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Knowledge and Views of Patients With Cardiovascular Disease Toward Pharmacogenomics in The United Arab Emirates

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ABSTRACT

Pharmacogenomics (PGx) can potentially tailor medication prescriptions to the genetic profiles of individuals, enhancing treatment outcomes and minimizing adverse drug reactions. This study assessed cardiovascular disease (CVD) patients' knowledge and views toward PGx testing in the United Arab Emirates (UAE). A cross-sectional study was conducted among CVD patients attending multiple clinics using a validated, culturally adapted, and piloted bilingual questionnaire. Participants were invited via phone calls or in-person contact at clinics. Data analysis was conducted using SPSS V.29, incorporating descriptive statistics and multivariable logistic regression. A total of 425 responses were analyzed; 67.5% were over 50 years old, and 67.5% held a bachelor's degree. Chronic diseases, excluding CVD, affected 65.2%, with 58.1% reporting medication side effects and 36.5% was hospitalized due to these effects. Knowledge varied, with 55.3% demonstrating good knowledge; 75.3% recognized DNA as gene-based, while 47.5% understood PGx for predicting medication responses. Participants were grouped into three PGx perception clusters: Cluster 1 (33.17%) concerned about risks but valued PGx, Cluster 2 (40.23%) worried about privacy/costs, and Cluster 3 (26.58%) confident in PGx benefits. Safety was the top priority for 60.2% of respondents, 34.8% would not pay for PGx tests, and 35.3% preferred preemptive testing. Regression linked higher PGx knowledge to females, non-healthcare workers, those with genetic diseases, and those hospitalized for side effects ($p < 0.05$). The study highlights a need for educational initiatives in the UAE to improve PGx literacy among CVD patients. The findings suggest that targeted awareness campaigns, policy interventions addressing privacy, and financial support could promote PGx wider adoption.

1 | Introduction

Pharmacogenomics (PGx) studies are concerned with how an individual's genetic makeup influences their response to drugs,

enabling the development of personalized treatment plans that aim to optimize therapeutic efficacy while minimizing adverse drug reactions [1, 2]. PGx examines genetic variations that affect key pharmacokinetic processes, such as drug absorption, distribution,

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Summary

- What is the current knowledge on the topic?
 - PGx can improve therapeutic safety and effectiveness, but global patient awareness remains low. In the Middle East, particularly the UAE, most PGx-related studies have focused on healthcare providers, leaving a critical gap in understanding patient perspectives and readiness.
- What question did this study address?
 - This study explored PGx knowledge, attitudes, and willingness to adopt PGx testing among cardiovascular patients in the UAE and identified demographic, clinical, and attitudinal factors associated with knowledge levels.
- What does this study add to our knowledge?
 - Over half of the 425 patients were unfamiliar with PGx. However, knowledge was significantly higher among females, individuals with genetic conditions, those hospitalized due to medication side effects, and patients on more than 10 medications. Despite 92.7% having insurance, one-third were unwilling to pay out of pocket, highlighting cost as a barrier. Preference for preemptive testing and trust in PGx benefits were strong, indicating openness to integration.
- How might this change clinical pharmacology or translational science?
 - The findings emphasize the importance of patient-targeted education and highlight patient subgroups that may serve as early adopters of PGx. The results also inform UAE health policymakers on insurance gaps, support integrating PGx into routine cardiovascular care, and underscore the urgency for regionally tailored implementation strategies.

metabolism, and elimination, as well as pharmacodynamic factors like drug-target interactions, thereby informing safer and more effective therapies [3, 4]. With the advent of cost-effective genotyping, including Next Generation Sequencing, this field has become a cornerstone of personalized medicine, particularly in managing chronic diseases such as cardiovascular disease (CVD), cancer, and psychiatric disorders, where individualized drug therapies often lead to improved outcomes [5, 6].

