Quality Improvement Study

Medicine®

OPEN

A survey of $PM_{2.5}$ preventive behavioral intention and related factors among community elderly in Northern Taiwan

Yu-Ling Weng, Doctoral Student, Registered Nurses (RN)[a,b], Chin-Chia Liang, PhD[c], Chie-Chien Tseng, PhD[a,*], Shih-Yi Lee, PhD[b,d], Gwo-Liang Yeh, PhD[a]

Abstract

Population aging and air pollution are global concerns. The purpose of this study is to explore the relationship among particulate matter with a diameter of 2.5 μm or less ($PM_{2.5}$) knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention in the elderly.

A cross-sectional survey design was applied in this study, including usage intention and snowball sampling. A total of 617 elderly people aged over 65 participated, and the collected data were quantitatively analyzed.

The results showed that the mean score of $PM_{2.5}$ knowledge of the elderly was 10.34 (79.53%) with the standard deviation (SD) of 3.42, the mean score of $PM_{2.5}$ preventive attitude was 4.58 (91.60%) with SD of 0.49, and the mean score of $PM_{2.5}$ preventive behavioral intention was 4.72 (94.40%) with SD of 0.40. Elderly people's characteristics regarding $PM_{2.5}$ knowledge and $PM_{2.5}$ preventive attitude explained 22% (adjusted $R^2 = 0.22$, $F = 30.44$, $P < .001$) of the variance in $PM_{2.5}$ preventive behavioral intention.

It is concluded that we found no difference in $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, or $PM_{2.5}$ preventive behavioral intention among the elderly with or without chronic diseases. In our opinion, health education regarding the threat of $PM_{2.5}$ to the health of the elderly should be strengthened, to enhance their knowledge, preventive attitude, and preventive behavioral intention of $PM_{2.5}$.

Abbreviations: ANOVA = analysis of variance, H1N1 = Influenza A virus subtype, $PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation.

Keywords: knowledge, particulate matter, preventive attitude, preventive behavioral intention

1. Introduction

Particulate matter with a diameter of 2.5μm or less ($PM_{2.5}$) is an important compound substance causing air pollution. $PM_{2.5}$ is mainly derived from nature and human behavior, and exposure of individuals to $PM_{2.5}$ environments will cause health damage.[1]

The World Population Prospects (2019) points out that the world is an aged society, and the health protection of the elderly is an important issue for countries all over the world.[2] $PM_{2.5}$ can easily cause cardiovascular diseases, lung diseases, anxiety, and other diseases in the elderly.[3–6] Exposure of patients with cardiovascular diseases to $PM_{2.5}$ environments may increase the risk of readmission to hospital and death.[7] The mortality from heart and lung diseases is higher in the elderly than in younger people.[8,9] The exposure of the elderly to the environment of $PM_{2.5}$ will reduce the telomere-mitochondrial axis length and mitochondrial deoxyribonucleic acid content and affect the health of the elderly.[10] Recent research in Taiwan found that there is a significant correlation between elderly exposure to $PM_{2.5}$ environment and frailty.[11] Therefore, the elderly are vulnerable to $PM_{2.5}$.[12] Taiwan is now an aged society, and the elderly population is mainly concentrated in the northern region.[13] The average annual concentration of $PM_{2.5}$ in northern Taiwan in 2019 was 13.8 μg/m^3,[14] which is higher than the World Health Organization standard of 10 μg/m^3.[15] Thus, it is evident that elderly living in a higher $PM_{2.5}$ concentration region for a long time are more likely to have health damage than general adults. Therefore, investigating the prevention and control factors related to $PM_{2.5}$ for elderly people in northern Taiwan is a primary task for health administration in Taiwan to maintain the health of elderly people.

Knowledge, attitude, and behavioral intention are important variables in psychological research on human health-related behaviors. Studies of the elderly have found that improving the knowledge of healthy diet and food safety in the elderly helps promote the behavior of healthy diet.[16] The higher the

Editor: Daryle Wane.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the present study are available from the corresponding author on reasonable request. All data generated or analyzed during this study are included in this published article [and its supplementary information files].

[a] Department of Health Promotion and Health Education, National Taiwan Normal University, Taipei, Taiwan, [b] MacKay Junior College of Medicine, Nursing and Management, Taipei, Taiwan, [c] Travel Quality Assurance Association, Taipei, Taiwan, [d] Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, Taitung MacKay Memorial Hospital, Taiwan.

[*] Correspondence: Chie-Chien Tseng, National Taiwan Normal University, Taipei, Taiwan (e-mail: chiechien@ntnu.edu.tw).

How to cite this article: Weng YL, Liang CC, Tseng CC, Lee SY, Yeh GL. A survey of $PM_{2.5}$ preventive behavioral intention and related factors among community elderly in Northern Taiwan. Medicine 2021;100:29(e26675).

Received: 16 October 2020 / Received in final form: 11 June 2021 / Accepted: 3 July 2021

http://dx.doi.org/10.1097/MD.0000000000026675

knowledge and attitude of the elderly regarding tetanus, pneumococcal, and influenza vaccination, the higher the behavior of vaccination against tetanus, pneumococcal, and influenza vaccine.[17] However, when predicting whether some health-related behaviors will be performed by human beings in the future, behavioral intention is a factor that directly predicts behavior.[18,19] Most studies took behavioral intention as a dependent variable; for example, in a study in Taiwan, elderly people were found to have a higher intention to get an influenza vaccine when their attitude toward influenza (H1N1) pandemic was of concern to them.[20] In Australia, the elderly with higher knowledge and attitude to use electronic health insoles have a stronger intention to use them.[21] It can be seen that the knowledge and attitude of the elderly affect their behavioral intention.

