Original Article

Self-Medication Following AI Advice among Adult Chatbot Users: A Cross-Sectional Study

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ABSTRACT

Background: AI chatbots are increasingly used for health information, but the accuracy and safety of their recommendations may vary. Evidence is limited on whether adults act on chatbot-generated health advice in Pakistan. The objective of this study was to determine the prevalence of following AI chatbot advice, compare trust in chatbot information across age groups, and identify associated attitudinal factors.

Methodology: This cross-sectional study was conducted by the Department of Medicine, Allama Iqbal Medical College, Lahore, from September 2025 to March 2026. Adults aged 18 years or older residing in Pakistan, with internet access, English proficiency, and previous AI chatbot use, were recruited through social media using a structured online questionnaire. Data from 702 participants were analysed using R version 4.5.1. Descriptive statistics, chi-square tests, Kruskal-Wallis tests, Spearman correlation, and multivariable logistic regression were used. Ethical approval and electronic informed consent were obtained.

Results: Of 702 participants, 640 (91.2%) were aged 18 to 25 years, and 658 (93.7%) had used AI chatbots for health queries. The main reasons for use were convenience and speed (457, 65.1%), privacy (114, 16.2%), limited healthcare access (76, 10.8%), and trust in AI capabilities (55, 7.8%). Symptom checking was the most common query type (53.0%). Overall, 213 participants (30.3%; 95% CI 27.1–33.8) reported following a treatment or medication plan based solely on AI chatbot advice. Confidence in self-medication (OR 1.87, 95% CI 1.55–2.25; p<0.001) and trust in chatbot information (OR 1.31, 95% CI 1.05–1.64; p=0.018) were independently associated with following advice. Healthcare professionals remained the preferred source of health advice across age groups. Trust in chatbot information differed across age groups (H=9.46, p=0.024). Outcome and side-effect questions were not restricted to participants who reported following advice and therefore were not interpreted as outcomes in that subgroup.

Conclusion: Approximately one-third of participants reported following a treatment or medication plan based solely on AI chatbot advice. Confidence in self-medication and trust in chatbot information were associated with this behaviour. Healthcare professionals remained the preferred source of health advice, supporting the need for responsible use of AI-generated health information.

Keywords: Self Medication; Artificial Intelligence; Chatbots; Digital Health; Information Seeking Behavior

INTRODUCTION

Artificial intelligence (AI) chatbots are increasingly being used to obtain health information and guidance. These tools allow users to describe symptoms, seek information about diseases, and obtain suggestions about treatment through conversational interfaces. Research on online health information seeking has begun to examine how people use large language models for health-related queries.[1] However, the availability of immediate, accessible information does not necessarily ensure that the advice provided is accurate, appropriate, or safe. Evidence regarding the diagnostic and triage performance of digital symptom checkers remains variable.[2,3] Studies evaluating ChatGPT responses to medication-related questions have also raised concerns about the appropriateness and reliability of its recommendations.[4] Despite these limitations, users may act on chatbot-generated advice when deciding whether to seek professional care, manage symptoms themselves, or consider treatment options. Research has examined users' intentions and experiences with symptom checkers, while studies among pharmacy students have explored the use of internet-based information and AI in self-diagnosis and self-medication.[5,6] Nevertheless, the extent to which users actually follow chatbot-generated treatment or medication advice

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remains an important question. Self-medication is a recognised public health concern in Pakistan. A systematic review and meta-analysis has documented its prevalence in the country, and studies among university students in Karachi and Lahore have examined self-medication and the use of online health information.[7-9] The growing availability of AI chatbots introduces an additional source of health information that may influence individual health decisions. However, evidence from Pakistan remains limited regarding the proportion of adult chatbot users who report acting on chatbot-generated treatment or medication advice and the attitudinal factors associated with this behaviour. The objective of this study was to determine the proportion of adult AI chatbot users in Pakistan who reported following a treatment or medication plan based solely on chatbot advice. The secondary objectives were to compare trust in chatbot-generated health information across age groups and identify attitudinal factors associated with following chatbot advice. The study also described participants' self-reported outcomes and side effects after following chatbot advice. It was hypothesised that trust in chatbot information would differ across age groups and that greater trust and confidence in self-medication would be associated with following chatbot advice.

