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# Public Needs for Wearable Particulate Matter Devices and Their Influencing Factors

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**Abstract:** Recently, increasing numbers of people have realized the harm that particulate matter (PM) causes to health, especially those with a diameter less than 2.5 µm (PM2.5). With the increasing popularity of wearable devices in recent years, it is believed that wearable technology can contribute feasible solutions to prevent health hazards caused by PM2.5. In order to better understand the public's needs regarding wearable devices, this study aimed to determine what kinds of PM2.5 wearable devices were needed by the public and the factors that may influence these needs. An online survey was conducted in the Beijing metropolitan area of China of a total of 894 subjects. The results showed that the public's overall need for wearable PM2.5 purifiers was higher than for wearable PM2.5 trackers. The public's needs for wearable breathing-zone PM2.5 devices were significantly higher than for any other type, indicating that people care about the quality of the air they actually breathe. It was also found that education, income level, and attitude toward PM2.5 positively affected their needs for wearable devices. In contrast, age had a negative influence on their needs. The results of this study are expected to serve as a valuable reference for related academic and industrial research.

**Keywords:** ultrafine dust; PM2.5; wearable devices; needs; influencing factors



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## 1. Introduction

Particulate matter (PM) is a major air pollutant in both indoor and outdoor environments [1]. PM10 is defined as a substance less than 10 µm in diameter, called fine dust. PM2.5 is defined as a substance with a diameter of less than 2.5 µm, called ultrafine dust [2]. Ultrafine dust is a fatal substance that causes respiratory system diseases and heart-related diseases because it cannot be filtered from the respiratory system [3,4]. PM is generally recognized by the public as small substances that are difficult to identify with the naked eye and are harmful to health. Some people may experience severe rhinitis or soreness of the eyes when fine dust concentration levels are high [5]. The level of PM affects many aspects of the public's daily lives and behavior patterns. For example, when checking daily weather forecasts, people may also check the air quality. On days with a high PM2.5 concentration, people may reduce unnecessary outings, wear masks when going out, and use air purification systems. As the public's awareness of PM2.5 deepens, more people realize that PM2.5 concentration is not only affected by the external natural environment. Many indoor pollution sources, including many human behaviors themselves, cause the concentration of indoor PM2.5 to increase [6,7].

Recently, wearable devices have been designed to help people reduce the possible harm caused by PM2.5 to health. Wearable technology is worn in various forms such as earphones [8], gloves [9], watches, e-textiles, pastes [10], smart tags [11] and glasses [12]. They are widely used in health care [13,14], virtual/augmented reality [12], robotics, teleoperation, education [15], and sports or even for everyday use [10]. With a combination of wearable devices and mobile apps, it is possible to measure personal PM2.5 concentration data and provide useful activity guidelines based on real-time data [16]. Moreover, PM2.5 purification systems are no longer limited to indoor air purification systems. Various portable small and mini air purification devices are gradually gaining public notice, such as car air purifiers and wearable air purifiers.

In order to better understand people's needs for such wearable devices, this study aimed to investigate people's needs for wearable PM2.5 devices and the factors that might affect these needs. It is expected that this research will constitute a meaningful reference for related academic research and industrial production.

## 2. Literature Review

Wearable devices have been in existence for many years. In this literature review, the literature on general wearables research and current applications of wearable technology are introduced; research on the application of wearable devices to fine dust is then reviewed.

### *2.1. Classification of Wearable Technology and Devices*

Wearable devices are physically closest to the human body [17]. There are many types of wearable devices, which can be classified according to the part on the body where they are worn and their purpose of use, which is naturally dependent on the former. In this study, wearable devices are described as used for monitoring or for transfer of information by application.

For monitoring, wearable devices can automatically and continuously collect users' physiological (e.g., temperature, heart rate, respiration rate, and blood pressure) or biochemical indicators (e.g., sweat), monitor the health condition of the human body, and detect physical movements [11,13], activities [9] and contextual information through wearable sensors [18,19], which can be used in various fields such as healthcare [14], fitness, sports, robotics, administration, education [15], and the military. For example, Apple Watch is a popular wearable device that incorporates many fitness and health data tracking functions.