CVD continue to be a leading cause of morbidity and mortality worldwide, necessitating ongoing advancements in diagnostic and therapeutic approaches [7]. PGx has shown promise in cardiovascular medicine, where genetic testing guides the prescription of medications such as anticoagulants, statins, and beta-blockers [8, 9]. Global clinical trials and implementation programs have demonstrated that PGx testing improves patient outcomes, reduces adverse drug reactions, and optimizes drug selection [10]. Recent advancements in genotyping and novel gene discoveries have expanded the availability of genetic tests, enabling healthcare providers to personalize treatments [11].

Adverse drug reactions (ADRs) are a major global health issue, with CVD medications being a notable contributor to these events [12]. Drugs such as anticoagulants, statins, and antihypertensives

can cause serious complications such as bleeding, myopathy, and hypotension [13–15]. PGx offers a solution by identifying patients at higher risk for ADRs, allowing for personalized medication choices, particularly for drugs like warfarin and clopidogrel, which can improve patient outcomes and reduce healthcare costs [16].

As PGx testing becomes more accessible in clinical practice, understanding patients' knowledge, attitudes, and perceptions is essential for successful implementation. In the Middle East, PGx adoption and integration into clinical practice have been slower than in Western countries [17]. Integrating PGx testing into clinical practice in the United Arab Emirates (UAE) is still in its early stages, with limited research exploring its potential [18]. Studies on Emirati patients have highlighted significant genetic variations impacting drug efficacy and safety. Recent studies in the UAE revealed significant genetic variations for statins, clopidogrel, warfarin, and antidepressant metabolism, highlighting the need for population-specific PGx research in the UAE [19–22]. Assessing cardiovascular patients' knowledge, perceptions, and willingness regarding PGx is crucial for informed decision-making and identifying areas where educational interventions are needed [23]. Additionally, understanding patients' attitudes and concerns, such as privacy, ethical considerations, and perceived barriers, will help address adoption challenges. While global attention to PGx is increasing, a need remains for focused studies within the UAE and the broader Middle East, particularly concerning its acceptance in cardiovascular care [24, 25].

This study aims to assess the knowledge and perspectives of cardiovascular (CVD) patients in the UAE regarding PGx testing. This study's objectives are: first, evaluate patients' understanding of fundamental genetic concepts and PGx applications, particularly concerning disease risk and medication response; second, explore patients' attitudes and perceptions on privacy, cost, and potential social implications associated with PGx testing; and finally, examine patients' preferences for the timing of PGx testing and their willingness to pay out of pocket for the PGx tests.

2 | Methods

2.1 | Study Design and Setting

This cross-sectional study was conducted among cardiovascular patients recruited from diverse healthcare settings across the United Arab Emirates (UAE), including government and private hospitals in different Emirates. The sample also included participants from the EmHeart Study, a clinical trial conducted in Al-Ain that investigated the clinical utility of PGx testing for commonly prescribed cardiovascular drugs such as warfarin, clopidogrel, atorvastatin, and rosuvastatin [21].

2.2 | Study Tool

A structured questionnaire developed from an extensive review of PGx literature [26–28] included five sections: demographics, genetic and PGx knowledge, perceptions and attitudes, testing priorities, and willingness to pay. Some sections were adapted

from validated instruments, while others were tailored to align with study objectives and the local context. A certified, back-to-back translation process ensured cultural and linguistic accuracy (Tables S1 and S2).

2.3 | Validation and Reliability

A panel of PGx experts and academic professionals reviewed the content for relevance, clarity, and accuracy. Following this, a pilot test was conducted with 40 cardiovascular patients in the UAE to evaluate readability, clarity, and cultural fit. Based on participant feedback, minor wording adjustments were made to enhance understanding. The overall reliability of the questionnaire was assessed with a Cronbach's alpha of 0.74, indicating acceptable internal consistency.

2.4 | Sample Size and Sampling

Using Daniel's formula ($n = Z^2 P(1 - P)/d^2$), a sample size of 384 was calculated based on a 95% confidence level, 50% estimated prevalence, and 5% margin of error. Without prior data on knowledge prevalence, an estimated prevalence of 50% (0.5) was assumed [29]. A total of 425 participants were recruited to ensure adequate representation.