In a study of air pollution prevention and control, it was found that the knowledge and attitude of residents regarding air pollution prevention and control would affect their behavioral intention of air pollution prevention and control.[22] When people have more knowledge of air pollution, their attitudes and intentions to reduce car use are higher.[23] In addition, the higher the attitude of students to use masks in an air polluted environment, the higher their behavioral intention to use masks.[24] When a residential environment suffers from air pollution, residents' attitude is to stay away from the polluted environment, meaning they intend to move away from the polluted environment, to avoid harm to their health, as caused by air pollution.[25] However, such studies found that the elderly population lacked knowledge of air pollution, as compared with other age groups,[26,27] thus, some elderly people still choose to live where the air is polluted.[28] It can be seen that different age groups have different knowledge, attitudes, and behavioral intentions toward air pollution.

To sum up, the increasing number of elderly people worldwide and the problem of air pollution are important public health issues at present. While the current research objects of air pollution are mainly young residents of the community,[29] teenagers,[30] students,[31] children,[32] and pregnant women,[33] there are few studies on the factors related to air pollution prevention and control by the elderly. Therefore, this study intends to investigate $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention in the elderly, to serve as a reference for future health maintenance policies and measures for the elderly.

1.1. Purpose

The purposes of this study are to explore (1) the relationship among $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention in the elderly and (2) the relevance of the demographic characteristics regarding $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention.

2. Methods

2.1. Design

This study applied the cross-sectional quantitative research method.

2.2. Research conceptual model

Figure 1 shows the conceptual model of this study. The relationship between elderly people's $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitudes, and their $PM_{2.5}$ preventive behavioral intention will be investigated. The relevance of demographic characteristics of the elderly (ie, gender, age, education level, and chronic disease) to $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention will also be investigated.

2.3. Participants

Intention and snowball sampling were applied in this study. The samples for intention sampling were from 2 elderly learning centers in Taipei City and 2 community elderly activity centers in New Taipei City. The elderly who participated in the courses, as organized by the learning centers and the community elderly activity centers, were restricted by the organizers to those without

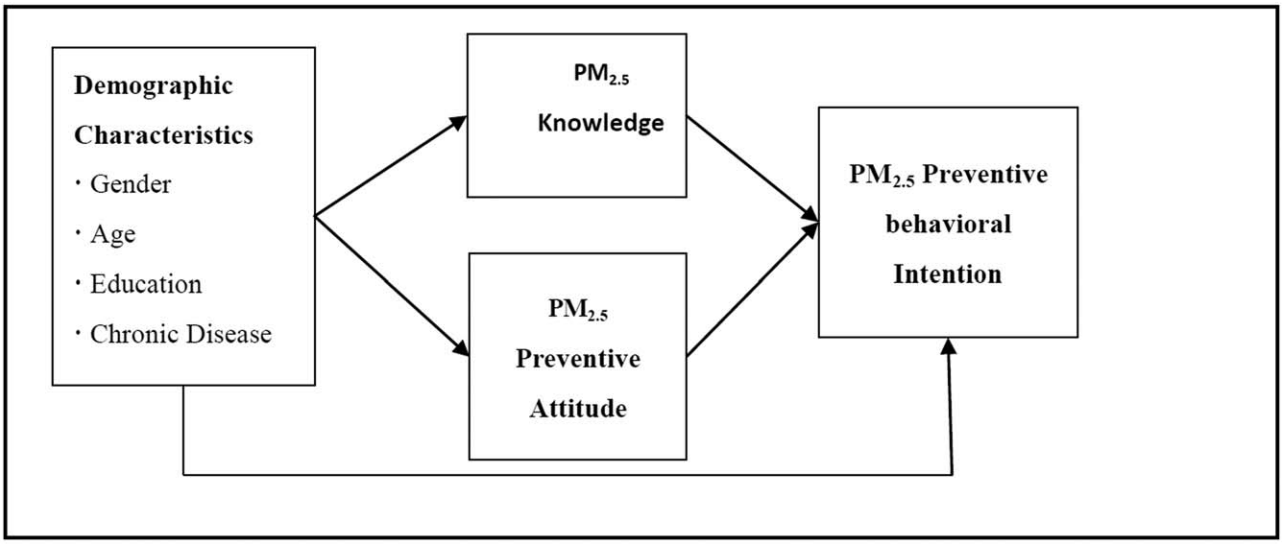

Figure 1. Conceptual model of this study.

senile dementia or abnormal mental conditions. Snowball sampling was also introduced to other elderly people in the community through the elderly of the elderly learning center and the community center so that they could participate. In this study, the minimum sample number was 116, which was calculated using G Power 3.1, *F* test, multiple regression, α.05, and power .95 of Heinrich-Heine-University. In this study, a total of 638 samples of people over 65 years old were collected from Taipei City and New Taipei City (205 from Taipei City and 433 from New Taipei City).

2.4. Ethical considerations

This study passed the research ethics audit of the National Taiwan Normal University (REC ID: 201905HS031) and can be accepted for trial. Before data collection, voluntary participants were sought out and informed of the purpose of this study. With the oral and written consent of the voluntary participants, researchers informed the participants that they would not suffer any penalty or loss of rights if they refuse to participate or withdraw from the study halfway.

