Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

Knowledge, Attitudes, and Practices of Healthcare Professionals Toward Internet-Based Hypertension Management: A Cross-Sectional Study

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Objective: Internet-based outpatient hypertension management offers a promising approach to improve treatment adherence and blood pressure control, yet its adoption remains suboptimal due to insufficient knowledge and inconsistent practices among healthcare professionals. This study aims to investigate the Knowledge, Attitude, and Practice (KAP) of healthcare professionals toward internet-based outpatient hypertension management.

Methods: This cross-sectional study was conducted at 25 hospitals across China between 30 December 2023 and 12 January 2024. Healthcare professionals were recruited through the medical affairs and nursing departments. KAP scores was collected using a structured questionnaire. Data were analyzed using descriptive statistics, Pearson correlation, logistic regression, and structural equation modeling (SEM).

Results: The study included 1, 199 valid questionnaire responses. Based on the 70% cutoff, 29.77% of the participants demonstrated adequate knowledge, 86.66% had positive attitudes, and 41.03% exhibited proactive practices. Significant positive correlations were observed between knowledge and attitude ($r = 0.346$, $P < 0.001$), knowledge and practice ($r = 0.183$, $P < 0.001$), and attitude and practice ($r = 0.389$, $P < 0.001$). Multivariate logistic regression revealed professional title and participation in hypertension management teams as key factors influencing knowledge and practice. Pearson correlation analysis revealed significant positive correlations between knowledge and attitude ($r = 0.346$, $P < 0.001$), knowledge and practice ($r = 0.183$, $P < 0.001$), and attitude and practice ($r = 0.389$, $P < 0.001$). Mediation analysis revealed that professional title directly affected knowledge ($\beta = 0.248$, $P = 0.007$) and indirectly influenced attitude ($\beta = 0.247$, $P = 0.006$) and practice ($\beta = 0.073$, $P = 0.010$). Additionally, participation in hypertension management teams directly affected practice ($\beta = -1.756$, $P = 0.020$) while having indirect effects on attitude ($\beta = -0.355$, $P = 0.042$) and practice ($\beta = -0.105$, $P = 0.025$).

Conclusion: Healthcare professionals demonstrated insufficient knowledge, positive attitudes, and suboptimal practices regarding internet-based outpatient hypertension management. These findings highlight the need for targeted training programs to enhance knowledge and practices and advocate for integrating digital strategies into routine clinical care. Strengthening healthcare professionals' competencies in digital hypertension management is essential for improving patient outcomes and ensuring the sustainability of such interventions.

Keywords: knowledge, attitude, practice, healthcare professional, hypertension, internet-based outpatient management, Cross-sectional study

Introduction

Hypertension is increasingly prevalent globally, affecting over 30% of adults and posing a significant risk for severe health problems like stroke, heart attack, and heart failure.[1] Recent estimates indicate that approximately 1.3 billion adults worldwide have hypertension, with prevalence rates varying across regions and demographic groups.[2] In China, a substantial number of adults are affected, with fewer than 15% achieving optimal blood pressure control.[3] Similarly, the

Received: 11 February 2025
Accepted: 3 June 2025
Published: 18 June 2025

World Health Organization reported in 2019 that less than 14% of hypertensive individuals globally have their blood pressure controlled to below 140/90 mm Hg, with even lower rates in low- and middle-income countries.[4] Without adequate control measures, hypertension could become a serious public health challenge for China in the next decade.[5]

In addressing this growing health concern, the emergence of the "Internet Plus" strategy represents a significant shift in the medical field. This new internet-based approach, driven by the rapid advancement of the internet and information technology, has introduced the "Internet Plus" ecosystem, leading to advancements in healthcare. It has played a crucial role in improving the development and distribution of medical resources, enhancing health professionals' skills and knowledge.[6] Out of 43 established Internet hospitals, 42% provide outpatient healthcare services accessible via a mobile app, demonstrating the digital evolution in patient care.[7] Despite this technological advancement, there remains a significant gap in our understanding of how healthcare professionals perceive and implement these digital tools for hypertension management. This knowledge gap presents a critical barrier to the effective implementation of internet-based interventions for chronic disease management in Chinese healthcare settings. Internet-based interventions, such as mobile health apps and telemonitoring systems, have been shown to improve blood pressure control through enhanced patient adherence and real-time feedback.[8,9] These interventions reduce the need for clinic visits, alleviate financial burdens, and provide a cost-effective and accessible approach to hypertension management. Healthcare professionals play a pivotal role in the success of such interventions, as their knowledge, attitudes, and practices directly influence the adoption and effectiveness of these strategies.[10,11] By ensuring accurate implementation and patient engagement, healthcare professionals contribute to the optimal utilization of internet-based hypertension management programs.

The Knowledge, Attitude, and Practice (KAP) survey is an invaluable tool in research, providing insights into a group's understanding, beliefs, and actions regarding a specific topic, particularly in health literacy. It operates on the premise that knowledge significantly influences attitude, which in turn shapes behaviors.[12,13] Previous studies have demonstrated that KAP assessments are essential for improving healthcare services by identifying gaps between knowledge and practice. For instance, Gassasse et al found that enhancing healthcare professionals' KAP regarding diabetes management led to improved patient outcomes and care quality.[14] This framework was selected for our study because it allows for comprehensive assessment of healthcare professionals' cognitive understanding, affective response, and behavioral implementation of internet-based hypertension management. Understanding healthcare professionals' perspectives is essential for the successful implementation of digital health strategies, particularly in addressing hypertension through internet-based outpatient management. Their knowledge, attitudes, and practices (KAP) significantly influence the adoption and effectiveness of these interventions by impacting patient acceptance and adherence. While KAP studies on hypertension are abundant, research specifically examining healthcare professionals' perspectives on internet-based outpatient management remains limited.[15–17] Previous studies have primarily focused on patients' perspectives and clinical outcomes of internet-based interventions, with Omboni et al demonstrating the effectiveness of telemonitoring in improving blood pressure control among patients.[18] Similarly, Li et al investigated the impact of mobile health applications on medication adherence in hypertensive patients,[19] while Wang et al explored patient satisfaction with telehealth services for chronic disease management.[20] However, there is a significant research gap regarding healthcare professionals' knowledge, attitudes, and practices toward internet-based hypertension management, which is crucial for successful implementation and sustainability of these digital health strategies. This gap is particularly notable in the Chinese healthcare context, where rapid technological advancement is transforming traditional healthcare delivery models.[21]

The Knowledge, Attitude, and Practice of healthcare professionals directly impacts the effectiveness of hypertension management programs. Inadequate knowledge can lead to improper implementation, while negative attitudes may result in resistance to adopting new technologies. Poor practices can compromise treatment outcomes through ineffective patient communication and follow-up. This study aims to investigate the KAP of healthcare professionals toward internet-based outpatient hypertension management. This cross-sectional design was chosen to identify current knowledge gaps, attitudinal barriers, and practice limitations that may hinder successful implementation of digital hypertension management solutions, thereby informing the development of targeted educational interventions.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted at 25 hospitals across China between 30 December 2023 and 12 January 2024. Healthcare professionals were recruited through the medical affairs and nursing departments. The inclusion criteria were: 1) aged 18 years or older; 2) specializing in clinical medicine and radiology. The exclusion criteria were: 1) patients with cognitive or communication impairments; 2) participants who withdrew from the study midway; and 3) respondents with incomplete questionnaires. The study was approved by the Ethical Committee on Biological and Medical Ethics of Pingdingshan University [PUBM (2023) No.116], and informed consent was obtained from all the study participants. This study was performed in line with the principles of the Declaration of Helsinki.