For the purpose of displaying information, wearable devices can be used to display visual information [12], auditory messages, or tactile information to users [8]. For example, Google Glass is an optical head-mounted display in the shape of eyeglasses used to display information in hands-free format [20]. Wearable devices can be used in many fields such as infotainment, business, healthcare, industry [21], and assistive devices for disabilities [8]. Table 1 classifies the wearable devices based on the body parts where they are worn, purpose of use, and application fields.

**Table 1.** Classification of wearable technology and devices.

| Body Parts | Devices/Technology | Monitoring | Display | Application Field |
|---|---|---|---|---|
| Eye | - VR/AR glasses<br>- smart lenses | - eye movement<br>- body movement<br>- contextual info. | - visual info.<br>- audio | - infotainment<br>- business<br>- daily use |
| Ear | earphone | N/A | - audio information | - infotainment<br>- business |

**Table 1.** *Cont.*

| Body Parts | Devices/Technology | Monitoring | Display | Application Field |
|---|---|---|---|---|
| Head | - wearable camera<br>- helmets<br>- caps | - physiological info<br>- body movement<br>- contextual info. | - head-mounted display<br>- audio | - industry<br>- professional fields<br>- hobby |
| Wrist/Hand | - smart watch<br>- fitness tracker<br>- scanner gloves | - hand/arm movement<br>- heart rate<br>- physiological info<br>- speed/distance | - visual information<br>- audio<br>- tactile/vibration | - infotainment<br>- sport<br>- healthcare<br>- daily use |
| Body | - body patch<br>- smart clothing<br>- e-textile | - heart rate<br>- body temperature<br>- body movement<br>- physiological info | - pressure<br>- tactile/vibration<br>- temperature | - fitness<br>- military<br>- healthcare |

### *2.2. Research on Applications of Wearable PM2.5 Devices*

When it comes to PM2.5, most people would first think of environmental air pollution, wearing masks when going out, reducing outside activities, and so on. Most of these are related to outdoor PM2.5 concentrations. However, on days when the outside PM2.5 concentration level is high, untreated indoor air conditions are not optimal. In fact, more attention should be paid to indoor air quality because most people spend much more time indoors than outdoors. Researchers investigating time-activity patterns in the United States reported that their respondents spent an average of 87% of their time in enclosed buildings [22]. Another study conducted in China reported that the subjects spent 90% of their time indoors [23]. The literature shows that people should pay more attention to their personal exposure to PM2.5 in indoor microenvironments than in outdoor environments [24,25]. Moreover, on the same day in the same city, even two people who are both indoors may have significantly different personal exposures to PM2.5 due to their geographical location (next to a road or a park), occupations (e.g., construction and clothing industry), activities (e.g., cooking, smoking), and so forth [26]. Awareness of this fact is important. Timely accurate information about PM2.5 exposure level is crucial, especially for vulnerable individuals, to help them take appropriate protective measures and prevent exposure to high concentrations of PM2.5 [27].

In recent years, wearable PM2.5 devices and technologies have been applied to solving PM2.5-related issues such as wearable air quality monitoring devices [28] and wearable air filters [29]. In this study, two categories of wearable PM2.5 devices were investigated. One category was wearable PM 2.5 trackers. Through wearable PM2.5 trackers, users can learn how clean or dirty the air around them is, either from the wearable devices themselves or from the smart devices (e.g., mobile phones and smart watches) linked with them. After measuring the PM2.5 concentration, users can be informed of the effect of the current air quality on their health or can receive advice or guidelines based on the PM2.5 concentration at the time [16,30,31]. Another category investigated in this study was wearable PM2.5 purifiers, which are designed to purify personal micro environmental air so as to mitigate personal exposure to fine and ultrafine particles. Most wearable PM2.5 purifiers are small in size and can be worn on the neck, collar, or bag to remove fine and ultrafine particles from the breathing zone [1].