2.5. Instruments

The research tool used in this study was modified from a self-administered structured questionnaire developed in the previous study [34] which was supported by the Ministry of Science and Technology of Taiwan (105-2511-S-003-025). The questionnaire in the previous study was designed for middle school students included 44 questions on $PM_{2.5}$ knowledge (23 items), $PM_{2.5}$ preventive attitude (12 items), and $PM_{2.5}$ preventive behavioral intention (9 items). A focus group was formed with four 65-year-old people (2 held elementary school education and the other 2 held junior high school education) to modify the questionnaire for the elderly item by item. The modified questionnaire included $PM_{2.5}$ knowledge (13 items), $PM_{2.5}$ preventive attitude (6 items), $PM_{2.5}$ preventive behavioral intention (5 items), and participants' demographic information (4 items). Five experts (2 senior professors in the field of environmental education, 2 professors in the field of public health, and 1 senior clinical thoracic physician) reviewed the content validity (content validity >0.8). Forty elderly people over 65 years old were selected from a community for the pre-test of the modified questionnaire. The content reliabilities of $PM_{2.5}$ preventive attitude and $PM_{2.5}$ preventive behavioral intention are, Cronbach Alpha 0.79 and Cronbach Alpha 0.84, respectively, The Kuder–Richardson reliability-20 for each of the $PM_{2.5}$ knowledge items was higher than 0.2, with the exception of Question 5. Question 5 refers to the World Health Organization that $PM_{2.5}$ exposure raises carcinogen risk. Experts believed that this item was related to health knowledge, and was necessary to include in the questionnaire. A 3-point scale was used for $PM_{2.5}$ knowledge. The scoring scale was 0 points for wrong and not sure, and 1 point for correct. The higher the score, the better the knowledge. A 5-point Likert measuring scale was used for $PM_{2.5}$ preventive attitude and $PM_{2.5}$ preventive behavioral intention, ranging from totally disagree (1 point) to completely agree (5 points). The higher the score, the better the $PM_{2.5}$ preventive attitude and $PM_{2.5}$ preventive behavioral intention. Demographic variables had 4 items including gender, age, education level, and chronic disease. There was a total of 28 questions in the modified questionnaire.

2.6. Data collection

The researchers explained to the participants that the main purpose of this study was to investigate the relationship among $PM_{2.5}$ knowledge, preventive attitude, and preventive behavioral intention in the elderly. Voluntary participants were required to complete the self-administered questionnaire for this study on their own and could not discuss the contents with each other. If there was any illiterate participant, the researchers would read out questions verbatim, and ask the participants to answer, but could not explain the original meanings of the questions. Upon completing the questionnaire, the participants were asked to check whether they have completed all the questions. When they hand it back to the researchers, the researchers would check the completion again; if incomplete, the participants were asked to answer the missed items. It took about 15 to 20 minutes to complete the questionnaire. This study collected 638 questionnaires from June 2019 to January 2020, of which 21 were incomplete and 617 (96.71%) were complete (204 from Taipei City and 413 from New Taipei City).

2.7. Data analysis

The IBM SPSS 22.0 statistical package was utilized to analyze all the data for this study, including frequencies, percentages, means, standard deviation (SD), Pearson correlation, regression, and one-way ANOVA.

3. Results

A total of 617 elderly people over 65 years old were enrolled in this study. The demographic background distribution results are, as follows: 421 females (68.23%) and 196 males (31.77%). The age group gap was 5 years: 305 people 65 to 69 years old (49.43%), 172 people 70 to 74 years old (27.88%), 81 people 75 to 79 years old (13.14%), 39 people 80 to 84 years old (6.32%), and 20 people ≥85 years old (3.24%). Education level is as follows: 3 people are illiterate (0.49%), 6 people are uneducated, but literate (0.97%), 88 people with elementary school education (14.26%), 114 with junior high school (18.48%), 170 with high school (vocational school) education (27.55%), and 236 with college, undergraduate, and higher education (38.25%). Chronic disease: Yes: 352 (57.05%) and No: 265 (42.95%).

3.1. Pearson correlation analysis on $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention

The results of Pearson correlation analysis indicate that $PM_{2.5}$ knowledge is positively correlated to $PM_{2.5}$ preventive attitude, $r = .404$ ($P < .01$) and $PM_{2.5}$ preventive behavioral intention $r = .284$ ($P < .01$). Furthermore, $PM_{2.5}$ preventive attitude is positively correlated to $PM_{2.5}$ preventive attitude, $r = .459$ ($P < .01$) (Table 1).

3.2. Elderly people's mean scores for $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention

The participants had an adequate sense of $PM_{2.5}$ knowledge, with a mean score of 10.34/13 items (79.54%), SD 3.42; $PM_{2.5}$ preventive attitude, with a mean score of 4.58/(5-point scale) (91.60%),

Table 1

Pearson correlation analysis on $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention.

Elderly (n = 617)	$PM_{2.5}$ knowledge	$PM_{2.5}$ preventive attitude	$PM_{2.5}$ preventive behavioral intention
$PM_{2.5}$ knowledge	1	.404**	.284**
$PM_{2.5}$ preventive attitude		1	.459**
$PM_{2.5}$ preventive behavioral intention			1

PM2.5 = particulate matter with a diameter of 2.5 μm or less.
** $P < .01$.

Table 2

Elderly people's mean scores on $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention.

Elderly people (n = 617)	Mean	SD
$PM_{2.5}$ knowledge	10.34 (79.54%)	3.42
PM $_{2.5}$ preventive attitude	4.58 (91.60%)	.49
$PM_{2.5}$ preventive behavioral intention	4.72 (94.40%)	.40

$PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation.

SD.49; and $PM_{2.5}$ preventive behavioral intention, with a mean score of 4.72/(5-point scale) (94.40%), SD.40 (Table 2).

3.3. Elderly people's characteristics and $PM_{2.5}$ knowledge

The results of participants' answers on each $PM_{2.5}$ knowledge item are listed in Table 3. The mean value of each question in $PM_{2.5}$ knowledge ranges from .76 to .93. The ratio of participants that gave the correct answer, incorrect answer, and "not sure" of each question are also presented in a separate columns. One-way ANOVA testing shows that participants' $PM_{2.5}$ knowledge has a significant difference in age ($P < .05$). Similarly, participants' $PM_{2.5}$ knowledge has a significant difference in education level ($P < .001$) but participants' $PM_{2.5}$ knowledge has no significant difference in gender ($P > .05$) or chronic diseases ($P > .05$) (Table 4).

