9
	Freelancer	195	8.9
	Worker	79	3.6
	Company or government staff	262	12.0
	Student	235	10.7
	Others	627	28.6
Location	Eastern China	1,711	78.1
	Mid-China	331	15.1
	Western China	150	6.8
Region	Urban	1,682	76.7
	Suburban	234	10.7
	Rural	276	12.6
Monthly income (yuan)	<10,000	943	43.0
	10,000–20,000	525	24.0
	20,000–30,000	185	8.4
	30,000–40,000	97	4.4
	≥40,000	442	20.2
Underlying diseases	Hypertension	139	6.3
	Diabetes	55	2.5
	Coronary heart disease (CHD)	43	2.0
	Stroke	24	1.1
	Others	17	0.8
	No underlying diseases	1,856	84.7
Surgery	Yes	374	17.1
	No	1,818	82.9

**Table 2** Current situation of intelligent medical products usage

Items	Type	Frequency	Percent (%)
Level of usage (N=2,192)	No understand, no use	1,497	68.3
	Understand, no use	507	23.1
	Understand and use	188	8.6
Classification of intelligent medical products usage (n=188)	Intelligent monitoring equipment	62	33.0
	Wearable intelligent medical devices	93	49.5
	Application of health management	72	38.3
	The online medical service platform	78	41.5
	Others	25	13.3
Ways to access intelligent medical devices (n=188)	Actively acquired	89	47.3
	Doctor recommend	49	26.1
	Family recommend	49	26.1
	Friend recommend	52	27.7
	Enterprise promotion	25	13.3
	Others	33	17.6
Degree of intelligent medical device usage (n=188)	Very difficult	24	12.8
	Difficult	16	8.5
	General	51	27.1
	Easy	41	21.8
	Very easy	56	29.8
Effect of intelligent medical device (n=188)	Very satisfied	53	28.2
	Satisfied	41	21.8
	General	68	36.2
	Dissatisfied	13	6.9
	Very dissatisfied	13	6.9

### *Differences between people with different health conditions*

A *t*-test was conducted to compare the mean differences in the constructs, including perceived cost and health expectation, between people with different health conditions. As indicated in *Table 6*, people with underlying diseases had a lower health expectation and perceived cost than those without underlying diseases did ( $P < 0.05$ ). The health expectation and perceived cost of patients who had undergone surgery were higher than those who had not received surgery, but there was no statistically significant difference in perceived cost ( $P > 0.05$ ).

### **Discussion**

As shown in previous studies and our questionnaire ([Appendix 1](#)), intelligent medical devices include WIMDs, intelligent monitoring equipment, application of health management, etc.; WIMDs are the most widely used. Therefore, this research aimed to advance our understanding of WIMDs and investigate the factors influencing their behavioral intentions. Compared with prior work, this study's major contribution is to empirically investigate the application of a modified UTAUT model in WIMDs, integrating TPR and TAM (7,46). Based on a literature review of the UTAUT

**Table 3** Construct reliability and convergent validity

Constructs	Construct code	Items loading	Average variance extracted (AVE)	Composite reliability (CR)	Cronbach's $\alpha$
Use behavior (UB)	UB1	0.94	0.923	0.960	0.973
	UB2	0.91			
Behavioral intention (BI)	BI1	0.82	0.839	0.940	0.965
	BI2	0.85			
	BI3	0.85			
Perceived risk (PR)	PR1	0.76	0.861	0.961	0.960
	PR2	0.91			
	PR3	0.93			
	PR4	0.85			
Perceived cost (PC)	PC1	0.87	0.878	0.956	0.956
	PC2	0.91			
	PC3	0.86			
Health expectancy (HE)	HE1	0.88	0.908	0.967	0.967
	HE2	0.93			
	HE3	0.92			
Perceived ease of use (PEOU)	PEOU1	0.92	0.930	0.964	0.964
	PEOU2	0.94			
Social influence (SI)	SI1	0.85	0.846	0.943	0.942
	SI2	0.89			
	SI3	0.80			
Facilitation conditions (FC)	FC1	0.89	0.881	0.957	0.957
	FC2	0.88			
	FC3	0.87			