Sampling and Participant Recruitment

This study was conducted from January 10 to 16, 2024, across 20 provincial-level administrative regions in China using a multi-center cross-sectional design. The sampling framework considered geographical representation, hospital type (82.82% tertiary public hospitals), and department type (eg, cardiology, respiratory medicine, neurology). Institutions that had implemented internet-based hypertension management were prioritized, while others served as comparison controls.

Recruitment followed a phased process: First, provincial health commissions provided hospital lists. Study coordinators contacted department heads to facilitate distribution. Eligible participants were clinicians or nurses aged ≥18 years, specializing in clinical medicine or radiology, and involved in outpatient hypertension management for at least 6 months. Exclusion criteria included cognitive/communication impairments, withdrawal during the survey, and incomplete questionnaires.

Participants were invited via internal systems (eg, OA platform, departmental briefings) and snowball sampling. IP restrictions and attention-check items ensured response quality. A total of 1,487 responses were collected, and after excluding 288 invalid submissions, 1,199 valid questionnaires were analyzed (effective rate: 80.63%). The minimum sample size was determined using the events per variable (EPV) rule, which recommends 5–10 participants per parameter estimated in multivariate analyses and structural equation modeling (SEM). With 1,199 valid responses, the sample was sufficient to ensure statistical power.

Questionnaire introduction

The construction of the questionnaire was guided by a comprehensive review of relevant literature, including the "Chinese Expert Consensus on Internet Management of Hypertension Outpatient" and the "ISH 2020 International Hypertension Practice Guidelines".[22] Following the initial design phase, adjustments were made based on feedback from three expert reviewers. A preliminary pilot study involving 40 participants, resulting in a Cronbach's α coefficient value of 0.859, indicating satisfactory reliability.

Questionnaires were administered to participants via the Sojump e-questionnaire platform (Wenjuanxing Tech Co., Ltd., Changsha, China). The final version of the questionnaire, presented in Chinese, comprised four distinct sections. The first section gathered demographic information, including variables such as age, gender, educational attainment, occupational status, departmental affiliation, length of service, professional designation, clinical experience duration, hospital classification, engagement in hypertension internet management-related training, exposure to hypertensive patients during professional duties, and sources of pertinent knowledge. The subsequent section focused on the Knowledge Dimension, containing 11 items assessing participants' understanding of hypertension and its outpatient management. Each item was scored dichotomously, with correct responses receiving one point and incorrect or ambiguous responses receiving zero points, resulting in a total score ranging from 0 to 11. The third section, the Attitude Dimension, consisted of 12 items measuring participants' attitude toward hypertension management. Responses were recorded using a five-point Likert scale, with options ranging from "very positive" (5 points) to "very negative" (1 point), allowing for a total score range of 12 to 60. Finally, the Practice Dimension, comprising 7 items, evaluated participants' self-reported practice related to hypertension management. Responses were also recorded using a five-point Likert scale, enabling scores ranging from 7 to 35. A threshold of achieving scores exceeding 70% of the maximum

attainable score within each section was set to indicate adequate knowledge (≥8/11), positive attitude (≥42/60), and proactive practice (≥25/35) regarding hypertension management.[23] Suboptimal practice was defined as scoring below 25 on the practice scale. The validity of the questionnaire was confirmed through both exploratory and confirmatory methods. The Kaiser-Meyer-Olkin (KMO) value was 0.915, and Bartlett's test of sphericity was significant ($P < 0.001$), indicating sampling adequacy. Confirmatory Factor Analysis (CFA) showed acceptable model fit: Comparative Fit Index (CFI) = 0.924, Tucker-Lewis Index (TLI) = 0.917, Incremental Fit Index (IFI) = 0.925, Root Mean Square Error of Approximation (RMSEA) = 0.056, and Chi-Square divided by Degrees of Freedom (CMIN/DF) = 4.788. All factor loadings were statistically significant ($P < 0.001$), demonstrating good construct validity for the knowledge, attitude, and practice dimensions.

Statistical Analysis

Statistical analysis was conducted using SPSS (IBM Corp., Armonk, NY, USA) version 22.0. Descriptive analysis was performed to summarize demographic information and KAP scores. Continuous variables were presented as mean and standard deviation (SD), with t-tests utilized for comparisons between two groups and ANOVA for comparisons among multiple groups. Categorical variables were expressed as frequencies and percentages (n, %). Pearson correlation analysis was employed to examine the correlations between the KAP scores. Multivariate logistic regression analysis was conducted with KAP scores as dependent variables to investigate the relationship between demographic information and knowledge and attitude. Variables for inclusion in the multiple regression analysis were selected based on single-factor variables with a significance level of $P < 0.05$. SEM was performed using Stata 18.0 to examine the relationships between knowledge, attitudes, and practices. Two-sided P-values < 0.05 were considered statistically significant.

Results

Demographic Characteristics

A total of 1,199 valid questionnaire responses were included. Among them, 1,030 (85.90%) were females, with a mean age of 33.62±7.80 years, 1,027 (85.65%) were nurses, 942 (78.57%) had bachelor's degree, and 416 (34.70%) had 11–20 years of work experience. Additionally, 616 (51.38%) reported almost daily contact with hypertensive patients or involvement in their treatment, while 696 (58.05%) were not aware of internet-based hypertension management. Moreover, 243 (20.27%) were part of hypertension management teams in their hospitals. Participants reported a mean work satisfaction rating of 8.27 ± 1.92 (Table 1).