Table 3

$PM_{2.5}$ knowledge items distribution.

			Ratio (%)		
Item	Mean	SD	Yes	No	Not sure
1	.76	.43	69.7	1.5	28.8
2	.86	.35	81.0	2.6	16.4
3	.93	.25	88.7	.3	11.0
4	.83	.38	75.5	4.4	20.1
5	.84	.37	78.4	.8	20.7
6	.91	.28	88.8	1.6	9.6
7	.79	.41	74.6	4.9	20.6
8	.90	.30	86.1	1.1	12.8
9	.84	.36	80.2	3.1	16.7
10	.87	.34	82.2	3.2	14.6
11	.76	.43	67.6	1.1	31.3
12	.93	.26	90.1	2.1	7.8
13	.81	.40	71.3	2.6	26.1

$PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation.

Table 4

One-way ANOVA of elderly people's characteristics and $PM_{2.5}$ knowledge.

	$PM_{2.5}$ knowledge			
Elderly people's characteristics (n = 617)	n	Mean	SD	*F* value
Gender				.13
Male	196	10.32	3.39	
Female	421	10.40	3.48	
Age				3.19*
65–69 yrs old	305	10.87	2.80	
70–74 yrs old	172	10.18	3.58	
75–79 yrs old	81	9.63	3.81	
80–84 yrs old	39	9.38	3.57	
85 yrs old and above	20	8.45	4.52	
Education level				6.77***
Illiterate	3	4	2	
Literacy uneducated	6	9.17	3.54	
Elementary school	88	9.14	3.86	
Junior high school	114	9.37	3.99	
High school and vocational school	170	10.75	3.05	
College and undergraduate and higher	236	11.08	2.87	
Chronic disease				.01
No	265	10.57	3.26	
Nes	352	10.17	3.53	

ANOVA = analysis of variance, $PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation
* $P < .05$.
*** $P < .001$.

3.4. Elderly people's characteristics and $PM_{2.5}$ preventive attitude

The results of one-way ANOVA testing show that participants' $PM_{2.5}$ preventive attitude has a significant difference in age ($P < .05$). On the other hand, participants' $PM_{2.5}$ preventive attitude has no significant difference in gender, education level, or chronic diseases (Table 5).

Table 5

One-way ANOVA of elderly people's characteristics and $PM_{2.5}$ preventive attitude.

	$PM_{2.5}$ preventive attitude			
Elderly people's characteristics (n = 617)	n	Mean	SD	*F* value
Gender				.00
Male	196	4.54	.49	
Female	421	4.59	.49	
Age				2.47*
65–69 yrs old	305	4.58	.49	
70–74 yrs old	172	4.62	.45	
75–79 yrs old	81	4.53	.52	
80–84 yrs old	39	4.45	.48	
85 yrs old and above	20	4.54	.62	
Education level				1.60
Illiterate	3	4.39	1.06	
literacy Uneducated	6	4.19	.73	
Elementary school	88	4.44	.56	
Junior high school	114	4.49	.48	
High school and vocational school	170	4.58	.50	
College and undergraduate and higher	236	4.68	.41	
Chronic disease				1.48
No	265	4.58	.49	
Yes	352	4.57	.48	

ANOVA = analysis of variance, $PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation.
* $P < .05$.

Table 6

One-way ANOVA of elderly people's characteristics and $PM_{2.5}$ preventive behavioral intention.

	$PM_{2.5}$ preventive behavioral intention			
Elderly people's characteristics (n = 617)	n	Mean	SD	*F* value
Gender				6.03*
Male	196	4.69	.43	
Female	421	4.73	.38	
Age				2.89*
65–69 yrs old	305	4.72	.38	
70–74 yrs old	172	4.72	.35	
75–79 yrs old	81	4.71	.46	
80–84 yrs old	39	4.64	.55	
85 yrs old and above	20	4.76	.42	
Education level				5.23***
Illiterate	3	4.20	.72	
literacy Uneducated	6	4.10	.92	
Elementary school	88	4.68	.50	
Junior high school	114	4.62	.51	
High school and vocational school	170	4.74	.31	
College and undergraduate and higher	236	4.78	.28	
Chronic disease				3.56
No	265	4.71	.36	
Yes	352	4.72	.42	

ANOVA = analysis of variance, $PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less, SD = standard deviation.
* $P < .05$
*** $P < .001$.

3.5. Elderly people's characteristics and $PM_{2.5}$ preventive behavioral intention

The results of one-way ANOVA testing show that participants' $PM_{2.5}$ preventive behavioral intention has a significant difference in gender ($P < .05$), in age ($P < .05$), and an education level ($P < .001$). On the contrary, participants' $PM_{2.5}$ preventive behavioral intention has no significant difference in chronic disease (Table 6).

3.6. Elderly people's characteristics, $PM_{2.5}$ knowledge, and $PM_{2.5}$ preventive attitude to predict $PM_{2.5}$ preventive behavioral intention

Participants' characteristics, $PM_{2.5}$ knowledge, and $PM_{2.5}$ preventive attitude can explain 22% of the variances of our model (adjusted $R^2 = .22$, $F = 30.44$, $P < .001$) (Table 6). Table 6 shows the results of regression analysis with the variables of participants' characteristics and education level ($B = .03$, $t = 2.31$, $P < .05$), $PM_{2.5}$ knowledge ($B = .01$, $t = 2.74$, $P < .01$), and $PM_{2.5}$ preventive attitude ($B = .32$, $t = 10.14$, $P < .001$). The results reveal that $PM_{2.5}$ knowledge and $PM_{2.5}$ preventive attitude combined have the strongest impact on participants' $PM_{2.5}$ preventive behavioral intention (Table 7). Moreover, the education level of participants has the second-highest impact on $PM_{2.5}$ preventive behavioral intention (Table 7). Although gender and age showed confounding effects on $PM_{2.5}$ knowledge (Table 4), $PM_{2.5}$ prevention attitude (Table 5), and $PM_{2.5}$ prevention intention (Table 6). These 2 variables did not show significance on $PM_{2.5}$ prevention intention in Table 7 but were kept in the model as control variables and list them in Table 7.