Inclusion criteria targeted adult patients (aged 18 years and older) diagnosed with one or more cardiovascular diseases, such as hypertension, dyslipidaemia, ischemic heart disease, myocardial infarction, stroke, or heart failure, and receiving at least one of the PGx relevant CVD medications.

Convenience sampling was applied: trial participants who completed follow-ups were contacted by phone, while patients visiting hospital cardiac clinics were invited in person.

2.5 | Data Collection

Data collection was conducted using two primary methods. The first group consisted of the trial participants contacted by phone, with follow-up reminders. The second group included patients recruited from various cardiac clinics, who were approached in the clinic waiting areas. Before inviting them to participate, clinic investigators verified each patient's cardiovascular diagnosis with current medication through the healthcare system. Following an introduction to the study, participants were allowed to complete the survey on-site or receive follow-up via email or WhatsApp. Data collection occurred from December 10, 2023, to November 30, 2024. Investigators received professional training to ensure the study was introduced clearly, allowing patients to understand the process and participate without bias.

2.6 | Data Analysis

Data analysis was performed using SPSS version 29. Descriptive statistics were used to summarize categorical variables, and normality was assessed with Kolmogorov–Smirnov and Shapiro–Wilk tests. Due to the non-normal data distribution,

non-parametric analyses were applied. Exploratory factor analysis (EFA) was conducted to identify latent constructs in the knowledge and perception sections, supported by a high Kaiser–Meyer–Olkin (KMO) value. K-means clustering was used to segment participant attitudes into distinct profiles. Multivariable logistic regression was employed to examine factors associated with PGx knowledge, and sensitivity analysis was performed to validate the model's robustness.

2.7 | Ethical Considerations

Ethical approval was obtained from ethics committees for both trial and hospital-recruited patients (DSREC-SR-11/2024_06) and the Abu Dhabi Health Research and Technology Ethical Committee (DOH/CVDC/2020/1187; DOH/CVDC/2021/1519; and DOH/CVDC/2022/1458). Participants provided electronic informed consent and were informed of their anonymity, right to withdraw, and data confidentiality. No personal identifiers were recorded, and consent forms were distributed electronically before survey participation.

3 | Results

3.1 | Participants Demographics

Participants' demographics revealed a slight majority of males, 221 (52%), with most participants, 287 (67.5%), being over 50 years of age. Educationally, the majority hold at least a bachelor's degree, 287 (67.5%), while 185 (43.5%) are not currently employed. Another chronic disease, rather than CVD, prevalence stands at 277 (65.2%), with over half, 247 (58.1%), having experienced medication side effects, and 155 (36.5%) of these individuals have been hospitalized due to such side effects. Additionally, 216 (50.8%) participants were unaware of PGx (Table 1).

3.2 | Participants Knowledge

Regarding the participant's knowledge, most participants correctly identified that genes are made of DNA, 320 (75.3%) and that a healthy person could be a carrier of genetic diseases, 315 (74.1%). However, only 202 (47.5%) understood that PGx could determine medication responses. Knowledge of specific applications of PGx was lower, with only 171 (40.2%) aware that tests could suggest suitable drugs (Table 2).

3.3 | Normality Test of Knowledge Score

The Kolmogorov–Smirnov (Statistic=0.109, $p < 0.001$) and Shapiro–Wilk (Statistic=0.950, $p < 0.001$) tests indicated significant deviations from normality in the Knowledge Score, justifying the use of non-parametric methods for subsequent analyses.

3.4 | Knowledge Score Categories

The median knowledge score was 6.00, with an interquartile range from 4.00 to 8.00. Given the non-normal distribution of

TABLE 1 | Characteristics of the participants.