METHODOLOGY

This cross-sectional study was conducted by the Department of Medicine, Allama Iqbal Medical College, Lahore, Pakistan, from 29 September 2025 to 28 March 2026. Data was collected online from adults residing in Pakistan during the study period. Residence in Pakistan was self-reported; province and district information was not collected. AI chatbots were defined as general-purpose conversational AI tools, such as OpenAI's ChatGPT, rather than chatbots specifically developed for medical use. Study was conducted in accordance with the Declaration of Helsinki. Ethical approval was obtained from the AIMC/JHL Ethical Review Board (Reference No. ERB193/6/29-08-2025/AIMC/JHL; approval date: 28 August 2025). Electronic informed consent was obtained on the first page of the Google Form before participants could proceed. Participation was voluntary. Eligible participants were adults aged 18 years or older who resided in Pakistan, had internet access, could read English, and reported previous use of at least one AI chatbot. English-reading ability and previous chatbot use were self-reported. Individuals younger than 18 years and those unable to read English were excluded. Accordingly, the study population comprised adult AI chatbot users and not the general adult population of Pakistan. The minimum sample size was calculated using the single-population proportion formula, $n = Z^2p(1 - p)/d^2$. Assuming a proportion of 50%, a 95% confidence level (Z = 1.96), and a margin of error of 5%, the required sample size was approximately 385. An additional 10% was allowed for non-response, giving a target of 424 participants. A total of 702 responses were included in the analysis. Non-probability convenience sampling was used. A structured, study-specific questionnaire was developed in English using Google Forms. The questionnaire was distributed through WhatsApp, Facebook and other social media platforms. To minimise duplicate submissions, the form was configured to allow only one response per Google account. The variables collected included demographic information (age group and gender), chatbot use, frequency of seeking medical advice through chatbots, types of health-related queries and the primary reason for using these tools. Participants were also asked about the perceived accuracy of chatbot advice, their preferred source of advice when facing a health problem, whether they had followed chatbot recommendations, and self-reported outcomes and side effects. The questionnaire further covered views on AI regulation and perceptions of AI reliance among people in the respondents' respective age groups. Seven attitude statements (Q15–Q21) assessed trust in chatbot information, perceived AI competence, confidence in self-medication, perceived reduction in the need for doctor visits, awareness of potential harms, perceived safety of self-diagnosis, and concerns about over-reliance. Each statement used a five-point Likert response scale ranging from strongly disagree to strongly agree. Perceived accuracy was assessed on a five-point scale ranging from very inaccurate to very accurate. The primary reason for chatbot use was recorded as a single response, whereas multiple responses were permitted for types of health-related queries. The primary outcome was self-reported following of a treatment or medication plan based solely on AI chatbot advice, defined by a "Yes" response to the question, "Have you ever followed a treatment or medication plan based solely on AI advice?" Secondary outcomes were assessed through participants' self-reported experiences and consequences following chatbot advice, including perceived benefits or adverse effects of the recommended treatment and drug-related side effects, where applicable. Principal variables were trust in chatbot information (Q15), confidence in self-medication after consulting a chatbot (Q17), and perceived accuracy of chatbot advice. Educational status, occupation, and socioeconomic status were not collected. The questionnaire was completed anonymously, and personal identifiers were not recorded. Available-case analysis was used, and denominators are reported where they differ from the total sample. Data was analysed using R version 4.5.1. Categorical variables were summarised as frequencies and percentages. Ordinal variables, including

Likert-scale responses and perceived accuracy, were scored from 1 to 5 and summarised using response distributions, percentages, and medians. Chi-square tests were used to examine associations between age group and preferred source of advice, following chatbot advice, and frequency of use; between gender and following chatbot advice; and between the primary reason for chatbot use and following advice. When more than 20% of cells had expected counts below 5, a Monte Carlo simulated p-value based on 20,000 replicates was also calculated. Kruskal–Wallis tests were used to compare ordinal responses across age groups and between participants who did and did not report following chatbot advice, as applicable. Spearman rank correlation was used to assess associations among the seven attitude items (Q15–Q21). Internal consistency was assessed using Cronbach's alpha after reverse-scoring Q19 and Q21. As the items addressed related but distinct constructs, individual items were also analysed separately. Multivariable binary logistic regression was used to examine factors associated with self-reported following of chatbot advice. Trust in chatbot information, confidence in self-medication, and perceived accuracy were entered as ordinal scores. Age group and gender were entered as categorical variables in the multivariable logistic regression analysis, using 18–25 years and female gender as the respective reference categories. The analysis also assessed whether the association between perceived accuracy of chatbot advice and following that advice varied across age groups. Results were expressed as odds ratios (ORs) with Wald 95% confidence intervals (CIs). Statistical significance was set at $p < 0.05$. Analyses were based on available responses, with the number of responses specified wherever it differed from the total sample.