Knowledge, Attitude, and Practice Dimensions

The mean scores for knowledge, attitude, and practice were 7.50±1.75 (range: 0–11), 48.01±5.59 (range: 12–60), and 23.25±5.16 (range: 7–35), respectively. Differences in KAP scores were observed among participants with different professional titles, frequency of contact or treatment of hypertensive patients, knowledge of internet-based hypertension management, and membership in hypertension management teams. Meanwhile, knowledge scores varied significantly by gender, position, education, teaching hospital affiliation, and work location. Attitude scores varied significantly by position, education, hospital type, department, years of work experience, teaching hospital status, and work location. Practice scores varied significantly by departments (all of $P < 0.005$) (Table 1).

The distribution of knowledge dimension revealed that the two knowledge items with the highest correctness rates were K11 with 96.08%, and K10 with 95.16%. Conversely, the two items with the lowest correctness rates were K2 with 37.11%, and K3 with 53.71%. Regarding attitude, most participants displayed a positive outlook, with 56.05% strongly believing that the hypertension management platform as an information network should protect patients' privacy (A12). Additionally, 50.21% strongly favored Internet hypertension management as a more innovative, efficient, and cost-effective model of hypertension management services (A2). Furthermore, 46.71% agreed that monitoring blood pressure and heart rate through wearable devices can indirectly understand hypertensive patients' emotional and psychological changes (A6). However, it is noteworthy that 32.03% were neutral to the statement that it is difficult for healthcare professionals to gain patients' trust in internet-based remote management (A4). Compared to their attitude level, the

Table 1 Demographic Characteristics and KAP Scores

Variables	n (%)	Knowledge	P	Attitude	P	Practice	P
Total	1199	7.50±1.75		48.01±5.59		23.25±5.16	
Gender			0.003		0.939		0.912
Male	169 (14.10)	7.87±1.66		47.98±4.89		23.21±4.68	
Female	1030 (85.90)	7.44±1.76		48.02±5.70		23.25±5.24	
Age (years)	33.62±7.80						
Position			<0.001		0.025		0.217
Physician	172 (14.35)	8.23±0.97		48.90±4.83		23.70±4.73	
Nurse	1027 (85.65)	7.38±1.82		47.86±5.69		23.17±5.23	
Education			0.048		<0.001		0.573
Associate degree and below	174 (14.51)	7.43±1.96		46.40±5.41		23.24±4.77	
Bachelor's degree	942 (78.57)	7.47±1.73		48.21±5.62		23.30±5.27	
Master's degree and above	83 (6.92)	7.95±1.45		49.11±4.96		22.67±4.70	
Professional title			<0.001		<0.001		0.010
No title	130 (10.84)	7.21±1.96		47.67±5.43		23.55±5.56	
Junior	463 (38.62)	7.32±1.87		46.91±5.71		22.62±5.22	
Intermediate	497 (41.45)	7.63±1.60		48.79±5.47		23.66±5.01	
Senior	109 (9.09)	8.01±1.48		49.55±4.85		23.68±4.94	
Hospital Type			0.933		<0.001		0.058
Public tertiary hospital	993 (82.82)	7.50±1.71		48.31±5.49		23.12±5.26	
Non-public tertiary hospital	206 (17.18)	7.49±1.94		46.57±5.83		23.87±4.61	
Department			0.433		0.024		0.012
Cardiology	192(16.01)	7.60±1.82		49.01±5.32		24.14±5.17	
Respiratory Medicine	42(3.50)	7.71±0.97		49.52±5.35		24.81±4.54	
Neurology	109(9.09)	7.62±1.57		48.02±5.58		23.59±5.36	
Electrocardiography Room/Ultrasound Room	10(0.83)	7.80±1.14		46.20±3.43		24.50±3.44	
Other Internal Medicine	375(31.28)	7.54±1.63		47.57±5.43		22.81±5.03	
Other Surgery	471(39.28)	7.37±1.91		47.87±5.82		22.99±5.24	
Job years			0.062		<0.001		0.195
≤1 year	101 (8.42)	7.16±2.23		47.04±5.44		23.94±5.08	
2~5 years	272 (22.69)	7.50±1.75		47.33±5.66		23.08±4.94	
6~10 years	269 (22.44)	7.47±1.68		47.38±5.83		22.98±5.18	
11~20 years	416 (34.70)	7.49±1.73		48.69±5.42		23.11±5.40	
>20 years	141 (11.76)	7.83±1.53		49.23±5.14		23.99±4.85	
Working in a teaching hospital			0.033		<0.001		0.287
Yes	1052 (87.74)	7.54±1.69		48.29±5.52		23.31±5.23	
No	147 (12.26)	7.21±2.15		46.01±5.66		22.82±4.65	
Frequency of contact with or treatment of hypertensive patients at work			<0.001		<0.001		<0.001
Frequent contact, almost every day	616 (51.38)	7.63±1.64		48.79±5.55		23.80±5.32	
Regularly	374 (31.19)	7.53±1.54		47.45±5.14		22.93±4.88	
Occasionally	141 (11.76)	7.22±2.14		46.45±6.31		22.58±4.97	
Rarely/never	68 (5.67)	6.69±2.50		47.26±5.66		21.34±4.97	
Familiar with the internet-based management of hypertension			<0.001		<0.001		<0.001
Yes	503 (41.95)	7.84±1.44		49.17±5.21		25.96±4.46	
No	696 (58.05)	7.25±1.91		47.18±5.71		21.29±4.74	
Join your institution's hypertension management team			<0.001		0.013		<0.001
Yes	243 (20.27)	7.91±1.57		48.81±5.16		26.29±4.46	
No	956 (79.73)	7.40±1.78		47.81±5.68		22.47±5.04	
Work location			0.015		0.001		0.053
Northeast region	418 (34.86)	7.38±1.90		48.63±5.73		23.47±5.42	
Eastern region	148 (12.34)	7.24±2.07		46.74±5.78		22.49±5.44	
Central region	585 (48.79)	7.66±1.52		48.00±5.34		23.39±4.95	
Western region	48 (4.00)	7.40±1.75		46.71±5.95		21.90±4.16	
Job satisfaction	8.27±1.92						

Table 2 Pearson Correlation Analysis

	Knowledge	Attitude	Practice
Knowledge	1		
Attitude	0.346 (P<0.001)	1	
Practice	0.183 (P<0.001)	0.389 (P<0.001)	1

participants' willingness was not very active overall, and the frequency of performing relevant practices was not high. Specifically, 42.45% of participants sometimes encountered hypertensive patients who refused to participate in Internet management during their work (P3), 34.28% sometimes obtained information about Internet management of hypertension through various channels (P1), and 30.53% sometimes actively collaborated with healthcare professionals in other departments to promote the practice of Internet management of hypertension (P5). On a relatively positive note, 31.61% always and 31.94% often followed the latest guidelines to guide practice (P6) (Table S1).