## 3. Methods

### *3.1. Research Questions*

In this study, there were three research questions.

Research Question 1: What types of wearable PM 2.5 devices are needed?

As introduced in the literature review part of this study, two categories of wearable devices were investigated. One category was PM2.5 trackers used to inform users of PM2.5-related information. The other category was a wearable PM2.5 device with air purification functions. There are three types of wearable PM2.5 trackers depending on the space where PM2.5 information was tracked: outdoor trackers, indoor trackers, and breathing-zone trackers. There are two types of purifiers depending on where the air is purified, including indoor purifiers and breathing-zone purifiers.

For wearable PM2.5 devices, first, it was examined whether people express the need for PM2.5 trackers or purifiers. Based on that, for both wearable PM2.5 trackers and purifiers, we examined which type would be more needed by potential users. In the survey conducted in this study, respondents' needs for wearable devices would be reflected by their self-reported scores.

Research Question 2: Will factors, such as education, income level, and age, influence people's needs for wearable PM2.5 devices?

Research shows that age, education, and income level significantly affect the acceptance of innovative technologies. Noh et al. investigated the influence of demographic factors on personal innovativeness toward technology acceptance and found that level of education had a significant influence on personal innovativeness [32]. In Laukkanen's research on consumer adoption of service innovation, it was found that both income and age significantly influenced consumer adoption behaviors [33]. It was expected that this study would find that respondents' education and income level positively influenced their needs for wearable PM2.5 devices. On the whole, it was expected that respondents' age would have a negative influence on their needs for wearable PM2.5 devices. The influences of these factors were analyzed by correlation analysis.

Research Question 3: Will respondents' attitudes toward PM2.5 affect their needs for wearable PM2.5 devices?

Many researchers have found that people's attitudes influence the perceived usefulness [34,35] and use intention [36,37] of technologies and innovations. In this study, respondents' attitudes towards PM2.5 were investigated in three respects: How severe an impact the respondents thought PM2.5 would have on their health, the extent to which the respondents cared about PM2.5 information, and the level of PM2.5 concentration they accepted in their daily lives (7-point Likert scales).

### *3.2. Variables and Questionnaire Construction*

As the dependent variable of this study, data were collected on subjects' needs for wearable PM2.5 devices. Independent variables were the types of wearable PM2.5 devices and subjects' age, education, income level, and attitude toward PM2.5.

The questionnaire used in the survey contained three parts. The first part elicited subjects' demographic information, including their age, gender, educational background, and income level. The second part of the survey investigated subjects' attitudes toward PM2.5 by investigating the perceived severity of PM2.5, the extent of care about PM2.5 information, and PM2.5 acceptance. Perceived severity of PM2.5 was measured by a question about how severe the impact the subjects thought the health hazards of the PM2.5 would have, which was used in Huang et al.'s study comparing individual exposure, perception, and acceptance levels of PM2.5 concentration with air pollution policy objectives [38]. It was rated on a 5-point Likert scale (1 = not severe at all, 2 = not really severe, 3 = average, 4 = quite severe, 5 = very severe). The extent of care about PM2.5 information was measured by a question asking the subjects the extent to which they thought they cared about PM2.5 information, also rated on a 5-point Likert scale (1: Check PM2.5 index every day, 2: Check PM2.5 index every week or more but less than every day; 3: Only pay attention to PM2.5 index in the severe haze seasons such as winter, 4: Check PM2.5 index only when there are notifications from TV news or the government, 5: Almost do not care). The level of PM2.5 concentration ($\mu g/m^2$) the subjects could accept in their daily lives was measured using a

7-point Likert scale (1: 0–12 μg/m$^2$, 2: 13–35 μg/m$^2$, 3: 36–55 μg/m$^2$, 4: 56–150 μg/m$^2$, 5: 151–250 μg/m$^2$, 6: 251–500 μg/m$^2$, 7: >500 μg/m$^2$), together with a color bar indicating the corresponding PM2.5 concentration.