RESULTS

A total of 702 participants were included. Most were aged 18–25 years (640, 91.2%), and 431 (61.4%) were male. Total 658 participants (93.7%) reported using AI chatbots for health-related queries. Convenience and speed were the most frequently reported primary reasons for use (457, 65.1%), followed by privacy concerns (114, 16.2%), limited access to healthcare (76, 10.8%), and trust in AI capabilities (55, 7.8%). Symptom checking was the most common type of health-related query (372, 53.0%); multiple query types could be selected. Participant characteristics and chatbot use patterns are summarized in Table 1.

Overall, 213 participants (30.3%; 95% CI 27.1%–33.8%) reported having followed a treatment or medication plan based solely on AI chatbot advice. Frequency of chatbot use did not differ significantly across age groups ($\chi^2(6) = 4.57$, $p = 0.600$). Following chatbot advice was not significantly associated with age group ($\chi^2(3) = 1.03$, $p = 0.793$) or gender ($\chi^2(2) = 2.58$, $p = 0.275$), but was associated with the primary reason for chatbot use ($\chi^2(3) = 8.53$, $p = 0.036$). The proportion reporting that they had followed advice was highest among participants citing privacy concerns (37.7%), followed by trust in AI (34.5%), convenience (30.0%), and limited healthcare access (18.4%). Healthcare professionals were the most frequently preferred source of advice across all age groups. Preferred source was associated with age group ($\chi^2(9) = 19.80$, $p = 0.019$; Monte Carlo $p = 0.037$). Trust ratings differed across age groups (Kruskal–Wallis $H(3) = 9.46$, $p = 0.024$). Perceived-accuracy ratings differed between participants who did and did not report following chatbot advice (Kruskal–Wallis $H(1) = 17.48$, $p < 0.001$). The median rating in both groups was "somewhat accurate"; participants who reported following advice more

Table 1. Participant characteristics, AI chatbot use, and responses to chatbot advice questions

Characteristics	Frequency n (%)
Age group (years)	
18–25	640 (91.2%)
26–35	47 (6.7%)
36–45	9 (1.3%)
46–60	6 (0.9%)
Gender	
Male	431 (61.4%)
Female	268 (38.2%)
Prefer not to say	3 (0.4%)
Used AI chatbots for health-related queries	
Yes	658 (93.7%)
No	44 (6.3%)
Frequency of use for medical advice	
Rarely (1–2 times a year)	263 (37.5%)
Occasionally (1–2 times a month)	220 (31.3%)
Often (once a week or more)	219 (31.2%)
Primary reason for use	
Convenience and speed	457 (65.1%)
Privacy concerns	114 (16.2%)
Limited access to healthcare	76 (10.8%)
Trust in AI capabilities	55 (7.8%)
Types of health query (multiple responses permitted)	
Symptom checking	372 (53.0%)
Health tips	339 (48.3%)
Diagnosis	286 (40.7%)
Medicine recommendations	207 (29.5%)
Followed a treatment or medication plan based solely on chatbot advice	
Yes	213 (30.3%)
No	489 (69.7%)
Outcome item response (n = 436)	
Partial improvement	244 (56.0%)
Full recovery	60 (13.8%)
No change	119 (27.3%)
Worsening	13 (3.0%)
Side-effect item response (n = 528)	
Yes	121 (22.9%)
No	407 (77.1%)

frequently selected "very accurate." Confidence in self-medication, perceived accuracy, and awareness that chatbot advice may be harmful did not differ significantly across age groups (all $p > 0.05$).

The seven attitude items (Q15–Q21), with Q19 and Q21 reverse-scored, had a Cronbach's alpha of 0.749. Corrected item–total correlations ranged from 0.27 to 0.67. The strongest positive Spearman correlations were between perceived AI competence and confidence in self-medication ($\rho = 0.634$), trust in chatbot information and confidence in self-medication ($\rho = 0.577$), and trust in chatbot information and perceived AI competence ($\rho = 0.556$); all had $p < 0.001$ (Table 2).