model, TPR, TAM, and WIMDs, and a pilot study, we developed a comprehensive research framework and used structural equation modeling to assess relationships among theoretical constructs in the modified model. The results showed that there were significant relationships between the research variables. Facilitating conditions were the most influential factors on people's use behavior, which has not been found in previous studies. Perceived risk was negatively related to behavioral intention, but perceived cost was positively related. Health expectation, perceived ease of use, and social influence positively affected behavioral intention, which in turn affected actual use behavior regarding WIMDs. Because the functions of WIMDs include monitoring fitness and health conditions, this research investigated people with different health conditions and found that people without

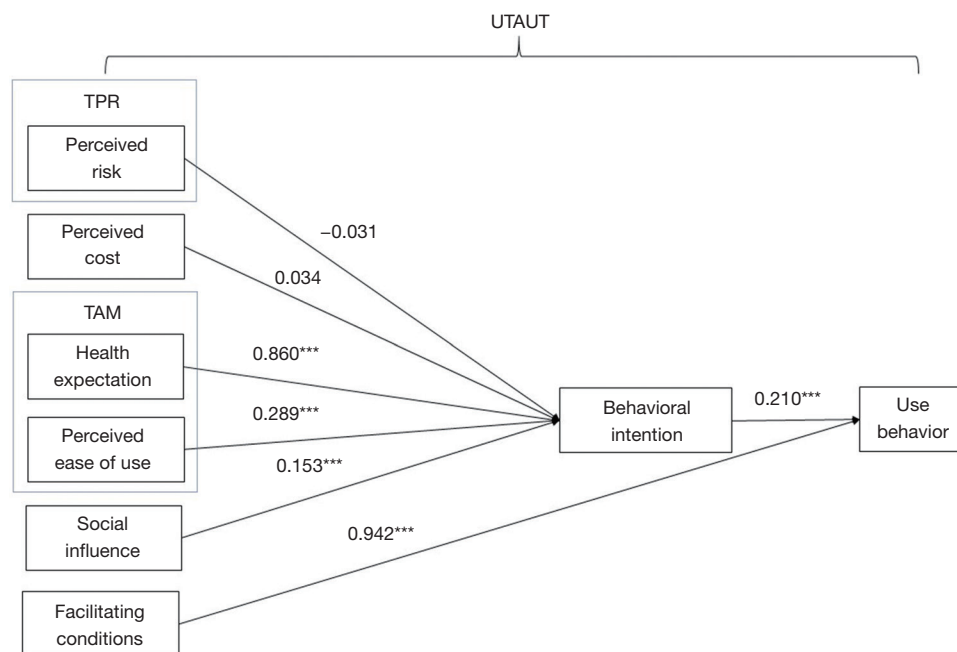
underlying diseases had a higher health expectation and expectation for using WIMDs, which was not consistent with the previous literature (40).

WIMDs have been one of the fastest-growing products in intelligent medical devices over the last decade, and the global market for WIMDs is growing at a remarkable rate (47). Some studies have focused on people's intention to use WIMDs and potential influencing factors (8,16,22,24,25). However, several issues still hinder the adoption and development of WIMDs. First, as noted in previous research, most of the 2,192 respondents were aged 20–30 years, as in previous studies, with a small percentage of respondents over 50 years of age (25). Among the people we followed up with, 68.3% did not know any information about WIMDs, which indicates that the social publicity

**Table 4** Correlation analysis

Constructs	UB	BI	PR	PC	HE	PEOU	SI	FC
UB	1							
BI	0.869	1						
PR	0.829	0.788	1					
PC	0.894	0.880	0.839	1				
HE	0.893	0.924	0.829	0.924	1			
PEOU	0.898	0.880	0.910	0.925	0.917	1		
SI	0.904	0.834	0.851	0.896	0.853	0.888	1	
FC	0.940	0.875	0.849	0.903	0.907	0.915	0.919	1

UB, use behavior; BI, behavioral intention; PR, perceived risk; PC, perceived cost; HE, health expectancy; PEOU, perceived ease of use; SI, social influence; FC, facilitation conditions.