The third part of the survey investigated the subjects' needs for different types of wearable PM2.5 devices. The descriptions of each type used in the survey are listed in Table 2. Subjects were asked if they needed the wearable devices listed in the questionnaire in order to reduce the harm caused by PM2.5. A 7-point Likert scale was used to measure subjects' needs (1: Not needed at all, 2: Not needed, 3: Not much needed, 4: May or may not be needed, 5: Need a little, 6: Need, 7: Very necessary).

**Table 2.** Wearable PM2.5 devices investigated in the survey.

| Wearable Devices | Type | Description of the Wearable Device |
|---|---|---|
| Wearable PM2.5 Trackers | Outdoor | Wearable devices that allow me to know the outdoor PM2.5 concentration level where I am in real time |
| | Indoor | Wearable devices that allow me to know the indoor PM2.5 concentration level where I am in real time (such as the kitchen where I am cooking, the restaurant where I am eating, the air quality in the car I am driving, etc.) |
| | Breathing zone | Wearable devices that allow me to know the PM2.5 concentration level of the air entering my respiratory tract in real time (such as a detection device built into a mask). |
| Wearable PM2.5 Purifiers | Indoor | Wearable devices that can partially purify the air in my indoor space (for example, devices placed on clothes or bags, or other portable air purification devices). |
| | Breathing zone | Wearable devices that can partially purify the air in the breathing zone (for example, PM2.5 purification devices that can be placed on glasses and masks). |

### *3.3. Subjects and Data Collection*

An online survey was conducted. Subjects were recruited from the Beijing metropolitan area of China. As the capital of the world's most populous country, Beijing's air quality has drawn global attention and is seen as a reflection of the national environmental condition [39]. A total of 894 subjects participated in the survey, including 396 men (44.3%) and 498 women (55.7%). Their average age was 30.74 years, and the SD was 8.78 years. The minimum age was 18 years, and the maximum age was 75 years. A total of 97 subjects (10.9%) were current graduate students or above, 442 subjects (49.4%) had bachelor's degrees, 171 subjects (19.1%) were current undergraduate students, 104 subjects (11.6%) had college degrees, 20 subjects (2.2%) were current college students, 53 subjects (5.9%) had high school or secondary school education, and 7 subjects (0.8%) had middle school or below education. There were 484 subjects (54.1%) living in Beijing and 410 subjects (45.9%) living in metropolitan areas besides Beijing.

There are nine income levels. There were 120 subjects whose family monthly income was less than CNY 5000 (13.4%), 220 subjects whose family monthly income was more than CNY 5000 and less than CNY 10,000 (24.6%), 173 subjects earned more than CNY 10,000 and less than CNY 15,000 (19.4%); 151 subjects earned more than CNY 15,000 and less than CNY 20,000 per month (16.9%), 124 subjects earned more than CNY 20,000 and less than CNY 30,000 per month (13.9%), 52 subjects earned more than CNY 30,000 and less than CNY 40,000 per month (5.8%), 24 subjects earned more than CNY 40,000 and less than CNY 50,000 per month (2.7%), 19 subjects earned more than CNY 50,000 and less than CNY 100,000 per month (2.1%); 11 subjects earned more than CNY 100,000 per month (1.2%).

An online questionnaire was used for the survey. The largest survey platform and agency in China, Wenjuanxing (https://www.wjx.cn), was used to distribute the questionnaire and collect samples. The survey was carried out in May, 2020 and took about one month. It took no more than 10 min to complete the entire questionnaire. Each respondent received a certain amount of recompense provided by Wenjuanxing.

## 4. Results and Discussion

The internal consistencies of the questionnaire are shown in Table 3. The overall internal consistency of the questionnaire was 0.840, indicating good internal consistency.

**Table 3.** Internal consistency of each part of the questionnaire.

| Survey Parts | No. of Items | Cronbach's Alpha |
|---|---|---|
| Wearable PM2.5 Trackers | 3 | 0.803 |
| Wearable PM2.5 Purifiers | 2 | 0.763 |

There were three research questions in this study. Data were analyzed to find answers for each research question, as discussed in the following three subsections.

