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Health Information Science and Systems

RESEARCH

Analyzing the changes of health condition and social capital of elderly people using wearable devices

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Abstract

Purpose: Rapid developments in information technology have enabled wearable devices to be applied in the health field. In elderly adults, wearable devices aid in data collection and exerts a positive effect on their social capital. This study evaluated the changes in these two parameters among elderly adults using wearable devices, and analyzed the effect of these devices on their daily lives.

Methods: We selected 18 elderly people using wearable devices, between February and May 2017. The data collected by the wearable devices included the number of steps taken, sleep duration, blood pressure, heart rate, respiratory rate, fatigue, and mood of the wearers. Using a questionnaire and the trajectory equifinality model, we interviewed and surveyed elderly adults in order to understand their health status and social capital.

Results: The health of the participants was generally good, and most were able to achieve > 8000 steps per day ($p < 0.05$). Mild and moderate fatigue symptoms were noted in elderly adults for 90% of the study period ($p < 0.05$). The number of steps, blood pressure, and heart rate changed significantly within a month. From the commencement of using the wearable devices, a steady increase was noted in the monthly number of steps. Interviews suggested that the elderly adults perceived wearable devices as having the potential to improve health and social capital.

Conclusions: By using wearable devices, the participants had a better understanding of their own health, and were willing to take health-boosting measures. The participants were also more willing to increase their social capital and expand their social network.

Keywords: Wearable devices, Elderly, Social capital, ICT, Health status

Background

Owing to the increase in the number of prevalent chronic diseases and the dramatic rise in the proportion of the aging population, health monitoring of the elderly is expected to gradually shift from the hospital to the family [1]. In China, aging has become a social problem. As of 2010, there were 176 million elderly people (over 60 years of age) in China, accounting for 13.3% of the total population From 2000 to 2010, the annual growth rate of elderly adults in China, 4.64%, was increasing. It is estimated that China's elderly population will account for 25% of the total population by 2050 [2]. With developments in information technology, the use of information and communication technologies (ICTs) such as computerized devices, home computers, the Internet and other communication devices has the potential to significantly improve the quality of life of elderly adults, and provide cost-effective care and efficient health monitoring [3].

Wearable devices are being increasingly used by elderly adults. Anti-fall technology is among the most prominently used functions among elderly adults. Based on the approach of wearable devices, garments with embedded sensors detect motion and location [4]. Wearable devices can easily and quickly determine if a fall has occurred, and issue an alert.

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The detection of chronic diseases is also an important scenario for wearable devices. Persons with high levels of health risk can be tracked in the comfort of their homes. Patients with epilepsy, risk of falls, heart disease, breathing problems, or other chronic diseases, can track their health data and communicate with their doctors, remotely [5]. Through the tandem connection between wearable devices and ICTs, an effective closed loop is formed, which provides full-time health services to elderly adults (Fig. 1). The health information obtained through wearable devices can help elderly adults better understand their own health. With the convergence of ICTs, various elements of healthcare and medicine have been developed to improve the service efficiency and promote the health of elderly adults.

The determinants of the acceptability of ICTs for elderly adults are predominantly reflected in the following six aspects: 1. Perceived usefulness, perceived impact, and relevance [6]; 2. Perceived ease of use [7]; 3. Issues associated with the technology [8]; 4. Personal traits [9]; 5. Social issues [10]; and 6. Facilitation issues [11]. The social issues are related to the social reference groups of the individual, including subjective norm, image and social capital [12].

Social capital refers to the aggregate of resources embedded in social relationships, which is the outcome of the constant investment in those social relationships [13]. In recent decades, social capital, as an important theoretical tool within the realm of public health research, has been used to explain the impact of changes within the social environment and social relationships on health. The application of ICTs has gradually become the subject of research and two main factors have been attributed to the interpretation of the relationship between ICTs and social capital: 1. Recognition of ICTs in enhancing social capital; 2. Concerns about ICTs reducing social capital [14]. One study suggested that the use of ICTs can increase parents' social capital [15]. Online communication tools allow parents to maintain social relationships, exchange social support, and seek advice for their children [16]. Elderly adults too require social capital. Through the use of ICTs, the range of the social capital available to elderly adults can be further expanded. Simultaneously, the use of ICTs has increased the awareness of elderly adults among their family members, friends, and the community, thereby improving their social capital. This also fulfills the social needs of elderly adults.