Demographics		N (%)
Gender	Female	204 (48)
	Male	221 (52)
Age	< 50	138 (32.5)
	> 50	287 (67.5)
Education	Bachelor's or higher	287 (67.5)
	Diploma	43 (10.1)
	High School	79 (18.6)
	Less than Secondary	16 (3.8)
Occupation	Not working	185 (43.5)
	Working-healthcare sector	36 (8.5)
	Working-non healthcare sector	204 (48)
Family monthly income	Less than 10,000 AED	184 (43.3)
	10,000–25,000 AED	154 (36.2)
	25,000–40,000 AED	52 (12.2)
	More than 40,000 AED	35 (8.2)
Medical insurance	Yes	394 (92.7)
	No	31 (7.3)
Medical History		
Do you have any genetic diseases ^a ?	Yes	287 (67.5)
	No	111 (26.1)
	Not sure	27 (6.4)
Do any of your family members have a genetic disease	Yes	302 (71.1)
	No	91 (21.4)
	Not sure	32 (7.5)
Do you have any other chronic diseases (Diabetes, arthritis, thyroid, cancer, kidney failure, liver failure, and others)	Yes	277 (65.2)
	No	122 (28.7)
	Not sure	26 (6.1)
Have you ever experienced side effects due to your medications	Yes	247 (58.1)
	No	124 (29.2)
	Not sure	54 (12.7)
Have you ever been hospitalized due to medication side effects?	Yes	155 (36.5)
	No	191 (44.9)
	Not sure	79 (18.6)
Have any of your family members ever been hospitalized due to medication side effects	Yes	184 (43.3)
	No	130 (30.6)
	Not sure	111 (26.1)

(Continues)

TABLE 1 | (Continued)

Demographics		N (%)
How long have you had any of the following cardiovascular diseases, such as high blood pressure, high cholesterol, heart disease, stroke?	1–5 years	96 (22.6)
	6–10 years	85 (20)
	> 10 years	244 (57.4)
How many medications are you taking daily?	< 5 medication/day	156 (36.7)
	5–9 medication/day	182 (42.8)
	> 10 medication/day	87 (20.5)
Source of information		
What is your source of information about Pharmacogenomics? (multi-selection)	Healthcare providers (physicians, pharmacists, nurses...)	169 (39.8)
	Books, Newspapers, and magazines	57 (13.4)
	Social media (Facebook, Instagram,...)	61 (14.4)
	Media (TV, Radio)	31 (7.3)
	Family and Friends	41 (9.6)
	I had not heard about PGx before	216 (50.8)

^aGenetic disease was defined for participants as any inherited condition, including thalassemia, sickle cell anemia, G6PD deficiency, familial hypercholesterolemia, and other hereditary disorders.

scores, the median serves as a reasonable threshold, dividing participants into “poor knowledge” (scores below 6) and “good knowledge” (scores of 6 or higher). This categorization resulted in 235 participants (55.3%) in the “good knowledge” group and 190 (44.7%) in the “poor knowledge” group.

3.5 | Participants' Perceptions and Attitudes

Participants' perceptions and attitudes toward PGx testing reveal that a majority, 363 (85.4%), believe test results will aid future health choices, and 348 (81.9%) would inform family members of any alarming findings. Privacy and confidentiality concerns are notable for 232 (54.6%), and 216 (50.8%) express concern about test costs if self-paid (Table 3).

3.6 | Participants' Priorities of the Pharmacogenomics Test

Participants prioritized safety in PGx testing, with 256 (60.2%) ranking it highest for confirming drug safety. Effectiveness was the second priority, 200 (47.1%), followed by cost efficiency, 188 (44.2%), and reducing the number of medications was the least prioritized, 275 (64.7% ranked it fourth) (Figure 1).