4. Discussion

Recent studies on air pollution have found that $PM_{2.5}$ is an important substance causing air pollution, which may affect

Table 7

Regression analysis on elderly people's characteristics, $PM_{2.5}$ knowledge, and $PM_{2.5}$ prevention attitude to predict $PM_{2.5}$ prevention intention.

	Unstandardized coefficients		Standardized coefficients			
Variables	*B* estimates	SE	Beta distribution	*T* values	Adjusted R^2	*F* values
Constant	2.93	.14		20.33	.22	30.44***
Gender	−.03	.03	−.03	−.96		
Age	.01	.01	.04	.94		
Education level	.03	.01	.09	2.31*		
Chronic disease	.02	.03	.02	.63		
$PM_{2.5}$ knowledge	.01	.01	.11	2.74**		
$PM_{2.5}$ prevention attitude	.32	.03	.40	10.14***		

$PM_{2.5}$ = particulate matter with a diameter of 2.5 μm or less.
* $P < .05$.
** $P < .01$.
*** $P < .001$.

people's health and even cause diseases; therefore, relevant research began to explore the relevant factors of $PM_{2.5}$ prevention and control to maintain health. Our study results show that regarding the demographic characteristics of the elderly, $PM_{2.5}$ knowledge and $PM_{2.5}$ preventive attitude explained 22% of the variances of $PM_{2.5}$ preventive behavioral intention. Elderly people's $PM_{2.5}$ knowledge has a significant positive impact on their $PM_{2.5}$ preventive behavioral intention, and elderly people's $PM_{2.5}$ preventive attitude has a significant positive impact on their $PM_{2.5}$ preventive behavioral intention (Table 7). Literature has pointed out that people's knowledge of air pollution and air pollution preventive attitude would affect their behavioral intention to prevent and control air pollution.[28] Our results are consistent with previous studies. In addition, we found that the elderly's education level has a significant positive impact on their $PM_{2.5}$ preventive behavioral intention (Table 7). Those with higher education level are more willing to reduce the generation of $PM_{2.5}$ (intention question 1: I will take public transportation to reduce exhaust emissions and energy consumption). Literature has pointed out that people with higher education level are more willing to buy electric vehicles to reduce air pollution.[35] While our results are in line with those found in the literature. Our study found that those with higher education level are more likely to reduce the harm of $PM_{2.5}$ to health (intention question 3: When the air quality is poor, I will wear a mask to prevent inhaling dirty air). Although there is literature regarding the motivation of young people to use masks in air pollution,[22] education level has not been mentioned.

In this study, the mean score of the $PM_{2.5}$ knowledge of the elderly is 10.34/13 items, the mean score of the $PM_{2.5}$ preventive attitude of the elderly is 4.58/6 items, and the mean score of the $PM_{2.5}$ preventive behavioral intention of the elderly is 4.72/5 items (Table 2). It can be seen that the elderly have high $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention, which may be because the elderly will increase their understanding of $PM_{2.5}$ through the relevant knowledge broadcasts of TV news media, and government organizations have provided publicity manuals regarding $PM_{2.5}$ prevention and control, to increase the public methods of $PM_{2.5}$ prevention and control. Moreover, the Taipei-Keelung metropolitan area is the major economic and industrial area in Taiwan. Despite subway and bus systems already exist, the major transportation tools are automobiles and other locomotives. Over 3 million locomotives were used as daily transportation which accounts for over one-fifth of the total locomotives in this country.[36] The emission of $PM_{2.5}$ from locomotives in the northern region is 32.1 $\mu g/m^3$, which is the highest in national $PM_{2.5}$ emission among public transportation.[37] Therefore, the elderly living in northern Taiwan can feel the emissions of automobile and locomotive exhaust and the potential impact on their physical health. In consequence, they have the behavioral intention to prevent and control $PM_{2.5}$ to avoid harm to their health.

The $PM_{2.5}$ knowledge of the elderly will be affected by age and education. We found that $PM_{2.5}$ knowledge has a significant difference in age ($P < .05$). The older the elderly, the lower their $PM_{2.5}$ knowledge (Table 4). Our results are similar to other studies.[26] The elderly receive new information by watching TV, reading newspapers, and listening to the radio.[22] However, with their increasing age, their sensory systems gradually degenerate,[38] and they become unable to accept a large amount of new information, resulting in the loss of knowledge. $PM_{2.5}$ knowledge has a significant difference in education level ($P < .001$). The elderly with lower education level has lower $PM_{2.5}$ knowledge (Table 4). Our results are similar to those found in the literature.[27] In other words, the elderly with higher education level would worry about the impact of $PM_{2.5}$ on their health and actively collect online information or use multimedia to acquire more $PM_{2.5}$ knowledge.[39,40] Therefore, we believe that digital advocate methods should be used to improve the knowledge of $PM_{2.5}$ among the elderly.

Elderly people's $PM_{2.5}$ prevention attitude will be affected by age and lifestyle. $PM_{2.5}$ preventive attitude has a significant difference in age ($P < .05$); the older the elderly, the more they comply with the $PM_{2.5}$ environment. (Table 5). Our results are similar to those found in Kenyan literature, which showed that young people in Kenya would move away from the places where air pollution was harmful to their health, while the elderly would be forced to stay in the places where air pollution was harmful due to their poor living conditions, even though they knew that air pollution caused harm to their health.[41,42] So, the older the elderly, the less they are able to do preventions, although they care about the damage of $PM_{2.5}$ to their health. Regarding convenience in life (attitude 2: Increasing product manufacturing and transportation to make life items easy to buy) and their original lifestyle (attitude 5: Burning joss paper for ancestor worship), the elderly living in this area would still choose to face the air pollution with a negative attitude, even if they know about it. Therefore, the attitudes of the elderly in different economic and cultural areas regarding air pollution are different.