Pearson Correlation Analysis

Pearson correlation analysis revealed significant positive correlations between knowledge and attitude ($r = 0.346$, $P = 0.002$), knowledge and practice ($r = 0.183$, $P < 0.001$), and attitude and practice ($r = 0.389$, $P < 0.001$), respectively, underscoring the interrelated nature of these components in internet-based hypertension management (Table 2). These findings directly correspond to our research objective, which aimed to examine the relationships among demographic factors, knowledge, attitudes, and practices. The identification of significant associations and mediating pathways through correlation, regression, and SEM analyses highlights the complexity of these interactions. In particular, variables such as professional title and team participation were shown to influence both direct and indirect outcomes across the KAP dimensions.

Univariate and Multivariate Logistic Regression Analysis

Using 70% of the maximum score as the cut-off value, 357 (29.77%), 1,039 (86.66%), and 492 (41.03%) individuals exceeded this value for knowledge, attitude, and practice, respectively. To further explore factors associated with knowledge, attitude, practice, and compliance, multivariate analyses were conducted. The results revealed that nurse (OR = 0.460, 95% CI: 0.308–0.688, $P < 0.001$), holding a senior professional title (OR = 2.150, 95% CI: 1.045–4.422, $P = 0.038$), familiarity with internet-based management of hypertension (OR = 1.825, 95% CI: 1.375–2.422, $P < 0.001$), and participation in a hypertension management team (OR = 1.511, 95% CI: 1.085–2.104, $P = 0.015$) were independently associated with knowledge. Similarly, knowledge score (OR = 1.451, 95% CI: 1.328–1.585, $P < 0.001$), holding a bachelor's degree (OR = 2.026, 95% CI: 1.262–3.253, $P = 0.003$), working in a public tertiary hospital (OR = 1.905, 95% CI: 1.160–3.130, $P = 0.011$), and satisfaction with work (OR = 1.303, 95% CI: 1.194–1.422, $P < 0.001$) were independently associated with a positive attitude. Furthermore, attitude score (OR = 1.138, 95% CI: 1.104–1.172, $P < 0.001$), familiarity with internet-based management of hypertension (OR = 3.760, 95% CI: 2.805–5.039, $P < 0.001$), participation in a hypertension management team (OR = 2.246, 95% CI: 1.565–3.223, $P < 0.001$), working in the western region (OR = 0.377, 95% CI: 0.167–0.850, $P = 0.019$), and satisfaction with work (OR = 1.122, 95% CI: 1.034–1.219, $P = 0.006$) were independently associated with practice (Table 3).

SEM Model & Mediation Analysis

Mediation analysis indicated that professional title ($\beta = 0.248$, $P = 0.007$), work location ($\beta = 0.152$, $P = 0.010$), and frequency of contact with or treatment of hypertensive patients at work ($\beta = -0.219$, $P = 0.005$) directly affected Knowledge. Join the institution's hypertension management team ($\beta = -1.756$, $P = 0.020$) directly affected practice. On the other hand, join the institution's hypertension management team indirectly affected attitude ($\beta = -0.355$, $P = 0.042$) and practice ($\beta = -0.105$, $P = 0.025$). Meanwhile, working in a teaching hospital indirectly affected practice ($\beta = -0.371$, $P = 0.049$). Further, professional title indirectly affected attitude ($\beta = 0.247$, $P = 0.006$) and practice ($\beta = 0.073$, $P = 0.010$). Moreover, work location indirectly affected attitude ($\beta = 0.151$, $P = 0.018$) and practice ($\beta = 0.045$, $P = 0.013$).

Table 3 Univariate and Multivariate Analysis of Knowledge, Attitude, and Practice

Knowledge	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	p	OR (95% CI)	p
Gender				
Male	ref.		ref.	
Female	0.486 (0.349 0.679)	<0.001	0.731 (0.485 1.103)	0.136
Age (years)	1.022 (1.006 1.038)	0.006	1.001 (0.978 1.025)	0.917
Position				
Physician	Ref.		Ref.	
Nurse	0.348 (0.251 0.485)	<0.001	0.460 (0.308 0.688)	<0.001
Education				
Associate degree and below	Ref.			
Bachelor's degree	0.829 (0.585 1.175)	0.292		
Master's degree and above	1.536 (0.896 2.635)	0.119		
Professional title				
No title	Ref.		Ref.	
Junior	1.233 (0.781 1.946)	0.369	1.340 (0.835 2.152)	0.225
Intermediate	1.483 (0.945 2.326)	0.087	1.569 (0.933 2.640)	0.090
Senior	2.722 (1.562 4.746)	<0.001	2.150 (1.045 4.422)	0.038
Hospital Type				
Non-public tertiary hospital	Ref.			
Public tertiary hospital	0.790 (0.574 1.087)	0.147		
Department				
Cardiology	Ref.			
Respiratory Medicine	0.497 (0.225 1.100)	0.085		
Neurology	0.827 (0.501 1.365)	0.457		
Electrocardiography Room/Ultrasound Room	0.782 (0.196 3.120)	0.727		
Other Internal Medicine	0.767 (0.530 1.110)	0.159		
Other Surgery	0.710 (0.497 1.015)	0.061		
Job years				
≤1 year	Ref.			
2~5 years	0.935 (0.566 1.543)	0.791		
6~10 years	0.932 (0.564 1.541)	0.783		
11~20 years	0.971 (0.603 1.563)	0.903		
>20 years	1.425 (0.826 2.461)	0.203		
Working in a teaching hospital				
No	Ref.			
Yes	0.991 (0.680 1.445)	0.965		
Frequency of contact with or treatment of hypertensive patients at work				
Rarely/never	Ref.		Ref.	
Frequent contact, almost every day	2.019 (1.078 3.782)	0.028	1.449 (0.758 2.769)	0.262
Regularly	1.718 (0.902 3.272)	0.100	1.404 (0.724 2.723)	0.315
Occasionally	1.505 (0.739 3.066)	0.260	1.225 (0.589 2.546)	0.587
Familiar with the internet-based management of hypertension				
No	Ref.		Ref.	
Yes	2.193 (1.705 2.820)	<0.001	1.825 (1.375 2.422)	<0.001
Join your institution's hypertension management team				
No	Ref.		Ref.	
Yes	2.271 (1.697 3.040)	<0.001	1.511 (1.085 2.104)	0.015

(*Continued*)

https://doi.org/10.2147/JMDH.S522108

Table 3 (Continued).