**Figure 2** Path analysis including facilitating conditions. \*\*\*,  $P < 0.001$ . UTAUT, unified theory of acceptance and use of technology; TPR, theory of perceived risk; TAM, technology acceptance model.

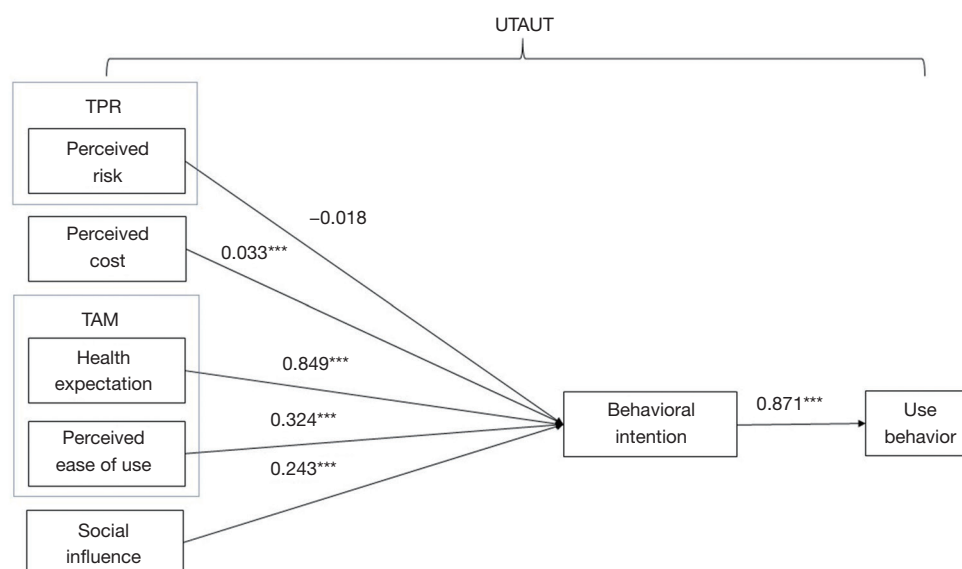
of WIMDs is insufficient and that further promotion by manufacturers, medical institutions, and medical personnel is needed. Second, approximately 40% of current WIMDs users reported that it was not easy to use WIMDs. Combined with the results elicited from the fourth section of the questionnaire on subjective feelings and suggestions for WIMDs, we found that the main complaints with ease of use included the following: (I) the data transmission of WIMDs was not accurate enough; (II) the operation

interface needed to be further humanized, especially for the elderly; and (III) the function was not intelligent enough, meaning that WIMDs alone cannot facilitate closed-loop management of medical behavior. With the rapid growth of the aging population in China and worldwide, using intelligent medical products, including WIMDs, as part of the existing workflow, such as medical behavior and community management, and to form an interactive mode of sharing information may be a valuable approach for

**Table 5** Model path analysis

The hypothesis	Path coefficient	P value	Support
H1: behavioral intention toward wearable fitness technology will be positively related to WIMDs use	0.210	<0.001	Yes
H2: facilitating conditions has a positive effect on WIMDs use	0.942	<0.001	Yes
H3: perceived risk has a negative effect on the intention to use WIMDs	−0.031	>0.05	Yes
H4: perceived cost has a negative effect on the intention to use WIMDs	0.034	>0.05	No
H5: health expectation has a positive effect on the intention to use WIMDs	0.860	<0.001	Yes
H6: perceived ease of use has a positive effect on the intention to use WIMDs	0.289	<0.001	Yes
H7: social influence has a positive effect on the intention to use WIMDs	0.153	<0.001	Yes

WIMDs, wearable intelligent medical devices.



**Figure 3** Path analysis without facilitating conditions. \*\*\*,  $P < 0.001$ . UTAUT, unified theory of acceptance and use of technology; TPR, theory of perceived risk; TAM, technology acceptance model.