In multivariable logistic regression, greater confidence in self-medication was associated with higher odds of reporting that chatbot advice had been followed (OR 1.87, 95% CI 1.55–2.25; $p < 0.001$), as was greater trust in chatbot information (OR 1.31, 95% CI 1.05–1.64; $p = 0.018$). Perceived accuracy, gender, and age 26–35 years were not significantly associated with the outcome. Estimates for the 36–45- and 46–60-year age groups and the "prefer not to say" gender category were not estimable because of sparse data (Table 3).

The outcome and side-effect items were completed by 436 and 528 participants, respectively. Because these items were not restricted by questionnaire skip logic to participants reporting following chatbot advice, their responses are presented for the respondents who completed each item and are not attributed exclusively to the 213 participants who reported following advice. Among respondents to the outcome item (n = 436), 244 (56.0%) reported partial improvement, 60 (13.8%) full recovery, 119 (27.3%) no change, and 13 (3.0%) worsening. Among respondents to the side-effect item (n = 528), 121 (22.9%) reported side effects and 407 (77.1%) did not. A total of 484 participants (68.9%) agreed that AI chatbots may provide incorrect or harmful medical advice. In addition, 60.4% considered over-reliance on AI for medical decisions a serious public health issue.

DISCUSSION

In this cross-sectional survey of adult AI chatbot users in Pakistan, approximately three in ten participants (30.3%, 213/702) reported having followed a treatment or medication plan based solely on chatbot advice. Confidence in self-medication and trust in chatbot information were the factors most strongly associated with this behaviour (p-values below 0.001 and 0.018, respectively). However, these findings are based on participants' self-reports and do not independently verify whether they took the recommended medication or whether their actions constituted self-medication in clinical terms. The proportion reporting that they had followed chatbot advice was lower in the present study (30.3%) than the 48.4% reported in an earlier web-based survey of 63 users of large language model chatbots seeking health information.[1] However, the two findings are not directly comparable. The earlier survey considered following chatbot advice across different health-related contexts, whereas the present study specifically assessed whether participants had followed a treatment or medication plan based solely on AI advice. Differences in participant selection, question wording, healthcare context and the behaviour assessed may explain the variation in

Table 2. Spearman correlation matrix of the seven attitude items (Q15–Q21)

Variable	1	2	3	4	5	6	7
1. Trust in AI information	1.000						
2. Perceived AI competence	0.556	1.000					
3. Confidence in self-medication	0.577	0.634	1.000				
4. AI reduces doctor visits	0.183	0.312	0.289	1.000			
5. Awareness of potential harm	−0.228	−0.230	−0.301	−0.266	1.000		
6. Safety of AI self-diagnosis	0.527	0.460	0.546	0.146	−0.093	1.000	
7. Concern about over-reliance	−0.291	−0.383	−0.394	−0.163	0.308	−0.314	1.000

Values are Spearman's ρ.

Table 3. Multivariable logistic regression estimates for following chatbot advice

Variable	OR (95% CI)	p-value
Confidence in self-medication	1.87 (1.55–2.25)	<0.001
Trust in chatbot information	1.31 (1.05–1.64)	0.018
Perceived accuracy	1.13 (0.87–1.47)	0.341
Male vs female	0.97 (0.67–1.40)	0.875
Age 26–35 vs 18–25 years	4.85 (0.20–120.53)	0.336
Age 36–45 years	Not estimable	—
Age 46–60 years	Not estimable	—
Prefer not to say vs female	Not estimable	—