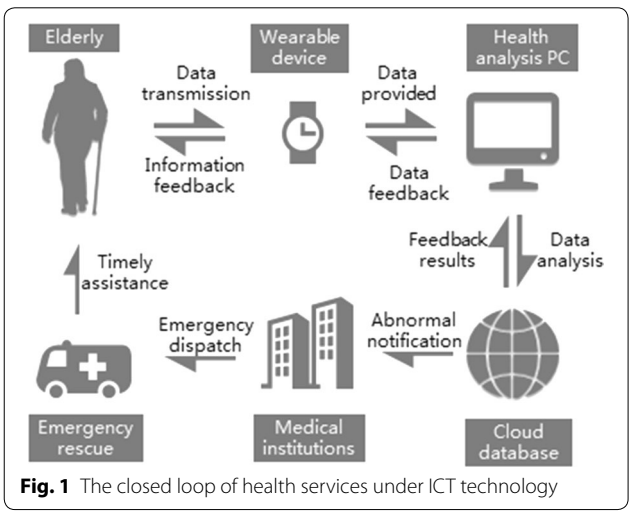

Fig. 1 The closed loop of health services under ICT technology

With developments in information technology, it is evident that mobile health (mHealth) is transforming healthcare in aging societies such as China, with the provision of continuous monitoring in self-healthcare, as well as supervised and assisted healthcare [17]. A study in Israel showed that making effective use of the opportunities offered by the Internet can help elderly adults maintain a good quality of life, in the long run, as well as in enjoying not only an "electronic" feel but also in allowing them to continue being important and influential members of society [18]. ICT, as a bridge of communication, can boost health by increasing the frequency of communication among older individuals. As carriers of ICT, wearable devices, when used by elderly adults, can provide timely, accurate and current health data, as well as data on living conditions to elderly adults. Wearable devices help these individuals understand their health, and, as storage-enabled tools, allow them to access their own health history at any point.

However, there remain issues related to the process of using ICTs, in the elderly. First, the accuracy of the current wearable devices is not high, especially in terms of medical indicators such as blood pressure, which most elderly adults are concerned about, thereby affecting their own health judgment. Second, the use of wearable devices entails a learning process that these adults may find difficult. Finally, in terms of trust, some older individuals believe that the privacy issues associated with these devices may affect their social capital.

There are also problems associated with the status of older individuals using ICTs. This study continuously monitored and collected data on wearable devices, and guided elderly adults on their use. We sought to understand the changes in the health and social capital among older adults using wearable devices, and analyze to the actual effect of wearable devices in elderly adults.

Methods

Participants

Twenty elderly adults receiving health management services in Hangzhou and Jiaxing, Zhejiang Province, China, were selected between February and May 2017. The

sample included 9 men and 11 women, aged 58–68 years (average age 63.44 ± 3.55 years) years. The inclusion criteria were: (1) male ≥ 60 years, female ≥ 55 years; (2) having a clear consciousness and normal communication; (3) voluntary participation in the study and providing signed informed consent. The exclusion criteria were the presence of: (1) cognitive dysfunction; (2) severe complications; (3) previous history of mental illness or use of antipsychotic drugs; and (4) severe liver and kidney dysfunction or heart disease.

Data collection methods

Wearable devices

This study used health bracelets produced by 37 Degree Technology. The specifications of the bracelet are: main dimension: $42.8 \times 17.3 \times 9.8$ mm; weight: 24 g; full length: 238 mm; waterproof level: IP67+; communication: Bluetooth low energy; and system requirement: Android 4.3+ or IOS 7+. The bracelet can detect heart and lung function (ambulatory blood pressure, heart rates, and respiratory rates), mood and fatigue, and can record the number of walking steps as well as sleep time (sleep quality). The specific implementation method included: (1) communicating one-on-one with elderly adults, and teaching patients (elderly adults) how to wear the bracelet and use the application (37 Degree Technology); (2) the elderly adults reporting their health data daily, at 20:00, to the researchers, along with screenshots, so a unified record could be created and maintained; and (3) using the app data export function, deriving and sending weekly hand ring data to the researchers.

Questionnaire

This 20-person study was conducted using a centralized approach. The survey included informed consent and a unified questionnaire. The main contents of the questionnaire included: (1) general information on the elderly adults, mainly pertaining to their marital status, education, personal income and family income; (2) basic health information; (3) physical activity; (4) quality of life; and (5) social capital.