**Table 6** Comparing perceived cost and health expectation between people with different health conditions

Variable	Underlying disease, mean (SD)			Surgery, mean (SD)		
	Yes	No	P value	Yes	No	P value
Health expectation	9.813 (3.505)	10.307 (2.850)	<0.01	10.505 (3.012)	10.125 (2.951)	<0.05
Perceived cost	9.634 (3.339)	10.003 (2.810)	<0.05	10.187 (2.944)	9.897 (2.889)	>0.05

people to adopt intelligent medical products (4,7).

Facilitating conditions are the most critical drivers for WIMDs in a developing country. Communities where users of WIMDs live need to strengthen their network

support, and manufacturers need to follow up their after-sales service to match users' preferences (7). In addition, this study verifies that health expectation is the most significant positive predictor of users' intention to adopt

WIMDs, which supports the research by Gao and Yang Meier (7,46). Developing, analyzing, and employing medical and health big data to expand WIMDs in other health fields, such as telemedicine, preventive medicine, and epidemiology, are the goals of WIMDs' development (17). Further, perceived ease of use was an essential driver for acceptance of WIMDs, which is consistent with previous studies (48,49). Therefore, this factor is also significant in China's other healthcare contexts. The more people view intelligent medical products such as WIMDs as easy-to-use technology, the more motivated they will be to utilize them. Consequently, WIMDs must be designed according to users' acceptance level of technology. In this way, people will not have to spend a tremendous amount of time and effort learning to utilize these products.

The research results for social influence indicated its significance for large-scale implementation of WIMDs, confirming previous studies' findings (24,25,36). People will be more likely to use WIMDs if their family members, acquaintances, and private doctors view these products as effective for improving health. For this purpose, prominent community members and health workers must be engaged in research discourse regarding WIMDs, leading to more positive results.

Although previous studies have suggested that perceived risk is a significant barrier to acceptance of WIMDs (46,50), it was not validated as a significant negative predictor of behavioral intention. This may be related to the younger age of the respondents surveyed in this study. Young people may not have experienced severe health problems and may not have privacy concerns about disclosing their health information that deter them from using wearable devices, consistent with Yang Meier's findings (24). In contrast to our predictions regarding the negative effects of perceived cost on the intention to use WIMDs, H4 is not supported by the survey data. One explanation for this unexpected finding is that WIMDs users are generally young people who do not think it takes extra time and experience to learn and use WIMDs. Since there are significant differences in perceived costs among people of different ages, manufacturers should design products tailored to different ages.

Our study is the first to show that people with underlying diseases had a lower health expectation and lower perceived cost, with further negative effects on use intention and behavior. However, this is likely because people with underlying diseases tend to have negative feelings about medical behavior because of chronic illness. Perhaps in a different research context, the explanatory power of each

factor of UTAUT would vary (25).

This study has several limitations. First, more than 90.0% of the respondents were younger than 50 years, and their behavior may differ somewhat from the rest of the population, which may have biased the results. Future research should examine more older people to validate a more generalized model. Second, although the gender, regional background, and educational background of the respondents were included in this study, they were not analyzed in detail. Further research is expected to help generalize our findings and discussions to include different genders, regions, and educational backgrounds in which WIMDs are utilized.

## Conclusions

Through the largest questionnaire so far, this study investigated the use of WIMDs in the Chinese population, and its findings contribute to the existing body of knowledge of WIMDs. The findings also highlight how the adoption process of WIMDs in developing countries can be improved. Based on the identified factors—including facilitating conditions, health expectation, perceived ease of use, social influence, and health conditions—countries, communities, medical institutions, and manufacturers can design better strategies and development plans to promote intelligent medical products.

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# Appendix 1

## A Questionnaire on the Use of Intelligent Medical Products (Patient Version)

Dear madam/sir:

Hello! We are a research team from the School of Public Health, Capital Medical University. We are now conducting a research about people’s opinions and the application status of intelligent medicine. We hope you can give some suggestions on the application of intelligent medicine so that intelligent medical products can better serve most people in the future. It will take about 20 minutes to complete the questionnaire. Thank you for your cooperation! This research uses the anonymity method, and any information will not be disclosed to others. Your answer is only used for research!