the reported proportions. An earlier study of an intelligent web-based symptom checker assessed users' intentions to follow recommendations, such as self-care or delaying medical consultation, rather than their actual subsequent behaviour. [5] Intending to follow online health advice is different from acting on a treatment or medication plan. In the present study, participants who felt more confident about managing their health without professional advice may have been more willing to act on chatbot recommendations, while greater trust may have made the advice seem more reliable. Trust in chatbot information, perceived AI competence and confidence in self-medication were also positively correlated (correlation coefficients 0.556–0.634; all p-values below 0.001), suggesting that these perceptions were related, although they represented different aspects of participants' views. Perceived accuracy was associated with following chatbot advice in the unadjusted analysis (p-value below 0.001) but was not independently associated in the multivariable model (p-value 0.341). This may be because perceived accuracy overlaps with trust and confidence, while a general impression of accuracy does not necessarily determine whether a particular recommendation is considered reliable enough to follow. Moreover, users' perceptions of accuracy may not reflect the actual quality of chatbot responses. The broader evidence on chatbot quality supports caution, although it cannot establish whether the advice followed by participants in the present survey was correct or harmful. Studies of symptom checkers have reported substantial variation in diagnostic and triage performance, with a subsequent systematic review also highlighting considerable heterogeneity across tools and evaluation methods.[2,3] In a study assessing ChatGPT responses to medication-related questions, only 10 of 39 responses were considered satisfactory according to the study criteria.[4] By contrast, an evaluation of chatbot responses to physician questions reported generally high ratings for accuracy and completeness, although limitations in reliability and generalisability were also identified.[10] These findings indicate that the quality of chatbot responses may vary according to the clinical task, type of question and evaluation criteria. Perceived accuracy was associated with following chatbot advice in the unadjusted analysis (p-value below 0.001) but was not independently associated in the multivariable model (p-value 0.341). This may be because perceived accuracy overlaps with trust and confidence, or because a general impression of accuracy does not necessarily determine whether a particular recommendation is considered reliable enough to follow. Importantly, users' perceptions of accuracy do not necessarily reflect the actual quality of the information provided by chatbots. The broader evidence on chatbot quality supports caution, but it cannot establish whether the advice followed by participants in the present survey was correct or harmful. Studies of symptom checkers have reported substantial variation in diagnostic and triage performance, with a subsequent systematic review also highlighting considerable heterogeneity across tools and evaluation methods.[2,3] In a study assessing ChatGPT responses to medication-related questions, only 10 of 39 responses were considered satisfactory according to the study criteria.[4] By contrast, an evaluation of chatbot responses to physician questions reported generally high ratings for accuracy and completeness, although limitations in reliability and generalisability were also identified.[10] These findings indicate that the quality of chatbot responses may vary according to the clinical task, type of question and evaluation criteria. A simulated-patient study in low- and middle-income country settings further illustrates why diagnostic correctness alone is insufficient, reporting frequent unnecessary or potentially harmful medication recommendations despite some correct diagnoses.[11] The present survey did not record the chatbot used, the clinical problem, the exact advice provided or the medication involved. Therefore, it was not possible to assess the accuracy or safety of individual recommendations. A systematic review and meta-analysis from Pakistan estimated a pooled self-medication prevalence of 64%, although substantial heterogeneity among the included studies and a wide prediction interval indicated considerable variation in prevalence estimates.[7] This variation may reflect differences in study populations and definitions of self-medication. Self-medication practices have also been reported in different student populations across the region. Research among South Indian pharmacy students has reported the use of the internet and AI for self-diagnosis and self-medication.[6] Similarly, a cross-sectional study of 451 university students in Lahore reported online self-diagnosis and self-prescription, including antibiotic self-medication.[9] However, these studies did not specifically assess whether participants followed treatment or medication advice provided by AI chatbots. The present study focused specifically on participants who reported following a treatment or medication plan based solely on chatbot advice, rather than on self-medication in general. Healthcare professionals remained the most frequently preferred source of health advice across all age groups, although preferences for information sources and trust in chatbot information varied significantly by age. This suggests that chatbot use may coexist with a continued preference for professional medical advice rather than necessarily replacing it. Qualitative research on young adults' use of