### *4.1. Needs for Wearable PM2.5 Devices*

It can be seen from the results of the descriptive data analysis that subjects need both wearable PM2.5 trackers (Mean = 4.99, SD = 1.33) and wearable PM2.5 purifiers (Mean = 5.24, SD = 1.32), as scored on a 7-point Likert scale. When comparing these two categories as a whole, subjects' needs for both types of wearable PM2.5 purifiers were higher than their needs for all three types of wearable PM2.5 trackers. Respondents' average needs for wearable indoor PM2.5 purifiers and for wearable breathing-zone PM2.5 purifiers were 5.23 (SD = 1.29) and 5.26 (SD = 1.36), respectively, while their average need for wearable outdoor PM 2.5 trackers was 5.00 (SD = 1.22), for wearable indoor PM2.5 trackers was 4.80 (SD = 1.39), and for wearable breathing-zone PM2.5 trackers was 5.16 (SD = 1.36).

When comparing different types of PM2.5 trackers, as shown in Table 4, ANOVA test results showed that there was a significant difference (F = 16.140, $p < 0.001$ *) among respondents' needs for different types of wearable PM2.5 trackers. Post hoc analysis (least significant difference, LSD) was used to compare the needs for each pair of wearable trackers. The results showed that the respondents' need to use wearable outdoor PM2.5 trackers (mean = 5.00, SD = 1.22) was significantly higher ($p = 0.001$ *) than their need to use wearable indoor PM2.5 trackers (mean = 4.80, SD = 1.39). In addition, the respondents' need to use wearable breathing-zone PM2.5 trackers (mean = 5.16, SD = 1.36) was significantly higher ($p = 0.013$ *) than the need to use wearable indoor PM2.5 trackers (mean = 4.80, SD = 1.39). Comparison of the three types of wearable PM2.5 trackers found the respondents' need for breathing-zone PM2.5 trackers to be the highest, followed by outdoor PM2.5 trackers and indoor PM2.5 trackers. Comparison of the two types of wearable PM2.5 purifiers showed no significant difference (F = 0.232, $p = 0.630$) between them. Respondents' self-rating scores showed that they needed both types of PM2.5 purifiers.

**Table 4.** Comparison of different types of wearable devices.

<table>
<tr><th>Category</th><th>Types</th><th>Min</th><th>Max</th><th>Mean</th><th>SD</th><th>F</th><th>p</th></tr>
<tr><td rowspan="3">Wearable PM2.5 Trackers</td><td>Outdoor</td><td>1</td><td>7</td><td>5.00</td><td>1.22</td><td rowspan="3">16.140</td><td rowspan="3"><0.001 *</td></tr>
<tr><td>Indoor</td><td>1</td><td>7</td><td>4.80</td><td>1.39</td></tr>
<tr><td>Breathing-zone</td><td>1</td><td>7</td><td>5.16</td><td>1.36</td></tr>
<tr><td rowspan="2">Wearable PM2.5 Purifiers</td><td>Indoor</td><td>1</td><td>7</td><td>5.23</td><td>1.29</td><td rowspan="2">0.232</td><td rowspan="2">0.630</td></tr>
<tr><td>Breathing-zone</td><td>1</td><td>7</td><td>5.26</td><td>1.36</td></tr>
</table>

* $p < 0.05$.

It can be seen from the above results that most people care about the air quality they actually breathe, which is in line with previous research findings on public concerns about micro environmental air quality [25,26]. The survey results of this study showed that people need wearable breathing-zone PM2.5 trackers most among different types of wearable devices. In the same way, they need wearable breathing-zone PM2.5 purifiers. The respondents' needs for outdoor PM2.5 trackers were higher than for general indoor PM2.5 trackers, perhaps because the outdoor air quality is less controlled and could determine people's behavioral choices such as whether to go out.