Interview

Individual face-to-face interviews were conducted, lasting 30–40 min each. The interviews were conducted 3 months after the start of the use of the wearable devices. The interviewer communicated with the interviewees to understand their changes in perception and behavior during the analysis period. The interviewers were professionally trained, and all interviews were completed by the same professional. The interview questions focused on changes in (1) physical health; (2) psychological health; (3) health indicators (heart rate; blood pressure; and respiratory rate); (4) social capital; and (5) self-perceived health while using wearable devices.

Research quality control

All personnel involved in the field investigation underwent rigorous training and assessment. During the investigation, data on the elderly adults were recorded accurately and the notes and recording methods were maintained in the research office. The results of the daily investigations were audited so that abnormities in the data could be verified in a timely manner. EpiData3.1 was used for data double entry, and to check, correct, and ensure the accuracy of the data. As two bracelets were found to be defective, during the research process, the final statistical analysis included only 18 individuals.

Statistical analysis

IBM SPSS Statistics for Windows, version 20.0 was used for the statistical analysis. The data are expressed as "$\chi \pm s$." Independent t tests were used for statistical analysis. The experiment time was divided into 4 months, using one-way repeated measures analysis of variance (ANOVA), based on the confirmation of the homogeneity of variance, judging the changes in the number of steps, blood pressure, sleep and heart rate during the period when the wearable devices were used. The mean blood pressure was calculated as the diastolic blood pressure + (systolic blood pressure − diastolic blood pressure)/3. Thematic Framework Analysis was used for the research interview. The steps were as follows:

(1) The finished materials were analyzed and a themed framework was formed according to the research purpose and interview outline, mainly pertaining to the changes in the health and social capital of the elderly adults using wearable devices.
(2) The original material problems were marked and coded.
(3) The materials were classified according to the content relevance.
(4) A comprehensive analysis of the theme focusing on the changes in the social capital and health was performed.

The trajectory equifinality model (TEM) was used to study the interviews and analyze the changes in the social capital during the period when wearable devices were used.

Results

General descriptive statistics

In terms of the general characteristics of the participants, 11 women and 7 men met the inclusion criteria;

their specific health indicators are shown in Table 1. The average number of walking steps for 15 of the participants was more than 8000, meeting the goal for the number of healthy exercise walking steps. In terms of the sleep score, the average score of six of the participants was above 90 points, while the remaining 12 had scores in the 80–90 points range, with generally better sleep quality. As for the blood pressure indicators, three daily average systolic blood pressure values higher than 130 mmHg, and diastolic blood pressure values higher than 89 mmHg were indicative of hypertensive disease, as were the relevant data collected through interviews. The heart rate of all the participants was 60–100 beats/min, in line with the health standard. All the participants had a respiratory rate in the 12–24 breaths/min range; also in line with the health standard. The independent *t* test of the health indicators of the participants was statistically significant ($p < 0.05$).

In terms of the emotional and fatigue indicators, based on four-month daily data, the majority of the elderly adults had mild and moderate fatigue. The total number of days in which the participants did not have fatigue or severe fatigue was less than 10%. In terms of emotion, most of the elderly adults had a peaceful state of mind, with only one individual having less than 80% of days with a peaceful mood (Table 2). The independent t test of the health indicators of the surveyed participants was statistically significant ($p < 0.05$).

Changes in the health status of the elderly during different periods

We statistically analyzed the health indicators of the participants, in different months. The time period was divided into 4 months, and analyzed changes in the number of steps, sleep, blood pressure, and heart rate. After the one-way repeated measures ANOVA was performed, using the Holm-Sidak test was used to show that the number of steps, mean blood pressure and heart rate had significantly changed; however, no significant changes were observed in terms of sleep (Table 3). After the start of the use of the wearable device, the monthly average number of exercise steps steadily increased. The average number of steps in the 3 months following the first month was higher than that in the first month (Fig. 2). In terms of blood pressure, the mean blood pressure of the elderly adults was found to be gradually stabilized, and showed a decreasing trend. The blood pressure-related health continued to improve (Fig. 3). In terms of sleep, the participants had better sleep quality, while the elderly adults generally maintained a normal heart rate (Fig. 4).