Intelligent medicine is to point to artificial intelligence, Internet, big data, cloud computing, wearable devices, IT infrastructure with the medical infrastructure integration, and on this basis to realize accurate triage, auxiliary diagnosis, health management, remote medical services, patients and medical staff, the real-time interaction between the medical institutions, medical equipment, building intelligent medical service system.

Typical intelligent medical application scenarios are as follows: Dr. Zhang in Beijing communicated with patient Li in Lhasa through the medical APP, designed a physical examination program for Li. The analysis results were then transmitted to Dr. Zhang by a wearable intelligent medical device. Dr. Zhang worked with the doctors in the local hospital in Lhasa to formulate the treatment plan and quickly adjust the medication plan. During the treatment, Li's daily physical condition was monitored by a wearable intelligent medical device in real-time. When Li's indicators appeared abnormal, doctors in Beijing and Lhasa all received alarm information at the same time and immediately took further measures to guide Li to the appropriate hospital department.

### I. Personal information (9 questions)

1. Sex: A. Female B. Male

2. Age (please fill in):

3. Occupation:

- A. Professional (teacher/doctor/lawyer/programmer et al.)
- B. Service personnel (catering waiter/driver/shop assistant et al.)
- C. Freelancer (writer/artist/photographer/guide et al.)
- D Workers (factory workers/construction workers/city sanitation workers, et al.)
- E. Company staff/government workers
- F. Student
- G. Business personnel
- H. Others

4. Educational background:

- A. High school or below
- B. Junior college
- C. Bachelor
- D. Master or above

5. Place of residence in recent two years (from National Health Commission (2018) China Health Statistics Yearbook)

- A. Eastern Region (Beijing/Tianjin/Hebei/Liaoning/Shanghai/Jiangsu/Zhejiang/Fujian/Shandong/Guangdong/Hainan)
- B. Middle Region (Heilongjiang/Jilin/Shanxi/Anhui/Jiangxi/Henan/Hubei/Hunan)
- C. Western Region (Inner Mongolia/Guangxi/Chongqing/Sichuan/Guizhou/Yunnan/Tibet/Shaanxi/Gansu/Qinghai/Ningxia/Xinjiang)

6. Residence location:

- A. City B. Suburban C. Rural

7. Monthly income (please fill in) :

8. Had underlying diseases? (multiple choice)

- A. Hypertension
- B. Diabetes
- C. Coronary heart disease (CHD)
- D. Stroke
- E. Others (please fill in) \_\_\_\_\_
- F. No underlying diseases

9. Had surgery  
A. Yes  
B. No

II. Understanding and application status evaluation (6 questions)

1. Do you understand and use intelligent medical products (wearable intelligent medical devices/mobile APP about health management et al.)? (select A or B, skip to the third part; select C, continue to answer Part II.  
A. No understanding and no use B. Understanding but no use C. Understanding and use
2. What types of intelligent medical products are you using? (multiple choice)  
A. Intelligent monitoring equipment (home intelligent blood pressure monitor/intelligent blood glucose monitor/intelligent electrocardiograph et al.)  
B. Wearable devices (smart bracelets et al.)  
C. APP of health management  
D. Electronic medical records  
E. Online medical service platform  
F. Others (please fill in) \_\_\_\_\_
3. Access to intelligent medical products (multiple choice)  
A. Active access  
B. Recommendation by doctor  
C. Recommendation by family  
D. Recommended by friends  
E. Enterprise promotion  
F. Others (please fill in) \_\_\_\_\_
4. According to your user experience, how do you feel about the use of intelligent medical products at present?  
A. Very difficult B. Difficult C. Ordinary D. Ease E. Very ease
5. According to your user experience, what do you think of intelligent medical products' current medical service effect?  
A. Very dissatisfied B. Dissatisfied C. Ordinary D. Satisfied E. Very satisfied

III. Usage intention and influencing factors evaluation (23 questions, 5 means “strongly disagree”; 4 means “disagree”; 3 means “ordinary”; 2 means “agree”; 1 means “strongly agree”)