### *4.2. Influence of Education, Income Level, and Age on Needs for Wearable PM2.5 Devices*

Correlation analysis was conducted between respondents' age, education, and income level and their needs for wearable PM2.5 devices. First, regarding the influence of education level, the results showed that there were significantly positive correlations between respondents' education level and their needs for both categories of wearable PM2.5 devices: The Pearson correlation was r = 0.171 ($p < 0.001$ *) between educational level and need for wearable PM2.5 trackers and r = 0.185 ($p < 0.001$ *) between educational level and need for wearable PM2.5 purifiers. This means that the higher the education level, the higher the need for wearable PM2.5 devices, including both wearable PM2.5 trackers and wearable PM2.5 purifiers.

Similarly, there were also significantly positive correlations between respondents' income level and needs for both categories of wearable PM2.5 devices. For wearable PM2.5 trackers, the Pearson Correlation was r = 0.189 ($p < 0.001$ *) with income level, while for wearable PM2.5 purifiers, the Pearson Correlation was r = 0.145 ($p < 0.001$ *) with income level. This means that the higher the income level, the higher the needs for wearable PM2.5 devices, including both wearable PM2.5 trackers and wearable PM2.5 purifiers.

Regarding the influence of age on needs for wearable PM2.5 devices, there was a significant negative correlation between respondents' age and need for wearable PM2.5 trackers (Pearson Correlation r = $-0.096$, $p = 0.004$ *); thus, the younger the participant, the higher the needs for wearable PM2.5 trackers. However, there was no significant correlation between respondents' age and need for a wearable PM2.5 purifier (Pearson correlation r = 0.039, $p = 0.247$). As discussed in Section 4.1, respondents' needs for wearable PM2.5 purifiers in this study are high regardless of type or age.

The results of this study are basically consistent with those of previous research, which found that education and income levels had a positive influence on people's innovation adoption [27,30,37], meaning the higher people's education and income, the higher their acceptance of innovations. Overall, age has a negative influence on people's innovation adoption [32,40,41].

### *4.3. Effects of Ones' Attitude toward Needs for Wearable PM2.5 Devices*

The last research question of this study was to investigate whether attitude toward PM2.5 affects the need for wearable PM2.5 devices. The effects were tested by correlation analysis conducted between the needs for wearable PM2.5 devices and three variables related to subjects' attitudes toward PM2.5: the severities of the health hazards that the impact subjects thought the PM2.5 would cause, the extent to which subjects care about PM2.5 information, and the maximum PM2.5 concentration they could accept as not affecting their daily lives without protective measures. Before running the correlation analysis, descriptive statistics were calculated on subjects' self-rating scores on questions related to their attitudes towards PM2.5, as shown in Table 5.

**Table 5.** Descriptive statistics of subjects' attitude towards PM2.5.

| Questions | Min | Max | Mean | SD |
|---|---|---|---|---|
| How severe of an impact do you think PM2.5 will cause your health hazards? | 1 | 5 | 3.43 | 1.02 |
| To what extent do you think you care about PM2.5 information | 1 | 5 | 2.30 | 1.02 |
| The level of PM2.5 concentration you can accept in daily lives | 1 | 6 | 2.66 | 1.01 |

First, correlation analysis was conducted between the severities of the health hazards that the impact subjects thought PM2.5 would cause and their needs for wearable PM2.5 devices, finding significant positive correlations for both categories of wearable PM2.5 devices. For wearable PM2.5 trackers, the Pearson correlation was r = 0.344 ($p < 0.001$ *), and for wearable PM2.5 purifiers, the Pearson correlation was r = 0.257 ($p < 0.001$ *); thus, the more severe the health hazards, the greater the needs for both trackers and purifiers.

Similarly, there were significantly positive correlations between the extent to which the subjects cared about PM2.5 information and their needs for both types of wearable PM2.5 devices. For wearable PM2.5 trackers, the Pearson correlation was r = 0.390 ($p < 0.001$ *), and for wearable PM2.5 purifiers, the Pearson correlation was r = 0.255 ($p < 0.001$ *). This means that the more the subjects care about PM2.5 information, the greater their needs for both trackers and purifiers.