Qualitative research on the interviews of the participants

We used Thematic Framework Analysis to interview the participants. The interviews focused on the following topics: health (physical and mental health), social capital (social networks and social participation), ICT applications (use of smartphones and use of wearable

Table 1 General respondent situations

No.	Steps	Sleep point	SBP (mmHg)	DBP (mmHg)	Heart rate (bpm)	Respiratory rate (breaths/min)
1	9648.69 ± 2935.76	86.31 ± 7.21	115.63 ± 15.05	80.72 ± 11.23	69.88 ± 8.34	17.56 ± 3.26
2	12696.17 ± 3671.17	91.14 ± 3.84	135.46 ± 10.29	93.40 ± 7.67	76.25 ± 6.94	17.70 ± 4.04
3	6373.36 ± 3064.77	90.24 ± 3.73	131.89 ± 12.52	89.99 ± 9.77	81.50 ± 10.68	17.77 ± 3.93
4	8360.88 ± 2881.58	89.83 ± 3.35	122.01 ± 9.04	85.22 ± 8.60	77.56 ± 11.48	17.71 ± 3.44
5	10227.27 ± 2866.89	90.56 ± 4.09	121.40 ± 12.06	86.24 ± 10.16	77.24 ± 10.12	19.78 ± 4.13
6	9425.81 ± 2399.11	81.56 ± 8.16	127.56 ± 8.74	88.37 ± 8.94	83.83 ± 7.86	18.74 ± 3.29
7	7965.25 ± 2394.59	91.64 ± 2.48	117.48 ± 11.59	81.26 ± 8.70	78.51 ± 9.66	18.31 ± 2.96
8	11898.06 ± 2832.62	94.10 ± 3.85	122.72 ± 11.58	84.15 ± 10.34	78.49 ± 10.03	16.76 ± 3.44
9	12115.31 ± 3426.76	85.60 ± 5.76	115.22 ± 14.51	77.04 ± 10.88	79.52 ± 9.64	18.06 ± 3.54
10	5538.05 ± 2095.20	85.58 ± 5.87	124.97 ± 10.82	86.11 ± 10.39	78.92 ± 12.07	18.71 ± 3.21
11	9539.33 ± 3419.16	89.85 ± 6.49	118.32 ± 12.51	84.65 ± 11.02	72.99 ± 9.79	19.15 ± 4.18
12	15010.40 ± 3939.83	86.60 ± 5.11	118.32 ± 12.95	79.63 ± 8.50	74.09 ± 11.91	17.67 ± 4.02
13	14157.27 ± 3043.62	90.74 ± 4.46	118.12 ± 8.66	79.48 ± 8.89	73.74 ± 8.90	18.20 ± 4.26
14	8960.79 ± 3331.43	82.37 ± 7.48	124.16 ± 9.19	84.34 ± 7.84	70.55 ± 11.51	19.12 ± 3.98
15	10021.69 ± 1574.53	83.46 ± 7.77	112.23 ± 11.93	73.51 ± 10.21	76.60 ± 10.32	18.50 ± 3.89
16	8262.26 ± 2194.85	86.60 ± 4.07	125.13 ± 9.52	78.86 ± 6.98	75.50 ± 8.65	16.71 ± 2.65
17	7710.45 ± 2193.92	87.80 ± 4.46	133.19 ± 8.93	89.87 ± 8.98	76.13 ± 4.50	15.87 ± 2.60
18	8943.83 ± 2010.37	87.08 ± 4.80	126.47 ± 8.39	83.02 ± 7.80	85.59 ± 5.78	16.64 ± 2.32

SBP systolic blood pressure, *DBP* diastolic blood pressure

Table 2 Fatigue and emotion status while using wearable devices (%)

N	Fatigue(%)				Mood(%)				
	Non	Mild	Moderate	Severe	Peace	Impassion	Pessimism	Depression	Anxiety
1	1.9	36.1	59.3	2.8	73.1	7.4	0	19.4	0
2	7.4	22.2	70.4	0	91.7	3.7	1.9	1.9	0.9
3	0	22.2	76.9	0.9	82.4	2.8	0.9	13.9	0
4	0.9	18.5	77.8	2.8	93.5	0	0	6.5	0
5	13.0	49.1	38.0	0	85.2	0	0	14.8	0
6	0	11.1	88.9	0	90.7	1.9	0.9	6.5	0
7	1.9	31.5	64.8	1.9	94.4	0	1.9	3.7	0
8	0	34.3	63.0	2.8	90.7	5.6	0	3.7	0
9	0	44.4	55.6	0	91.7	0	0	8.3	0
10	8.3	70.4	21.3	0	80.6	2.8	1.9	5.6	9.3
11	8.2	18.4	73.5	0	87.8	4.1	2.0	6.1	0
12	0	16.3	83.7	0	93.9	0	0	6.1	0
13	0	8.2	91.8	0	89.8	0	0	10.2	0
14	0	10.2	89.8	0	94.9	0	0	5.1	0
15	0	9.2	90.8	0	90.8	0	1.0	8.2	0
16	1.0	85.7	13.3	0	93.9	3.1	0	0	3.1
17	2.0	87.8	10.2	0	88.8	1.0	0	10.2	0
18	2.0	84.7	13.3	0	83.7	0	0	2.0	14.3