symptom checkers has similarly described their use for self-diagnosis and their role in decisions about seeking professional help.[12] Although healthcare professionals remained the preferred source of advice across age groups, differences in trust ratings by age require cautious interpretation. Participants aged 18–25 years (640, 91.2%) constituted the large majority of the sample, whereas those older than 25 years (62, 8.8%) were relatively few. This imbalance limited meaningful comparisons across age groups and made the findings for older participants less reliable. The observed difference in trust scores therefore does not establish a consistent age-related pattern. Convenience and speed were the most frequently reported reasons for chatbot use (457, 65.1%), while a smaller proportion cited limited access to healthcare (76, 10.8%). These findings indicate that convenience was the leading reported motivation, but do not establish that difficulties in accessing healthcare led participants to use chatbots or follow their advice. However, the questionnaire did not collect information on affordability, waiting times, distance from healthcare facilities, service availability or participants' ability to obtain a timely clinical consultation. National and regional evidence on physician availability and inequalities in healthcare access in Pakistan provides useful context but does not establish the circumstances of individual respondents.[13,14] Further research could assess these barriers directly and clarify their relationship with chatbot use and treatment decisions. Furthermore, responses to the outcome and side-effect questions were obtained from all participants who completed these items, rather than exclusively from the 213 participants who reported following chatbot advice. Consequently, the responses from the 436 participants who completed the outcome item and the 528 who completed the side-effect item cannot be attributed specifically to those who acted on chatbot advice. These findings therefore do not establish recovery, treatment effectiveness or adverse effects among participants who followed chatbot recommendations. They describe only the responses provided by those who completed each item. Future studies could obtain more meaningful information by directing these questions to participants who confirm acting on chatbot advice and recording the clinical problem, recommended treatment, actual medication use, subsequent outcomes and any adverse effects. The questionnaire also did not collect information on affordability, waiting times, distance from healthcare facilities, service availability or participants' ability to obtain a timely clinical consultation. National and regional evidence on physician availability and inequalities in healthcare access in Pakistan provides useful context, but cannot establish the circumstances of individual respondents.[13,14] Further research could assess these barriers directly and clarify their relationship with chatbot use and treatment decisions. One further finding was that 68.9% of participants recognised that AI chatbots may provide incorrect or harmful medical advice, while 30.3% reported having followed a treatment or medication plan based solely on chatbot advice. The coexistence of these findings raises the possibility of a gap between awareness of potential harm and decisions to act on chatbot recommendations. However, the available results do not establish whether the same participants who recognised these risks also followed chatbot advice. The survey cannot establish whether participants who recognised these risks were the same individuals who reported following chatbot advice, as this individual-level association was not assessed. Awareness of potential harm, therefore, does not necessarily translate into safer decisions. World Health Organization guidance on large multimodal models for health highlights the importance of governance, human oversight and safeguards against misleading or harmful outputs.[15] Research on AI deployment in low- and middle-income countries has also identified potential benefits alongside contextual challenges relating to implementation, infrastructure, privacy and cultural appropriateness.[16,17] This evidence highlights the importance of responsible implementation and clear public guidance, although it does not establish the frequency of harm among participants in the present survey.

Several limitations need to be considered when interpreting these findings. Recruitment through social media using convenience sampling may have favoured digitally active individuals who could read English, and the sample was heavily concentrated in the youngest age group. Residence was self-reported, and province and district information was not collected, limiting geographical analysis. All key behaviours and attitudes were self-reported and may have been affected by recall or social desirability bias. Restricting the form to one response per Google account may have reduced duplicate submissions but did not confirm that each response came from a unique individual. The cross-sectional design does not establish temporality, while education, occupation, socioeconomic status and individual healthcare access were not measured, leaving potential for residual confounding. Finally, the seven attitude items addressed related but distinct constructs; therefore, the internal consistency estimate does not establish that they constitute a single unidimensional scale. Future research could include more representative recruitment across age groups, provinces, languages and levels of digital access. Prospective studies would help establish whether trust and confidence precede subsequent decisions to follow chatbot advice. Collecting detailed information about each episode of chatbot use would also help assess the clinical

context, the advice provided and the safety of the recommended treatment. Further studies could distinguish between seeking health information, intending to act on chatbot advice, actually using recommended treatments or medicines, and self-medication without prior professional guidance. Public education could focus on verifying AI-generated health information and seeking professional assessment for serious symptoms or before starting medicines associated with important risks. The effectiveness of such educational interventions would need to be evaluated.

CONCLUSION

Among adult AI chatbot users surveyed in Pakistan, approximately one-third reported following a treatment or medication plan based solely on chatbot advice. Greater confidence in self-medication and trust in chatbot information were independently associated with this behaviour, whereas perceived accuracy, age and gender were not independently associated. Trust in chatbot information varied across age groups, although healthcare professionals remained the preferred source of health advice in all age groups. These findings highlight the association of trust and confidence in self-medication with decisions to follow chatbot advice and emphasise the importance of reliable health information and professional guidance in treatment-related decisions.

Author Contributions

MZ: Conceptualization, Supervision, Writing – original draft; MM: Formal analysis; MA: Data curation, Writing – review & editing; MF: Investigation, Writing – original draft; AA: Investigation; SRR: Investigation; MAb: Investigation; MS: Writing – original draft, Writing – review & editing; MHM: Writing – original draft, Writing – review & editing; US: Writing – original draft, Writing – review & editing; AH: Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

AI Disclosure

ChatGPT (OpenAI) was used during the preparation of this manuscript for language editing and improvement of manuscript clarity. The AI tool was not used to generate or manipulate original research data, perform statistical analysis, or independently develop scientific conclusions or interpretations. All AI-assisted text and suggestions were critically reviewed, edited, and approved by the authors. The authors remain fully responsible for the accuracy, originality, integrity, scientific content, data interpretation, and conclusions of the manuscript

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