Elderly people's gender has a different effect on $PM_{2.5}$ preventive behavioral intention. In addition, $PM_{2.5}$ preventive behavioral intention has a significant difference in gender ($P < .05$). The $PM_{2.5}$ air pollution preventive behavioral intention of females was higher than that of males (Table 6). The long-term household work of females (intention question 2: Cooking and using detergent to produce indoor air pollution) causes increased $PM_{2.5}$ levels,[43] and their health effects were higher than those of the male respondents.[44] Therefore, the long-term exposure to the domestic work of females would enhance their indoor $PM_{2.5}$ preventive behavioral intention. Thus, housework women have higher $PM_{2.5}$ preventive behavioral intention.

The age and education of the elderly influence $PM_{2.5}$ preventive behavioral intention. $PM_{2.5}$ preventive behavioral intention has a significant difference in age ($P < .05$) (Table 6); the older the age group, the lower the $PM_{2.5}$ preventive behavioral intention. Relevant literature had pointed out that young people's willingness to buy electric vehicles was higher than that of the elderly because young people have a deeper understanding of the government's environmental policies and green consumption. Those are important factors to affect their behavior intention in their willingness to buy electric vehicles.[45] In our study, the convenience provided by metropolitan transportation is what the elderly are concerned about in northern Taiwan. Because the older age group the elderly has less mobility in their daily life, their intention to take metropolitan transportation is low compared with the elderly in the younger age group. Preventive behavioral intention has a significant difference in education level ($P < .001$) (Table 6). Highly educated people are more likely to buy electric cars than less educated people,[35] and such results are similar to our results. Compared to those with higher education level, the elderly with lower education level has insufficient understanding of $PM_{2.5}$ knowledge or do not know how to search relevant information, thus, they cannot have correct $PM_{2.5}$

preventive behavioral intention. Therefore, the higher the education level of the elderly, the stronger the $PM_{2.5}$ preventive behavioral intention.

Many studies have found that $PM_{2.5}$ may cause cardiovascular diseases, respiratory diseases, and depression,[3–6] while few pieces of literature mentioned elderly patients with chronic diseases and the correlation of $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, and $PM_{2.5}$ preventive behavioral intention to diseases. Our results show that there is no significant difference between the elderly with chronic diseases and those without chronic diseases in terms of $PM_{2.5}$ knowledge, $PM_{2.5}$ preventive attitude, or $PM_{2.5}$ preventive behavioral intention. The reason may be that the current health education for the elderly with chronic diseases focuses on the pathogenesis of diseases and the improvement of daily living habits, such as sleep, diet, exercise, and weight loss while ignoring the adverse impact of air pollution on the health of the elderly.

4.1. Limitations

The results of this study came from a cross-sectional questionnaire survey of the elderly in communities in Taipei City and New Taipei City, Taiwan. It may not be inferred to people of all ages or elderly people in other areas with different education level. Our research results are not as inferable as the results from longitudinal studies.

5. Conclusions

$PM_{2.5}$ knowledge and $PM_{2.5}$ preventive attitude can affect $PM_{2.5}$ preventive behavioral intention. When the elderly with different education level has a different understanding of $PM_{2.5}$ knowledge, their $PM_{2.5}$ preventive behavioral intention will also be different. In addition, the elderly with different education level has different $PM_{2.5}$ preventive attitude and $PM_{2.5}$ preventive behavioral intention. Therefore, the elderly with low education level should be given different education methods, such as pictures, videos, and animations, to convert words that are difficult to understand or abstract (eg, knowledge question 1: $PM_{2.5}$ is particles with a diameter of less than 2.5 microns) into simple picture language, and the elderly can actually understand $PM_{2.5}$ knowledge. The elderly with low education level have low $PM_{2.5}$ preventive attitude, and they can improve their health through living habits (eg, attitude question 1: I think more public transportation should be used to reduce $PM_{2.5}$, and attitude question 5: I think we should worship ancestors in an environmentally friendly way) and maintain the health of others (eg, attitude question 3: I think my environmental actions have a good impact on the health of Taiwanese), to improve $PM_{2.5}$ preventive attitude for those with low education level. The elderly with low education level has low $PM_{2.5}$ preventive behavioral intention, and they can change their life behaviors to improve their health (eg, intention question 3: When the air quality is poor, I will wear a mask to prevent inhaling dirty air, and intention question 4: I will open the window to keep air circulation when the indoor air quality is poor), to improve $PM_{2.5}$ preventive behavioral intention for those with low education level. In addition, the existing health education content for the elderly focuses on maintaining good living habits and alleviating their own chronic diseases, while little attention is paid to the impact of air pollution on the health of the elderly, which results in the elderly with chronic diseases ignoring the threat of air pollution to their health. Therefore, in the future, health education for the elderly should be promoted in terms of $PM_{2.5}$ knowledge, preventive attitude, and preventive behavioral intention, to improve the health of the elderly.

Author contributions

Conceptualization: Chie-Chien Tseng.
Data curation: Yu-Ling Weng, Chin-Chia Liang.
Formal analysis: Yu-Ling Weng, Chin-Chia Liang.
Funding acquisition: Yu-Ling Weng.
Investigation: Yu-Ling Weng, Chin-Chia Liang.
Methodology: Yu-Ling Weng, Gwo-Liang Yeh, Shih-Yi, Lee, Chie-Chien Tseng, Chin-Chia Liang.
Project administration: Yu-Ling Weng, Chie-Chien Tseng.
Resources: Yu-Ling Weng, Chin-Chia Liang.
Software: Yu-Ling Weng, Chin Chia Liang.
Supervision: Gwo-Liang Yeh, Chie-Chien Tseng.
Validation: Gwo-Liang Yeh, Chie-Chien Tseng, Shih-Yi, Lee.
Visualization: Gwo-Liang Yeh, Chie-Chien Tseng.
Writing – original draft: Yu-Ling Weng.
Writing – review & editing: Chie-Chien Tseng, Shih-Yi, Lee, Chin Chia Liang.