Knowledge	Univariate Analysis		Multivariate Analysis	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
Work location				
Northeast region	Ref.			
Eastern region	1.124 (0.746 1.694)	0.577		
Central region	1.162 (0.882 1.531)	0.287		
Western region	0.956 (0.488 1.870)	0.894		
Job satisfaction	1.061 (0.992 1.134)	0.082		
Attitude	**Univariate analysis**		**Multivariate analysis**	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
Knowledge score	1.484 (1.368 1.610)	<0.001	1.451 (1.328 1.585)	<0.001
Gender				
Male	Ref.			
Female	0.594 (0.340 1.039)	0.068		
Age (years)	1.026 (1.003 1.049)	0.029	1.007 (0.974 1.041)	0.695
Position				
Physician	Ref.		Ref.	
Nurse	0.445 (0.242 0.821)	0.010	0.776 (0.376 1.601)	0.492
Education				
Associate degree and below	Ref.		Ref.	
Bachelor's degree	2.077 (1.384 3.119)	<0.001	2.026 (1.262 3.253)	0.003
Master's degree and above	3.707 (1.501 9.155)	0.004	2.768 (0.894 8.573)	0.077
Professional title				
No title	Ref.		Ref.	
Junior	0.845 (0.490 1.456)	0.544	0.777 (0.417 1.446)	0.426
Intermediate	1.348 (0.770 2.361)	0.296	0.831 (0.404 1.709)	0.614
Senior	2.494 (1.007 6.180)	0.048	1.138 (0.343 3.779)	0.833
Hospital Type				
Non-public tertiary hospital	Ref.		Ref.	
Public tertiary hospital	1.825 (1.233 2.701)	0.003	1.905 (1.160 3.130)	0.011
Department				
Cardiology	Ref.		Ref.	
Respiratory Medicine	0.983 (0.315 3.069)	0.976	0.930 (0.265 3.264)	0.910
Neurology	0.648 (0.313 1.345)	0.244	0.630 (0.279 1.423)	0.267
Electrocardiography Room/Ultrasound Room	0.414 (0.082 2.099)	0.287	0.435 (0.075 2.534)	0.355
Other Internal Medicine	0.543 (0.311 0.949)	0.032	0.629 (0.331 1.194)	0.156
Other Surgery	0.695 (0.399 1.211)	0.199	0.966 (0.491 1.568)	0.914
Job years				
≤1 year	Ref.			
2~5 years	1.174 (0.631 2.182)	0.612		
6~10 years	1.007 (0.546 1.857)	0.981		
11~20 years	1.628 (0.889 2.980)	0.114		
>20 years	2.176 (0.989 4.786)	0.053		
Working in a teaching hospital				
Yes	1.819 (1.170 2.827)	0.008	1.288 (0.820 2.025)	0.272
No	Ref.		Ref.	

(*Continued*)

Table 3 (Continued).

Attitude	Univariate analysis		Multivariate analysis	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
Frequency of contact with or treatment of hypertensive patients at work				
Frequent contact, almost every day	1.555 (0.778 3.110)	0.212		
Regularly	1.311 (0.642 2.674)	0.457		
Occasionally	0.632 (0.297 1.342)	0.232		
Rarely/never	Ref.			
Familiar with the internet-based management of hypertension				
Yes	2.162 (1.493 3.131)	<0.001	1.532 (0.839 2.796)	0.165
No	Ref.		Ref.	
Join your institution's hypertension management team				
Yes	2.040 (1.236 3.367)	0.005		
No	Ref.		Ref.	
Work location				
Northeast region	Ref.		Ref.	
Eastern region	0.897 (0.521 1.544)	0.695		
Central region	0.994 (0.684 1.444)	0.973		
Western region	0.643 (0.295 1.401)	0.266		
Job satisfaction	1.335 (1.236 1.441)	<0.001	1.303 (1.194 1.422)	<0.001
Practice	**Univariate analysis**		**Multivariate analysis**	
	OR (95% CI)	**p**	**OR (95% CI)**	**p**
Knowledge score	1.228 (1.135 1.329)	<0.001	1.020 (0.931 1.119)	0.670
Attitude score	1.157 (1.128 1.186)	<0.001	1.138 (1.104 1.172)	<0.001
Gender				
Male	Ref.			
Female	1.274 (0.909 1.785)	0.160		
Age (years)	1.010 (0.995 1.025)	0.182		
Position				
Physician	Ref.			
Nurse	0.884 (0.638 1.225)	0.459		
Education				
Associate degree and below	Ref.			
Bachelor's degree	1.087 (0.782 1.511)	0.620		
Master's degree and above	0.604 (0.344 1.061)	0.080		
Professional title				
No title	Ref.			
Junior	0.755 (0.508 1.122)	0.165		
Intermediate	1.119 (0.757 1.653)	0.573		
Senior	1.073 (0.642 1.794)	0.788		
Hospital Type				
Non-public tertiary hospital	Ref.			
Public tertiary hospital	0.760 (0.562 1.028)	0.075		
Department				
Cardiology	Ref.		Ref.	
Respiratory Medicine	1.916 (0.959 3.827)	0.065	1.973 (0.867 4.489)	0.105
Neurology	0.748 (0.466 1.203)	0.232	0.914 (0.525 1.591)	0.750
Electrocardiography Room/Ultrasound Room	1.065 (0.299 3.796)	0.923	2.712 (0.646 11.389)	0.173
Other Internal Medicine	0.620 (0.436 0.882)	0.008	0.938 (0.614 1.432)	0.767
Other Surgery	0.682 (0.487 0.957)	0.027	0.979 (0.644 1.488)	0.921

(*Continued*)

Table 3 (Continued).

Practice	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p	OR (95% CI)	p
Job years				
≤1 year	Ref.			
2~5 years	0.724 (0.455 1.150)	0.171		
6~10 years	0.861 (0.543 1.366)	0.525		
11~20 years	0.851 (0.549 1.320)	0.472		
>20 years	1.159 (0.694 1.936)	0.572		
Working in a teaching hospital				
No	Ref.		ref.	
Yes	1.455 (1.011 2.094)	0.044	0.901 (0.571 1.421)	0.653
Frequency of contact with or treatment of hypertensive patients at work				
Rarely/never	Ref.		Ref.	
Frequent contact, almost every day	2.013 (1.167 3.473)	0.012	1.088 (0.579 2.047)	0.793
Regularly	1.503 (0.857 2.635)	0.155	1.076 (0.570 2.032)	0.820
Occasionally	1.200 (0.640 2.249)	0.569	1.051 (0.515 2.146)	0.891
Familiar with the internet-based management of hypertension				
No	Ref.		Ref.	
Yes	5.504 (4.282 7.076)	<0.001	3.760 (2.805 5.039)	<0.001
Join your institution's hypertension management team				
No	Ref.		Ref.	
Yes	3.794 (2.816 5.112)	<0.001	2.246 (1.565 3.223)	<0.001
Work location				
Northeast region	Ref.		Ref.	
Eastern region	0.767 (0.522 1.126)	0.175	1.108 (0.698 1.759)	0.665
Central region	0.882 (0.685 1.137)	0.334	0.868 (0.631 1.193)	0.382
Western region	0.331 (0.161 0.683)	0.003	0.377 (0.167 0.850)	0.019
Job satisfaction	1.327 (1.235 1.425)	<0.001	1.122 (1.034 1.219)	0.006

Additionally, frequency of contact with or treatment of hypertensive patients at work indirectly affected attitude (β = −0.217, P = 0.009) and practice (β = −0.065, P = 0.006) (Table 4 and Figure 1). And the SEM had good model fit (Table S2).