Table 3 Health status by month (one-way ANOVA)

Variable	S.V	SS	df	MS	F	p
Steps	Subj	407671524.11	17	23980677.88		
	Month	14076512.05	3	4692170.68	9.76	**
	s*Month	24525274.44	51	480887.73		
Mean blood pressure;	Subj	1978.12	17	116.36		
	Month	268.42	3	89.47	10.84	**
	s*Month	421.10	51	8.25		
Heart rate	Subj	1182.76	17	69.57		
	Month	172.81	3	57.60	7.68	**
	s*Month	382.43	51	7.49		

** Statistically significant difference ($p < 0.05$)

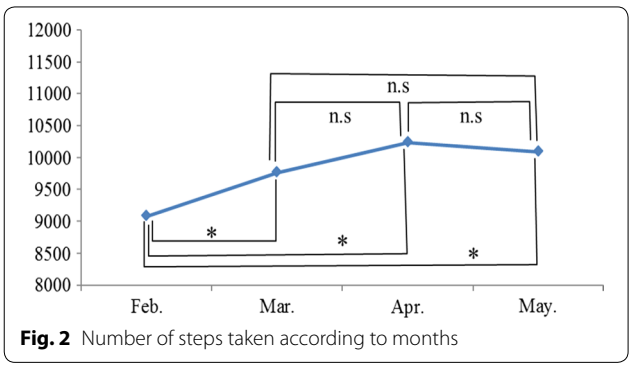

Fig. 2 Number of steps taken according to months

devices), and health self-inductance during the use of wearable devices (Table 4).

In terms of health status, all participants expressed concern about their health. However, only three indicated that they were more concerned about their mental health.

No. 2: "I mostly pay attention to my health. Now I feel stress and I feel no problem in mental health."

No. 8: "I think it's important to be healthy. Basically, when I feel uncomfortable, I call my children, and I can adjust myself. But if the body is sick, in our age, I must go to the hospital for help immediately."

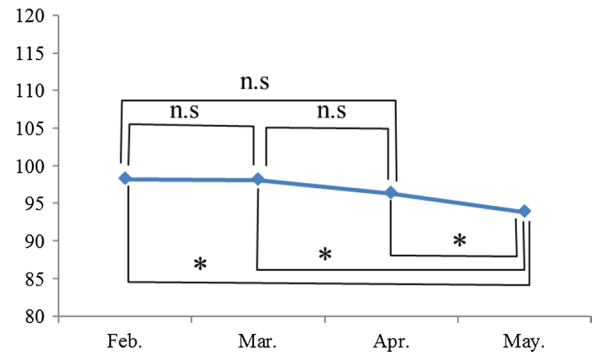

Fig. 3 Changes in the blood pressure according to months

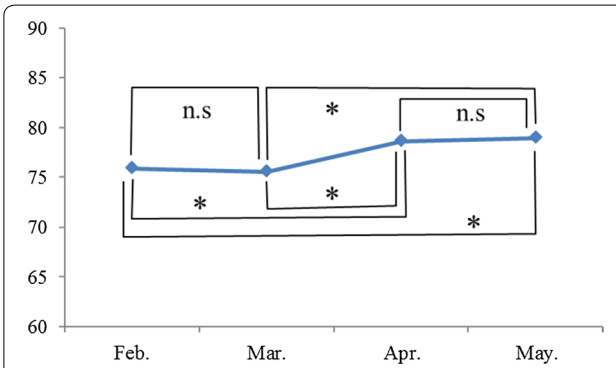

Fig. 4 Changes in the heart rate according to months

Table 4 Topics and subtopics of the qualitative interviews with the participants

Topics	Subtopics
Health	Physical health
	Mental health
Social capital	Social network
	Social participation
ICT applications	Use of smartphones
	Use of wearable devices
Self-inductance during the use of wearable devices	1. Self-inductive health 2. Health habits 3. Social relationship

No. 13: "Mental health is of course important. I have a friend who always feels depressed all day. Now she has a lot of problems in sick, and I think it is caused by her unhealthy psychology."