References

[1] Kampa M, Castanas E. Human health effects of air pollution. Environmental Pollut 2008;151:362–7. https://doi.org/10.1016/j.envpol.2007.06.012.
[2] United Nation DoEaSA, Population Division. World Population Prospects 2019: Highlights. 2019; https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf. Accessed September 04, 2020.
[3] Chien T-Y, Ting H-W, Chan C-L, et al. Does the short-term effect of air pollution influence the incidence of spontaneous intracerebral hemorrhage in different patient groups? Big data analysis in Taiwan. Int J Environ Res Public Health 2017;14:1547https://doi.org/10.3390/ijerph14121547.
[4] Wang C, Tu Y, Yu Z, Lu R. $PM_{2.5}$ and cardiovascular diseases in the elderly: an overview. Int J Environ Res Public Health 2015;12:8187–97. https://doi.org/10.3390/ijerph120708187.
[5] Luo L, Jiang J, Zhang G, et al. Stroke mortality attributable to ambient particulate matter pollution from 1990 to 2015 in China: an age-period-cohort and spatial autocorrelation analysis. Int J Environ Res Public Health 2017;14:772https://doi.org/10.3390/ijerph14070772.
[6] Pun VC, Manjourides J, Suh H. Association of ambient air pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environ Health Perspect 2017;125:342–8. https://doi.org/10.1289/EHP494.
[7] Leiser CL, Smith KR, VanDerslice JA, Glotzbach JP, Farrell TW, Hanson HA. Evaluation of the sex-and-age-specific effects of $PM_{2.5}$ on hospital readmission in the presence of the competing risk of mortality in the medicare population of Utah 1999–2009. J Clin Med 2019;8:2114https://doi.org/10.3390/jcm8122114.
[8] Nie D, Chen M, Wu Y, et al. Characterization of fine particulate matter and associated health burden in Nanjing. Int J Environ Res Public Health 2018;15:602https://doi.org/10.3390/ijerph15040602.
[9] Cakmak S, Dales RE, Rubio MA, Vidal CB. The risk of dying on days of higher air pollution among the socially disadvantaged elderly. Environ Res 2011;111:388–93. https://doi.org/10.1016/j.envres.2011.01.003.
[10] Pieters N, Janssen BG, Dewitte H, et al. Biomolecular markers within the core axis of aging and particulate air pollution exposure in the elderly: a cross-sectional study. Environ Health Perspect 2016;124:943–50. https://doi.org/10.1289/ehp.1509728.
[11] Lee WJ, Liu CY, Peng LN, Lin CH, Lin HP, Chen LK. $PM_{2.5}$ air pollution contributes to the burden of frailty. Sci Rep 2020;10:1–6. https://doi.org/10.1038/s41598-020-71408-w.
[12] Health Effects Institute. State of Global Air 2019 Special Report. 2019; https://www.stateofglobalair.org/sites/default/files/soga_2019_report.pdf. Accessed September 04, 2020.