Discussion

Healthcare professionals have demonstrated inadequate knowledge, positive attitudes, and suboptimal practices concerning internet-based outpatient hypertension management. Notably, this study identified significant positive correlations among knowledge, attitude, and practice, confirming their interdependence. Furthermore, differences in professional roles, particularly professional title and participation in hypertension management teams, were found to directly influence both knowledge and practice, highlighting the varying levels of engagement among healthcare professionals. There is a pressing need to enhance their understanding and practices in this area through targeted training programs and continuous education initiatives. These targeted training programs are essential for several reasons. First, the rapid evolution of digital health technologies creates a continuous knowledge gap that needs addressing through regular updates and skill development. Second, our findings revealed specific knowledge deficits, particularly regarding eligibility criteria for internet-based management (only 37.11% answered correctly) and home blood pressure measurement focuses (only 53.71% answered correctly), which require focused educational interventions. Third, the positive correlations between knowledge, attitudes, and practices demonstrated in our study suggest that improving knowledge through targeted education would likely enhance both attitudes and clinical practices. Additionally, continuous education

Table 4 Mediation Analysis

Model paths			Total effects		Direct Effect		Indirect effect	
			β (95% CI)	P	β (95% CI)	P	β (95% CI)	P
K	<-	Join your institution's hypertension management team	−0.357 (−0.504, −0.104)	0.056	−0.357 (−0.504, −0.104)	0.056	/	/
A	<-	Join your institution's hypertension management team	−0.355 (−0.532, −0.124)	0.042	/	/	−0.355 (−0.532, −0.124)	0.042
P	<-	Join your institution's hypertension management team	−1.861 (−2.276, −1.293)	0.025	−1.756 (−2.145, −1.184)	0.020	−0.105 (−0.176, −0.030)	0.025
K	<-	Working in a teaching hospital	−0.319 (−0.574, 0.010)	0.105	−0.319 (−0.574, 0.010)	0.105	/	/
A	<-	Working in a teaching hospital	−1.252 (−2.067, −0.133)	0.054	−0.935 (−1.617, 0.046)	0.106	−0.317 (−0.617, −0.018)	0.072
P	<-	Working in a teaching hospital	−0.371 (−0.632, −0.055)	0.049	/	/	−0.371 (−0.632, −0.055)	0.049
K	<-	Professional title	0.248 (0.161, 0.355)	0.007	0.248 (0.161, 0.355)	0.007	/	/
A	<-	Professional title	0.247 (0.164, 0.358)	0.006	/	/	0.247 (0.164, 0.358)	0.006
P	<-	Professional title	0.073 (0.034, 0.115)	0.010	/	/	0.073 (0.034, 0.115)	0.010
K	<-	Work location	0.152 (0.066, 0.257)	0.010	0.152 (0.066, 0.257)	0.010	/	/
A	<-	Work location	0.151 (0.053, 0.257)	0.018	/	/	0.151 (0.053, 0.257)	0.018
P	<-	Work location	0.045 (0.015, 0.098)	0.013	/	/	0.045 (0.015, 0.098)	0.013
K	<-	Frequency of contact with or treatment of hypertensive patients at work	−0.219 (−0.354, −0.116)	0.005	−0.219 (−0.354, −0.116)	0.005	/	/
A	<-	Frequency of contact with or treatment of hypertensive patients at work	−0.217 (−0.314, −0.098)	0.009	/	/	−0.217 (−0.314, −0.098)	0.009
P	<-	Frequency of contact with or treatment of hypertensive patients at work	−0.065 (−0.116, −0.024)	0.006	/	/	−0.065 (−0.116, −0.024)	0.006
K	<-	Gender	−0.332 (−0.525, −0.092)	0.036	−0.332 (−0.525, −0.092)	0.036	/	/
A	<-	Gender	−0.330 (−0.532, −0.107)	0.021	/	/	−0.330 (−0.532, −0.107)	0.021
P	<-	Gender	−0.098 (−0.209, −0.031)	0.014	/	/	−0.098 (−0.209, −0.031)	0.014
A	<-	Familiar with the internet-based management of hypertension	−1.406 (−1.831, −0.822)	0.016	−1.406 (−1.831, −0.822)	0.016	/	/
P	<-	Familiar with the internet-based management of hypertension	−3.907 (−4.407, −3.374)	0.012	−3.491 (−3.890, −2.924)	0.019	−0.416 (−0.573, −0.268)	0.006
A	<-	Job years	0.436 (0.215, 0.640)	0.016	0.436 (0.215, 0.640)	0.016	/	/
P	<-	Job years	0.129 (0.073, 0.190)	0.009	/	/	0.129 (0.073, 0.190)	0.009
A	<-	Hospital Type	−1.312 (−2.073, −0.670)	0.007	−1.312 (−2.073, −0.670)	0.007	/	/
P	<-	Hospital Type	−0.388 (−0.637, −0.201)	0.005	/	/	−0.388 (−0.637, −0.201)	0.005
A	<-	Education	1.080 (0.582, 1.646)	0.012	1.080 (0.582, 1.646)	0.012	/	/
P	<-	Education	0.320 (0.168, 0.492)	0.014	/	/	0.320 (0.168, 0.492)	0.014
A	<-	K	0.993 (0.786, 1.182)	0.014	0.993 (0.786, 1.182)	0.014	/	/
P	<-	K	0.295 (0.165, 0.422)	0.012	0.001 (−0.119, 0.136)	0.972	0.294 (0.236, 0.361)	0.008
P	<-	A	0.296 (0.259, 0.342)	0.006	0.296 (0.259, 0.342)	0.006	/	/