Questions	Answer
1. I am willing to use intelligent medical products.	5 4 3 2 1
2. I would like to recommend intelligent medical products to my family and friends.	5 4 3 2 1
3. I will accept a more comprehensive range of intelligent medical products in the future.	5 4 3 2 1
4. The use of intelligent medical products can improve the understanding of physical conditions (such as monitoring blood pressure and heart rate).	5 4 3 2 1
5. Intelligent medical products can provide appropriate medical advice and find appropriate doctors (such as recommending medical departments and hospitals).	5 4 3 2 1
6. Intelligent medical products can enhance overall health status and improve the quality of life.	5 4 3 2 1
7. Compared with traditional medical care, I need to pay more to use and maintain intelligent medical products.	5 4 3 2 1
8. Compared with traditional medical care, I need to spend more time learning to use intelligent medical products.	5 4 3 2 1
9. By using intelligent medical products, I feel I need more time to communicate with doctors.	5 4 3 2 1
10. I think through my efforts, I can master the use of intelligent medical products.	5 4 3 2 1
11. I think I can master the use of intelligent medical products with the help of the people around me.	5 4 3 2 1
12. I worry that I will be cheated in hospitals where intelligent medical products are used for triage.	5 4 3 2 1
13. I worry that intelligent medical products cannot accurately report the health condition.	5 4 3 2 1
14. I worry that the triage and treatment of intelligent medical products are not timely and may delay the illness.	5 4 3 2 1
15. I worry that intelligent medical products may disclose personal information.	5 4 3 2 1
16. Many people (doctors/family/friends et al.) have recommended using s intelligent medical products.	5 4 3 2 1
17. Many people (friends/family et al.) are using intelligent medical products.	5 4 3 2 1
18. The use of intelligent medical products can reflect that I pay more attention to personal health.	5 4 3 2 1
19. The network conditions around me can support me to use intelligent medical products.	5 4 3 2 1
20. When problems arise in using intelligent medical products, my family, community or hospital can help me solve time problems.	5 4 3 2 1
21. I think the manufacturers of intelligent medical products should timely feedback my usage problems.	5 4 3 2 1
22. I will take the initiative to use intelligent medical products to monitor health conditions.	5 4 3 2 1
23. I will use intelligent medical products to monitor health status in real-time.	5 4 3 2 1

**IV. Functions and benefits of intelligent medical products (2 questions)**

1. Compared with traditional medical care, what benefits do you think intelligent medical products bring to you?
- A. Make an appointment for diagnosis and treatment on the APP, which saves time and is convenient and fast.
  - B. More humanized and can check and understand the health conditions at any time.
  - C. Compared with going to the hospital, it saves a lot of unnecessary medical costs.
  - D. Family doctor, who can make an appointment for home service, can provide one-to-one follow-up service and home service.
  - E. Health services can be provided for self-examination.
  - F. Services such as reminders to take medicine on time and physical examination.
  - G. Recovery and treatment tracking service for patients with chronic diseases.
  - H. Health management service for the elderly (APP health tracking service).
  - I. Other (please fill in) \_\_\_\_\_
2. Do you have any suggestions and opinions on the future function expansion of intelligent medical products?