[13] Interior Mot. Report on the 40th Week of Domestic Statistics in 2019. 2019; https://www.moi.gov.tw/chi/chi_news/news_detail.aspx?sn=16871&type_code=01&search_k=%e8%80%81%e5%b9%b4&search_d1=2019-01-01&search_d2=2020-08-01&pages=0&src=news. Accessed September 04, 2020.
[14] Environmental Protection Administration EY. 2019 Annual Report of Air Quality Monitoring Report of the Republic of China. 2019; https://www.epa.gov.tw/DisplayFile.aspx?FileID=6DF52F28D8A44EC3. Accessed September 04, 2020.
[15] World Health Organization. World health statistics 2016: monitoring health for the SDGs, sustainable development goals. 2016; http://apps.who.int/iris/bitstream/10665/206498/1/9789241565264_eng.pdf?ua=1. Accessed September 04, 2020.
[16] Laurenti P, De Meo C, Sacchini D, et al. Factors affecting safe and healthy diet in older adults in Italy: results of a preliminary study performed in a community-dwelling sample. Public Health Nutr 2020;23:432–8. https://doi.org/10.1017/S1368980019002301.
[17] Klett-Tammen CJ, Krause G, Seefeld L, Ott JJ. Determinants of tetanus, pneumococcal and influenza vaccination in the elderly: a representative cross-sectional study on knowledge, attitude and practice (KAP). BMC Public Health 2015;16:121https://doi.org/10.1186/s12889-016-2784-8.
[18] Fishbein M, Ajzen I. Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Reading, MA: Addison-Wesley; 1975.
[19] Azjen I. Understanding Attitudes and Predicting Social Behavior. Englewood Cliffs, NJ: Prentice-Hall; 1980.
[20] Chan T-C, Fu Y-C, Wang D-W, Chuang J-H. Determinants of receiving the pandemic (H1N1) 2009 vaccine and intention to receive the seasonal influenza vaccine in Taiwan. PloS One 2014;9:e101083https://doi.org/10.1371/journal.pone.0101083.
[21] Macdonald EM, Perrin BM, Kingsley MI. Factors influencing Australian podiatrists' behavioural intentions to adopt a smart insole into clinical practice: a mixed methods study. J Foot Ankle Res 2020;13:1–12. https://doi.org/10.1186/s13047-020-00396-x.
[22] Zhao M, Zhang M, Ying J, et al. Knowledge, attitudes, practices and information demand in relation to haze in China: a cross-sectional study. BMC Public Health 2019;19:1396https://doi.org/10.1186/s12889-019-7772-3.
[23] Wang S, Wang J, Ru X, Li J. Public smog knowledge, risk perception, and intention to reduce car use: evidence from China. Hum Ecol Risk Assess 2019;25:1745–59. https://doi.org/10.1080/10807039.2018.1471580.
[24] Hansstein FV, Echegaray F. Exploring motivations behind pollution-mask use in a sample of young adults in urban China. Global Health 2018;14:122https://doi.org/10.1186/s12992-018-0441-y.
[25] Wong C, Wu H-C, Cleary EG, et al. Visualizing air pollution: communication of environmental health information in a Chinese immigrant community. J Health Commun 2019;24:339–58. https://doi.org/10.1080/10810730.2019.1597949.
[26] Qian X, Xu G, Li L, et al. Knowledge and perceptions of air pollution in Ningbo, China. BMC Public Health 2016;16:1138https://doi.org/10.1186/s12889-016-3788-0.
[27] Odonkor ST, Mahami T. Knowledge, attitudes, and perceptions of air pollution in Accra Ghana: a critical survey. J Environ Public Health 2020;12https://doi.org/10.1155/2020/3657161.
[28] De Pretto L, Acreman S, Ashfold MJ, Mohankumar SK, Campos-Arceiz A. The link between knowledge, attitudes and practices in relation to atmospheric haze pollution in Peninsular Malaysia. PloS One 2015;10:e0143655https://doi.org/10.1371/journal.pone.0143655.
[29] Shi H, Wang S, Zhao D. Exploring urban resident's vehicular PM2. 5 reduction behavior intention: an application of the extended theory of planned behavior. J Clean Prod 2017;147:603–13. https://doi.org/10.1016/j.jclepro.2017.01.108.
[30] Lin TT, Li L, Bautista JR. Examining how communication and knowledge relate to Singaporean youths' perceived risk of haze and intentions to take preventive behaviors. Health Commun 2017;32:749–58. https://doi.org/10.1080/10410236.2016.1172288.
[31] Hales NM, Barton CC, Ransom MR, Allen RT, Pope CAIII. A quasi-experimental analysis of elementary school absences and fine particulate air pollution. Medicine 2016;95:e2916https://doi.org/10.1097/MD.0000000000002916.
[32] Hirshon JM, Shardell M, Alles S, et al. Elevated ambient air zinc increases pediatric asthma morbidity. Environ Health Perspect 2008;116:826–31. https://doi.org/10.1289/ehp.10759.
[33] Sheffield PE, Speranza R, Chiu YH, et al. Association between particulate air pollution exposure during pregnancy and postpartum maternal psychological functioning. PloS One 2018;13:e0195267https://doi.org/10.1371/journal.pone.0195267.
[34] Chou W-L, Tseng C-C, Yeh G-L, Huang J-J, Shi L-J. A Study on the preventive behavioral intention and its related factors of fine particulate matters for senior high students. Chin J Sci Educ 2018;26:123–47. https://doi.org/10.6173/CJSE.201806_26(2).0002.
[35] Habich-Sobiegalla S, Kostka G, Anzinger N. Citizens' electric vehicle purchase intentions in China: an analysis of micro-level and macro-level factors. Transp Policy 2019;79:223–33. https://doi.org/10.1016/j.tranpol.2019.05.008.
[36] Motor vehicle registrations. 2018. https://stat.motc.gov.tw/mocdb/stmain.jsp?sys=100&funid=b3301. Accessed September 04, 2020.
[37] Environmental Protection Administration EY. Investigation Report on Air Pollutant Exposure during Commuting in Taipei-Keelung Metropolitan Area. 2017; https://enews.epa.gov.tw/Page/3B3C62C78849F32F/2650cb9c-feaa-4a42-8be5-cd13b0895104. Accessed September 04, 2020.
[38] Heine C, Gong CH, Browning C. Dual sensory loss, mental health, and wellbeing of older adults living in China. Front Public Health 2019;7:92https://doi.org/10.3389/fpubh.2019.00092.
[39] Stieb DM, Paola J, Neuman K. Do smog advisories work? Results of an evaluation of the Canadian Smog Advisory Program. Can J Public Health 1996;87:166–9. PMID: 8771917.
[40] Badland HM, Duncan MJ. Perceptions of air pollution during the work-related commute by adults in Queensland, Australia. Atmos Environ 2009;43:5791–5. https://doi.org/10.1016/j.atmosenv.2009.07.050.
[41] Muindi K, Egondi T, Kimani-Murage E, Rocklov J, Ng N. "We are used to this": a qualitative assessment of the perceptions of and attitudes towards air pollution amongst slum residents in Nairobi. BMC Public Health 2014;14:1–9. https://doi.org/10.1186/1471-2458-14-226.
[42] Hooper LG, Kaufman JD. Ambient air pollution and clinical implications for susceptible populations. Ann Am Thorac Soc 2018;15(Supplement 2):S64–8. https://doi.org/10.1513/AnnalsATS.201707-574MG.
[43] Díaz E, Bruce N, Pope D, Díaz A, Smith KR, Smith-Sivertsen T. Self-rated health among Mayan women participating in a randomised intervention trial reducing indoor air pollution in Guatemala. BMC Int Health Hum Rights 2008;8:7https://doi.org/10.1186/1472-698X-8-7.
[44] Clougherty JE. A growing role for gender analysis in air pollution epidemiology. Environ Health Perspect 2010;118:167–76. https://doi.org/ 10.1289/ehp.0900994.
[45] Hao Y, Dong X-Y, Deng Y-X, Li L-X, Ma Y. What influences personal purchases of new energy vehicles in China? An empirical study based on a survey of Chinese citizens. J Renew Sustain Energy 2016;8:65904https://doi.org/ 10.1063/1.4966908.