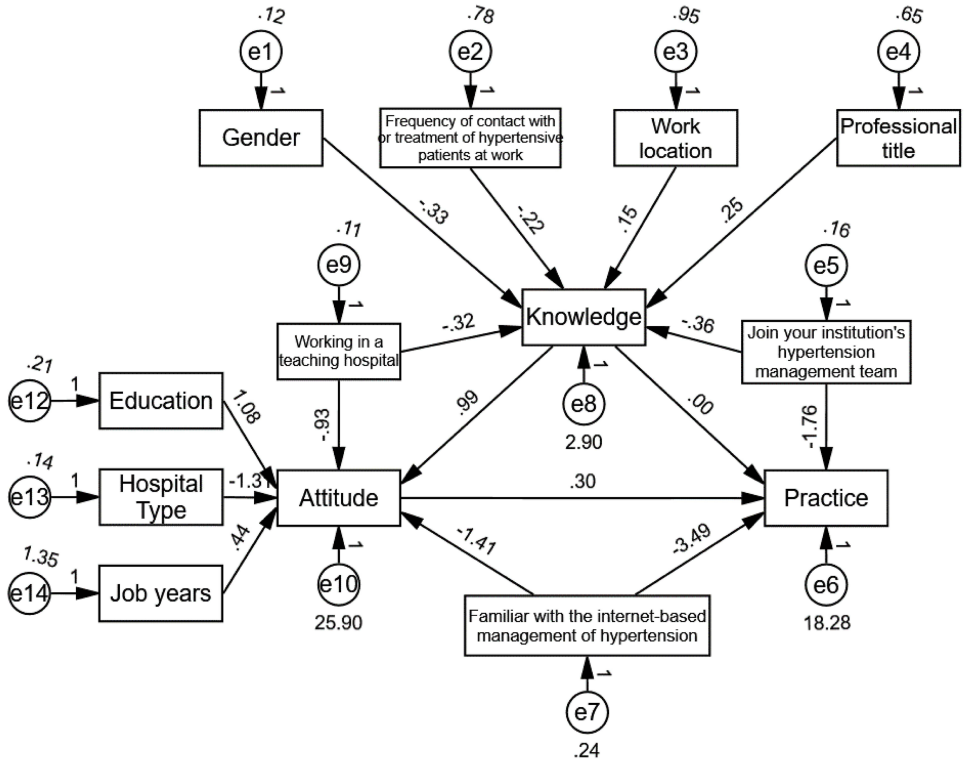

Figure 1 Path diagram of mediation analysis based on structural equation modeling (SEM), illustrating the total, direct, and indirect effects of key variables on knowledge, attitude, and practice.

initiatives would help healthcare professionals stay updated with evolving guidelines and technological advancements in internet-based hypertension management, ensuring the sustainability and effectiveness of these digital health approaches in routine clinical practice.[24]

Our study findings highlight several crucial aspects regarding healthcare professionals' knowledge, attitude, and practice in internet-based outpatient hypertension management. Firstly, the results reveal a concerning knowledge gap, with healthcare professionals scoring below optimal levels despite their positive attitudes toward this management approach. Additionally, the suboptimal practices reported underscore the importance of interventions aimed at translating positive attitudes and theoretical knowledge into practical skills and actions.[25,26] In line with the KAP framework, professional title was found to have a direct influence on knowledge and an indirect influence on both attitudes and practices, indicating that professional seniority may enhance understanding and promote greater engagement in clinical applications. Participation in hypertension management teams had a direct association with practice and also indirectly influenced attitudes and practices, highlighting the value of collaborative team-based approaches.[27] Additionally, work location and the frequency of contact with hypertensive patients affected knowledge directly and were further associated with changes in attitudes and practices through indirect pathways. These findings emphasize that both individual characteristics and workplace context can contribute to shaping healthcare professionals' behavioral responses to digital hypertension management.

The SEM analysis offers important insights into how individual and institutional factors shape healthcare professionals' engagement with internet-based hypertension management. This interpretation aligns with the Knowledge-Attitude-Practice (KAP) theoretical framework, which suggests that knowledge can influence attitudes, and together they affect practice. Notably, professional title, work location, and frequency of contact with hypertensive patients directly influence knowledge levels, while participation in hypertension management teams has a direct effect on practice. These findings suggest that both individual characteristics and institutional factors play crucial roles in shaping healthcare professionals' competencies and engagement with digital health solutions. Demographic and professional variables have emerged as significant determinants of knowledge, attitude, and practice when considering inter-group

comparisons. For example, gender-based differences have shown that males tend to exhibit higher knowledge scores than females. This finding could be attributed to various factors such as differences in educational opportunities, societal expectations, or professional experiences. The multivariate regression analyses provide additional insights into factors influencing KAP scores. Being a nurse was negatively associated with knowledge scores, while holding a senior professional title showed a positive association. This finding may be attributed to several factors. Physicians typically receive more extensive training in hypertension pathophysiology and management protocols as part of their medical education compared to nurses, whose education often emphasizes broader patient care aspects.[28] Additionally, senior professionals, regardless of their role, have accumulated more clinical experience and typically have greater exposure to continuing education opportunities, which contributes to their enhanced knowledge. The difference in knowledge levels between nurses and physicians highlights the need for tailored educational programs that address the specific learning needs of different healthcare professional groups.[29] Nursing-focused training programs should emphasize the technical aspects of internet-based hypertension management, including patient eligibility criteria, monitoring protocols, and interpretation of digital health data. Meanwhile, senior professionals could serve as knowledge disseminators within healthcare teams, facilitating peer-learning environments that leverage their expertise while promoting interprofessional collaboration in hypertension management.[24] These findings suggest that targeted educational interventions may be particularly beneficial for nursing staff, while senior professionals could potentially serve as mentors and knowledge disseminators.[30,31]

Moreover, our mediation analysis reveals important indirect effects that highlight the interconnected nature of knowledge, attitudes, and practices. For instance, participation in hypertension management teams indirectly affects both attitudes and practices, while working in a teaching hospital has indirect effects on practice. These findings emphasize the importance of considering both direct and indirect pathways when developing interventions to improve healthcare delivery. Notably, our SEM model revealed that work location and frequency of contact with hypertensive patients have significant direct effects on knowledge levels. These findings highlight the importance of practical experience and regional factors in shaping healthcare professionals' understanding of internet-based hypertension management.[32,33] This emphasizes the importance of education and professional development in shaping healthcare professionals' competencies and underscores the necessity for continuous learning opportunities throughout their careers. Additionally, our analysis revealed that working in a public tertiary hospital and job satisfaction were independently associated with positive attitudes. These institutional factors, combined with the SEM model's findings regarding teaching hospital effects, underscore the critical role of organizational environment in shaping healthcare professionals' engagement with digital health solutions.[34,35] Understanding the organizational context and implementing targeted interventions to address specific challenges within different healthcare settings could enhance the effectiveness of interventions aimed at improving hypertension management practices.