**Table S1** Survey items-UTAUT Measurement Constructs and Entries

Constructs	Construct code	Entries	References
Health expectancy	HE1	The use of intelligent medical products can improve the understanding of physical conditions (such as monitoring blood pressure and heart rate)	Zheng Y, Poon CCY, Yan BP, <i>et al.</i> Pulse arrival time based cuff-less and 24-h wearable blood pressure monitoring and its diagnostic value in hypertension. J Med Syst 2016;40:195.
	HE2	Intelligent medical products can provide appropriate medical advice and find appropriate doctors (such as recommending medical departments and hospitals)	Mannini A, Trojaniello D, Cereatti A, <i>et al.</i> A machine learning framework for gait classification using inertial sensors: application to older adults, post-stroke and huntington's disease patients. Sensors 2016;16:1-14.
	HE3	Intelligent medical products can enhance overall health status and improve the quality of life	Chen Y, Wu F, Wu Y, <i>et al.</i> Development of interventions for an intelligent and individualized mobile health care system to promote healthy diet and physical activity: using an intervention mapping framework. BMC Public Health 2019;19:1311.
Perceived cost	PC1	Compared with traditional medical care, I need to pay more to use and maintain intelligent medical products	Lewy H. Wearable technologies-future challenges for implementation in healthcare services. Healthc Technol Lett 2015;2:2-5.
	PC2	Compared with traditional medical care, I need to spend more time learning to use intelligent medical products	Iftikhar P, Kuijpers MV, Khayyat A, <i>et al.</i> Artificial Intelligence: A New Paradigm in Obstetrics and Gynecology Research and Clinical Practice. Cureus 202;12:e7124.
	PC3	By using intelligent medical products, I feel I need more time to communicate with doctors	Lewy H. Wearable technologies-future challenges for implementation in healthcare services. Healthc technol lett 2015; 2:2-5.
Perceived ease of use	PEOU1	I think through my efforts, I can master the use of intelligent medical products	Lewy H. Wearable technologies-future challenges for implementation in healthcare services. Healthc technol lett 2015; 2:2-5.
	PEOU2	I think I can master the use of intelligent medical products with the help of the people around me	
Perceived risk	PR1	I worry that I will be cheated in hospitals where intelligent medical products are used for triage	Cilliers L. Wearable devices in healthcare: privacy and information security issues. Health Inf Manag 2020;49:150-156.
	PR2	I worry that intelligent medical products cannot accurately report the health condition	Rodgers MM, Alon G, Pai VM, <i>et al.</i> Wearable technologies for active living and rehabilitation: Current research challenges and future opportunities. J Rehabil Assist Technol Eng 2019;6:2055668319839607.
	PR3	I worry that the triage and treatment of intelligent medical products are not timely and may delay the illness	Dewsbury G, Clarke K, Rouncefield M, <i>et al.</i> Designing appropriate assistive technology for home users: Developing dependable networks. Inclusive Design and Mobility Response in Indoor/ Outdoor Public Buildings and Facilities: CIB Working Group W084-Building Non-Handicapping Environments, 2002; Rome.
	PR4	I worry that intelligent medical products may disclose personal information	Wen D, Zhang X, Lei J. Consumers' perceived attitudes to wearable devices in health monitoring in China: A survey study. Comput Methods Programs Biomed 2017;140:131-137.
Social influence	SI1	Many people (doctors/family/friends <i>et al.</i> ) have recommended using intelligent medical products	Kamal SA, Shafiq M, Kakria P. Investigating acceptance of telemedicine services through an extended technology acceptance model (TAM). Technol Soc 2019; 60:101212.
	SI2	Many people (friends/family <i>et al.</i> ) are using intelligent medical products	
	SI3	The use of intelligent medical products can reflect that I pay more attention to personal health	
Facilitation conditions.	FC1	The network conditions around me can support me to use intelligent medical products	Lewy H. Wearable technologies-future challenges for implementation in healthcare services. Healthc technol lett 2015; 2:2-5.
	FC2	When problems arise in using intelligent medical products, my family, community or hospital can help me solve time problems	
	FC3	I think the manufacturers of intelligent medical products should timely feedback my usage problems	
Behavioral intention	BI1	I am willing to use intelligent medical products	Venkatesh V, Morris M G, Davis G B, <i>et al.</i> User acceptance of information technology: Toward a unified view. MIS Quarterly 2003;27:425-478.
	BI2	I would like to recommend intelligent medical products to my family and friends	Li N, Zhang P. Consumer online shopping attitudes and behavior: an assessment of research. Information Technology 2006: 102-110.
	BI3	I will accept a more comprehensive range of intelligent medical products in the future	Ho Cheong J, Park, Myeong-Cheol. Mobile internet acceptance in Korea. Internet Res 2005;15:125-140.
Use behavior	UB1	I will take the initiative to use intelligent medical products to monitor health conditions	Venkatesh V, Morris M G, Davis G B, <i>et al.</i> User acceptance of information technology: Toward a unified view. MIS Quarterly 2003;27:425-478.
	UB2	I will use intelligent medical products to monitor health status in real-time	