In terms of social capital, most of the participants stated that they had their own social networks and could seek timely help from family or friends. In addition, they were willing to participate in a series of activities as part of community organizations.

No. 5: "I set up an elderly study class in our community to provide the elderly with a place to show their talents. I am good at drawing and teaching other elderly people who like painting."

No. 6: "I prefer to go to a friend's house when I have enough time. we also regularly go to the tea room to sit and chat. After retirement, I should find something to do."

No. 16: "I now take my grandson and often go to the community park. Nowadays, we often chat in community parks and with other elderly."

However some elders exhibited a lack of social participation.

No. 13: "I do not like get together with other elderly. It is too noisy for me. I still prefer to stay at home watching TV, or gathering with family."

In terms of the use of ICT applications, all participants knew how to use a smart phone.

No. 5: "My smartphone was bought by my son and I like it very much. Sometimes I can read the news online and play games."

No. 11: "I like to use my smartphone more than other elderly. I use online shopping every month. It was very convenient for me."

No. 14: "I like to take photos. Now I have bought this smartphone with a very good camera function. I took beautiful photos and sent them to my friends."

No. 16: "I do not know how to use this smartphone. I mainly used it to receive messages and did not have much time to study its usage."

Only one participant said that he had used a wearable device some months ago.

No. 1: "I used to use another one, but it was not very accurate, so I used it for no more than two months. But this one is quite accurate."

No. 3: "This wearable device is convenient for me, and I can see my health data every day. It is better now because I did not know my health data before."

No. 18: "When I went to see my friend with this wearable device, they all asked me what it was, and I also introduced it to them directly. I feel it is good to know my health."

The participants generally expressed having an increased awareness of their own health when using the wearable devices.

No. 6: "After using this wearable device, I basically have to take a look every hour. I have high blood pressure, so when I pay more attention to this data, I feel more concerned about the better blood pressure control."

In terms of health habits, the participants said that they had adjusted to their habits according to the data provided by the bracelet.

No. 9: "I like walking very much, but the exact number of walking steps depends on my mood. With this wearable device, I ask myself daily for more than 10,000 steps and now I feel it becomes a habit."

No. 15: "This wearable device has a great function to share my health data with my friends, so I now share my status with my friends every day and they can monitor me in walking."

We used the TEM to analyze the interviews, the main items are shown in Table 5.

Based on the contents of the interview, we designed a TEM flow chart (Fig. 5). The participants were willing to continue using wearable devices; they believed that the use of ICTs increased their self-esteem and helped them to increase both their personal and group social capital. Some of them thought that while their health status did not change much, their social capital had increased.

Figure 5 shows the classification of BFP1 (health condition) is derived from the health data by wearable devices. Through the social network support, social trust, and social reciprocity norms, wearable device lead to changes in social capital (BFP2). When the elderly share their health data with family and friends, the social networking support (SG1), social trust (SG2), and social reciprocity norms (SG3) were increasing, and the elderly willing to use wearable devices. When the elderly only use the health data for self-examination, the social network support (SD1), social trust (SD2), and social reciprocity norms (SD3) will decline. Wearable devices are just simply tools that provide health data.

On comparing the social networks, the presence of good levels of trust and reciprocity as well as good social networks supported the participants in achieving a high social capital. Conversely, poor social networks, and low levels of trust and reciprocity resulted in a lower social capital. Different levels of social capital directly affected the participants' willingness to continue using ICTs. Overall, the use of ICTs increased the social capital of the elderly.

Table 5 Trajectory equifinality model main content

TEM	Content of the study
Equifinality point	Continue to use ICT
Polarized equifinality point	Dis continue to use of ICT
Bifurcation point	1. Health condition 2. Social capital
Obligatory passage point	Using a wearable device
Social guidance	Positive social capital
Social direction	Negative social capital

ICT Information Communications Technology

Discussion

Owing to the continuous popularization of information technology, wearable devices are likely to be increasingly used to detect health concerns and promote health management in elderly adults [19]. The finding of the present study promote the use of wearable devices by elderly individuals so they can gain a better understanding of their health conditions as well as the changes in their social capital.