Multivariate analyses have provided further insights into the factors independently associated with knowledge, attitude, and practice. For instance, being a nurse was negatively associated with knowledge, highlighting the necessity to address specific educational needs within this professional group. Conversely, familiarity with internet-based management of hypertension and participation in hypertension management teams emerged as significant predictors across multiple domains, underscoring the importance of experiential learning and collaborative approaches in enhancing healthcare practice.[36,37] Additionally, satisfaction with work consistently emerged as a predictor, indicating that organizational factors play a crucial role in shaping healthcare professionals' attitudes and practices toward hypertension management.[38,39]

Moreover, our results demonstrate that healthcare professionals' familiarity with internet-based hypertension management and participation in hypertension management teams are strongly associated with better practices. These findings, coupled with the SEM model's mediation pathways, suggest that comprehensive training programs incorporating both theoretical knowledge and practical experience may be most effective in improving healthcare delivery.[40,41]

In the knowledge dimension, most healthcare professionals exhibited a strong understanding of the effectiveness of comprehensive community-based hypertension prevention and treatment strategies. However, there seemed to be a lack of clarity regarding the eligibility criteria for internet-based hypertension management programs. To bridge this gap, targeted educational programs should be developed, emphasizing the importance of identifying suitable candidates for

remote management to maximize program effectiveness. Additionally, regular updates and training sessions could help healthcare professionals stay informed about advancements in hypertension management strategies, ensuring their knowledge remains up-to-date.[42,43]

Regarding attitudes toward internet-based hypertension management platforms, healthcare professionals generally agreed on prioritizing patient privacy. However, there appeared to be some skepticism regarding gaining patient trust in remote management initiatives. To address this, it is recommended that robust privacy measures be implemented, and the benefits and limitations of remote management be transparently communicated to build trust among healthcare professionals and patients. Additionally, fostering a culture of openness and inclusivity, where healthcare professionals feel empowered to voice their concerns and provide feedback on remote management initiatives, could help address any lingering doubts or apprehensions.[44,45]

Healthcare professionals demonstrated a strong commitment to following the latest guidelines to guide their practice regarding the willingness to engage with internet-based hypertension management. However, significant challenges were observed in patient acceptance of internet-based management, with many healthcare professionals encountering patients who refuse to participate. To overcome this barrier, comprehensive patient education initiatives should be developed to address common misconceptions and concerns about remote management. Tailored support, such as one-on-one consultations or group education sessions, could help alleviate patient apprehension and enhance engagement in internet-based hypertension management programs. Additionally, collaborating with patient advocacy groups and community organizations to raise awareness about the benefits of remote management and address barriers to participation could further enhance acceptance and uptake among hypertensive patients.[46,47] The mediation analysis findings provide valuable insights into the complex relationships between healthcare professionals' characteristics and their engagement with internet-based hypertension management. Professional title emerged as a significant factor with both direct effects on knowledge and indirect effects on attitude and practice, suggesting that professional advancement not only enhances direct understanding but also positively influences overall engagement with digital health solutions. The analysis also revealed that participation in hypertension management teams had significant direct effects on practice while indirectly influencing both attitude and practice, highlighting the importance of team-based approaches in shaping healthcare professionals' perspectives and behaviors. Furthermore, work location and frequency of contact with hypertensive patients showed significant direct effects on knowledge and indirect effects on both attitude and practice, emphasizing how workplace environment and clinical experience create cascading effects on healthcare professionals' overall approach to internet-based hypertension management.

However, this study still had several limitations. Firstly, it relied on convenient sampling from hospitals in China, which may introduce sampling bias, limiting the generalizability of findings beyond this specific context. Secondly, self-administered questionnaires might lead to potential response bias and measurement error. Finally, the cross-sectional design prevents the establishment of causal relationships between healthcare professionals' characteristics and their attitudes and practices towards internet-based hypertension management. Despite these limitations, the study's strengths lie in its thorough exploration of healthcare professionals' perspectives, a large sample size, and rigorous statistical analyses, which collectively offer valuable insights into outpatient care practice and provide a strong foundation for future research and interventions in this critical area of healthcare delivery.

In conclusion, our study indicates that healthcare professionals demonstrate less than optimal knowledge, a positive attitude, and less than optimal practice regarding internet-based outpatient management of hypertension. It is recommended to prioritize targeted educational interventions and training programs to improve healthcare professionals' understanding and implementation of internet-based hypertension management protocols.

Scope Statement

This study investigates the Knowledge, Attitude, and Practice (KAP) of healthcare professionals regarding internet-based outpatient hypertension management across 25 hospitals in China. Conducted from December 2023 to January 2024, 1,199 valid questionnaire responses were analyzed to evaluate healthcare professionals' understanding and engagement with digital health strategies. The results revealed inadequate knowledge (mean score: 7.50±1.75), positive attitudes towards online management (mean score: 48.01±5.59), but suboptimal practices (mean score: 23.25±5.16). Significant

positive correlations were observed between knowledge, attitude, and practice, underscoring their interconnectedness. Mediation analysis indicated that professional title and participation in hypertension management teams directly influenced knowledge and practice, suggesting varying levels of engagement based on professional roles. These findings emphasize the urgent need for targeted training programs to enhance healthcare professionals' knowledge and practices in internet-based hypertension management. This research aligns with the journal's focus on digital health innovations in clinical practice, highlighting the importance of integrating technology into routine hypertension care to improve patient outcomes and foster efficient healthcare delivery.

Data Sharing Statement

All data generated or analysed during this study are included in this published article.

Ethics Approval and Consent to Participate

The study was approved by the Ethical Committee on Biological and Medical Ethics of Pingdingshan University [PUBM (2023) No.116], and written informed consent was obtained from all the study participants. This study was performed in line with the principles of the Declaration of Helsinki. I confirm that all methods were performed in accordance with the relevant guidelines. All questionnaire responses were collected anonymously via an encrypted online platform, and only the principal investigators had access to the de-identified dataset, which is securely stored.

Acknowledgments

We would like to thank Professor Yan Yan Luo of Xinxiang Medical College, Yu Hong Wu, Director of the Nursing Department of the First People's Hospital of Pingdingshan City, Professor Xinhua Zheng, Dean of the Medical School of Pingdingshan University, and all the contacts of the interviewed hospitals, Wei Wei Jia, Yitao Zhang, Ruobing Zheng, Wen Shenghan, Zhaodi Huang, Peng Jiejin, Ruixue Li, Lijun Liu, Yubin Liu, Xiaguang Li, Shu Wenluan and so on for their support in liaison and questionnaire distribution, more than 20 nursing colleges that involved in the questionnaire survey, all the nursing students who participated in this study, and the nursing department of the Nursing Department of Pingdingshan First People's Hospital for their professional support and assistance.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study was funded by the Education Department of Henan Province and the Science and Technology Bureau of Pingdingshan City, First-class Undergraduate course Construction project of Henan Province (online and offline hybrid course) (grant numbers [2021] 21548); 2021 Pingdingshan Smart Nursing Key Laboratory.

Disclosure

The authors declare that they have no competing interests in this work.

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