Finally, there were significant negative correlations between the maximum concentration of PM2.5 that subjects thought would not affect their daily lives without protective measures and their needs for both kinds of wearable PM2.5 devices. For wearable PM2.5 trackers, the Pearson correlation was r = −0.126 ($p < 0.001$ *), and for wearable PM2.5 purifiers, the Pearson correlation was r = −0.117 ($p < 0.001$ *). This means that the lower the concentration of PM2.5 the subjects would accept in their daily lives, the higher their needs for both trackers and purifiers. In other words, the higher the subjects' requirements for air quality, the more they need wearable PM2.5 products.

In summary, this study used three variables to measure subjects' attitudes towards PM2.5, including their perceived severity of PM2.5, the extent of care, and their PM2.5 acceptance. All three variables significantly influenced needs for both wearable PM2.5 trackers and wearable PM2.5 purifiers. Among these variables, subjects' perceived severity of PM2.5 and extent of care had positive significant influences, meaning that the more severe the perceived health impact of PM2.5 or the more they cared about PM2.5 information, the higher their needs for wearable PM2.5 devices. On the contrary, their PM2.5 acceptance had a negative significant influence, meaning that the lower the PM2.5 concentration level they could accept in their daily lives, the higher their need for wearable PM2.5 devices.

## 5. Conclusions

This study investigated the public's needs for wearable PM2.5 devices and the factors affecting these needs. There were three research questions, including what types of wearable PM2.5 devices were needed, whether education, income level, and age influenced the need for wearable PM2.5 devices, and whether attitudes towards PM2.5 affect the need for wearable PM2.5 devices. To find answers to these questions, an online survey was conducted in the Beijing metropolitan area of China. A total of 894 subjects participated in the survey.

For the first research question, there were two categories of wearable PM2.5 devices: wearable PM2.5 trackers and purifiers. Among wearable PM2.5 trackers, three types were investigated and compared: outdoor PM2.5 trackers, indoor PM2.5 trackers, and breathing-zone PM2.5 trackers. Among wearable PM2.5 purifiers, two types were investigated and compared: indoor PM2.5 purifiers and breathing-zone PM2.5 purifiers. Comparing the two categories as a whole showed the public needs for wearable PM2.5 purifiers to be higher than for wearable PM2.5 trackers. There were also significant differences among the three types of wearable PM2.5 trackers, such that the need for wearable breathing-zone PM2.5 trackers was significantly higher than for other types of trackers. These results show that people care about the quality of the air they actually breathe.

For the second research question, this study investigated the influence of peoples' education, income level, and age on their needs for wearable PM2.5 devices. The results showed that there were significantly positive correlations between subjects' education level and their needs for both categories of wearable PM2.5 devices, such that the higher the education level, the higher the need for both trackers and purifiers. There were also significant positive correlations between subjects' income level and needs for both trackers and purifiers. Conversely, there was a significantly negative correlation between subjects' age and needs for wearable PM2.5 trackers; that is, the younger the subject, the higher the need for trackers. There was no significant correlation between subjects' age and need for a wearable PM2.5 purifier, meaning that subjects need a purifier regardless of age.

The last research question concerned the effects of subjects' attitudes towards PM2.5 on their needs for wearable PM2.5 devices. There were significant positive correlations between the severities of the health hazards that the subjects thought PM2.5 would cause and their needs for both categories of wearable PM2.5 devices: The more severe the subjects thought the health hazards of PM2.5 would be, the higher their needs for both wearable PM2.5 trackers and wearable PM2.5 purifiers. Similarly, there were significantly positive correlations between the extent to which subjects cared about PM2.5 information and their needs for both trackers and purifiers. Conversely, there were significant negative correlations between the maximum concentration of PM2.5 the subjects would accept without affecting their daily lives with protective measures and their needs for both types of wearable PM2.5 devices. In other words, the higher the subjects' requirements for air quality, the greater their need for wearable PM2.5 products.

With the popularization of wearable technology in recent years, it is believed that wearable technology can contribute feasible solutions for preventing health hazards caused by PM2.5. It is expected that the results of this study can serve as a valuable reference for related academic and industry research.

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