First, the use of wearable devices helps elderly adults to visualize their health data. Table 1 shows that our participants were relatively healthy; were moderately physically active, and their quality of sleep was generally higher. According to the health standard pertaining to heart and respiratory rates (heart rate: 60–100 beats/min; respiratory rate: 12–24 breaths/min), the values in our population were within the normal range and in line with their self-perceived health. Table 2 shows that the severity of fatigue was low in our study. After exercise, a certain degree of fatigue contributes to better sleep, concordant with the sleep quality results. In terms of emotions, our participants were able to maintain a more peaceful attitude in the vast majority of situations; however they sometimes experienced stress and anxiety [20]. After retirement, most individuals do not have work pressure, and having a good attitude can contribute to better mental health [21].

Second, the use of the wearable devices added to the health concerns of the elderly. Studies have shown that the elderly are more interested in the health management functions of wearable devices. Health advice obtained through health data can guide the elderly to improve healthy living habits [22]. In the field of human resource health management, companies have used wearable devices to monitor the use of human resources. By predicting potential health and safety risks, a plan can be prepared before productivity losses occur [23]. The health status of the elderly differed across various time periods. The average numbers of steps taken in the 3 months following the first month of use were higher than that taken in the first month. There are two explanations for this finding: (1) With the onset of warm weather conditions, the demand for participation in outdoor sports increases. (2) After the initial phase of adapting to their use, elderly adults' approval of wearable devices made them willing to make better use of them [24]. The elderly adults were unable to accurately grasp their own health data, based only on their past experience in judging their health. After starting to the use the wearable devices, some participants stated that they looked at their health data daily and were able to take more accurate health-related measures. The health status of our participants changed each month. ANOVA showed that the number of steps

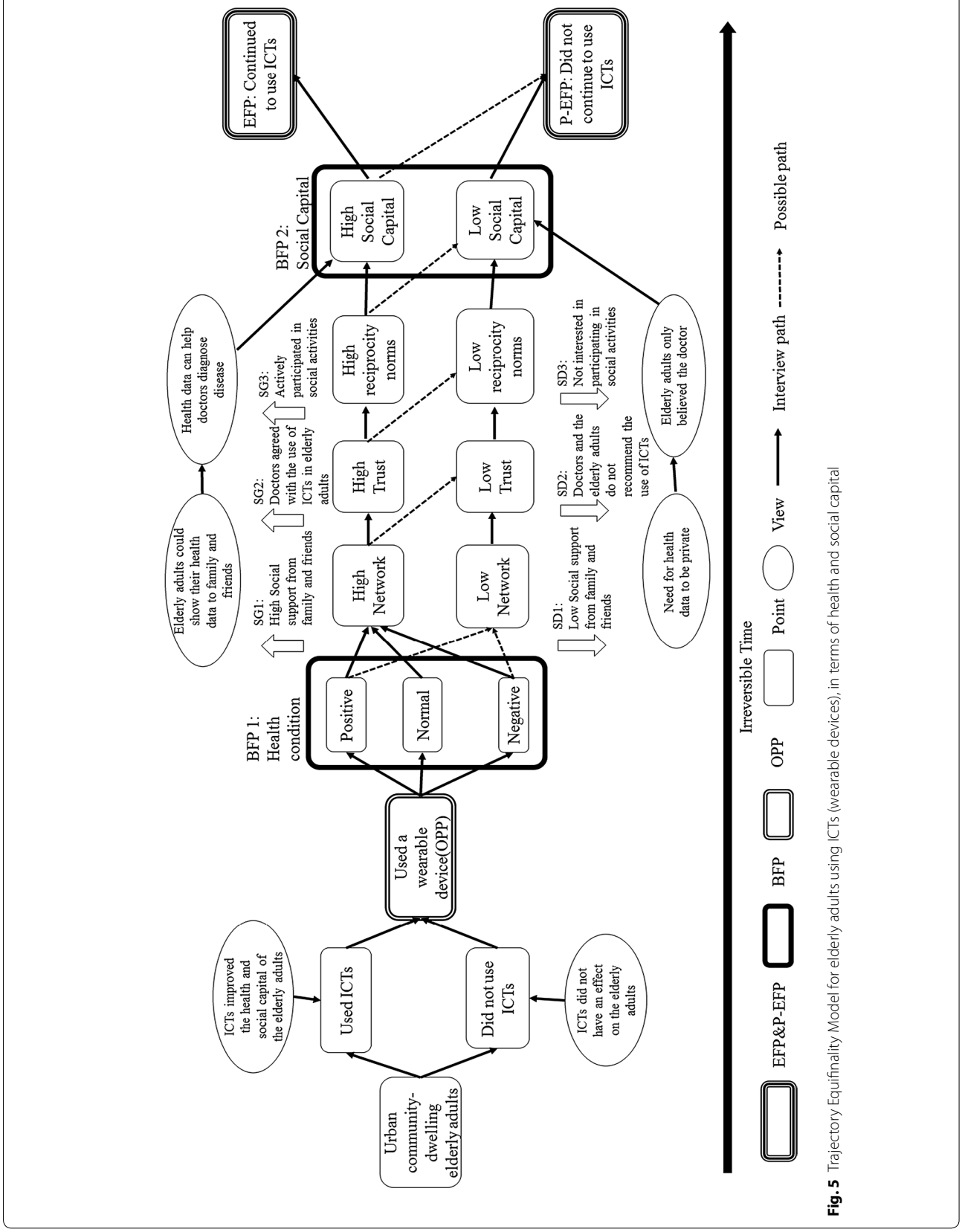

Fig. 5 Trajectory Equifinality Model for elderly adults using ICTs (wearable devices), in terms of health and social capital

taken, blood pressure, and heart rate changed significantly according to month. The use of wearable devices can help elderly adults, except in terms of the number of steps taken, blood pressure, and heart rate [25].

Third, the use of wearable devices stimulated the health of the participants. Previous studies suggested that health promotion work for the elderly required more active guidance so that the elderly could passively accept health improvement methods. In this study, the use of wearable devices had a positive effect on the health of elderly individuals. Through interviews, we found that the participants were very interested in visualizing their health data and taking measures to improve their health: (1) the participants set themselves a goal to take 10,000 steps a day; and (2) they regarded their heart rate, blood pressure, and respiratory rate as indicators of health, and regularly observed the changes in these values. Through the implementation of these measures, the elderly have a deeper understanding of self-health indicators. However, it is also necessary to consider weather large deviations in health indicators; will have a negative impact on the health consciousness of the elderly.

Fourth, compared with previous studies, this study used the TEM method to analyze the pathways affecting the changes in the social capital of the elderly to find that the use of wearable devices by the elderly has a positive effect on their social capital. The TEM method is widely used in qualitative research mainly to determine the path from the cause to the result. Studies have used this TEM method to analyze the paths of communication between childcare professionals and children to determine the main factors affecting children's communication [26]. The use of the TEM method in health research has revealed that psychological motivation and actual experience are the main factors that affect curriculum in the teaching process of clinical medicine [27]. The use of wearable devices contributed to the social capital extension of the elderly adults, predominantly in the following areas: 1. After using wearable devices, they were willing to share their health data with family and friends; 2. They were willing to wear their devices in public and publicize the concept of health; and 3. They asked their family or friends to supervise their daily exercise. The TEM is mainly used for the qualitative survey of elderly adults, and reflects their thinking path [28]. Through the TEM analysis, we observed that all the dimensions of social capital had an impact on the ultimate willingness of the elderly adults to use ICTs. To improve the social capital of elderly individuals, there must be a focus on the three aspects of social network support, social trust and social reciprocity. With the continued use of wearable devices, ensuring a subsequent continued increase in the social capital of the elderly over a long period of time must also be considered.

Finally, our participants were willing to continue using wearable devices even though they felt unhealthy. As we observed in the interviews, elderly adults think that the use of wearable devices increases their personal and group social capital and helps in better integration into society.

Conclusion

In this study, we monitored the health data of elderly participants during a period in which they were using wearable devices. We found that, through the use of wearable devices, elderly adults had a better understanding of their own health, and were willing to take some measures to promote their own health. After interviewing the participants, we found that they had grown accustomed to using the wearable devices. These participants were also willing to increase their social capital and expand their social network.

Analysis of the health data of the elderly combined with interview information can effectively refine knowledge of their living habits. In this way, the elderly can be taught positively and can be encouraged to correct their bad health habits for health promotion. In addition, the use of wearable devices has become a hot topic among the elderly. While participating in these topics, the elderly unconsciously increase and expand their social capitals resulting in a preventive effect against psychological depression caused by the lack of participation in social activities.

However, this study has some limitations. For example, it is not clear if the health status of the participants could change over time. The correlation between the time variables and variables in the wearable devices were also not clear. Future studies should extend the period of use of the wearable devices and observe further changes; this is the focus of the next phase of our research.

Authors' contributions

SZ was responsible for conducting the questionnaires and interviews, as well as data analysis, based on social capital and a statistical approach. AO lead the project and participated in the experiment design. SN contributed to the data analysis framework design. QJ participated in the data acquisition system design. All authors read and approved the final manuscript.

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Competing interests
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