3.7 | Participants' Willingness to Pay and Preferred Timing for Pharmacogenomics Testing

The willingness of participants to pay for PGx testing showed varied responses. A significant proportion, 148 participants (34.8%), were unwilling to pay any out-of-pocket costs. Meanwhile, 124 participants (29.2%) were willing to pay up to 1000 AED, 89 participants (20.9%) up to 300 AED, and 64 participants (15.1%) up

to 500 AED. Moreover, participants had differing preferences regarding the timing of PGx testing. Most participants 150 (35.3%) favored undergoing testing preemptively before any medical conditions developed. Others preferred testing only upon a doctor's recommendation, 106 (24.9%) (Figure 2).

3.8 | Explanatory Factor Analysis (EFA)

The KMO and Bartlett's tests confirmed the suitability of the data for factor analysis, with a strong KMO score of 0.863 and a significant Bartlett's test ($p < 0.001$), indicating sufficient inter-item correlations. Exploratory Factor Analysis revealed acceptable factor loadings for knowledge-related items, supporting the construct of PGx knowledge, with loadings between 0.481 and 0.821. For perception-related items, the analysis identified four distinct dimensions: (i) discrimination and social impact concerns, (ii) financial and privacy concerns, (iii) personal health empowerment, and (iv) unwanted health information, with factor loadings from 0.592 to 0.763, emphasizing strong associations within each construct.

3.9 | Cluster Analysis of Participants' Attitudes and Perceptions

K-means clustering was used to categorize participants based on their attitudes toward PGx testing, with hierarchical analysis guiding the selection of a three-cluster solution. Agreement with each statement was rated on a scale from 1 to 3, with 3 indicating the highest level of agreement. The first cluster, comprising 141 participants (33.17%), exhibited low concerns about discrimination and privacy, largely disagreed with statements on unfair treatment, and held a neutral view on costs while generally recognizing the health benefits of PGx. The second

TABLE 2 | Participants' knowledge of genetics and pharmacogenomics.

Question	Correct answer N (%)	Incorrect answer N (%)
Genes are made of DNA	320 (75.3)	105 (24.7)
Genes determine the risk of developing certain diseases	273 (64.2)	152 (35.8)
Genes affect how the body reacts to certain medications	223 (52.5)	202 (47.5)
A healthy person could be a genetic disease carrier	315 (74.1)	110 (25.9)
Healthy parents could have a child with a genetic disease	312 (73.4)	113 (26.6)
Pharmacogenomics can determine how the body responds to certain medications	202 (47.5)	223 (52.5)
Pharmacogenomics tests can suggest a suitable drug dose	171 (40.2)	272.6 (59.8)
Pharmacogenomics tests can identify patients at higher risk of side effects from medication	197 (46.4)	228 (53.6)
Pharmacogenomic test samples could be obtained from saliva (spit), a cheek swab, or blood	248 (58.4)	177 (41.6)
Pharmacogenomic tests for specific medications are typically done only once in a lifetime	171 (40.2)	254 (59.8)

cluster, with 171 participants (40.23%), expressed high concerns regarding privacy, confidentiality, and financial costs, showing heightened caution about sharing genetic information. The third cluster, including 113 participants (26.58%), showed minimal concerns about risks such as discrimination and privacy, focusing instead on the empowerment and health benefits of PGx and expressing strong confidence in using test results to inform their health decisions (Figure 3 and Table S3).

3.10 | Comparative Analysis of the Clusters

The Kruskal-Wallis test shows significant differences in knowledge scores across clusters ($p = 0.040$). Cluster 2 has the highest mean rank, suggesting higher knowledge scores than Clusters 1 and 3. A pairwise comparison was conducted using the Mann-Whitney U test with Bonferroni correction. The results revealed that only the difference between Cluster 2 and 3 remained statistically significant ($p = 0.012 < 0.0167$), which indicates that participants in Cluster 2 have significantly higher knowledge levels than those in Cluster 3. In contrast, no significant differences were observed between Clusters 1 and 2 or Clusters 1 and 3.

3.11 | Multivariable Logistic Regression

Chi-square analysis revealed significant associations between PGx knowledge and demographic and health-related variables. Participants under 50, those with a bachelor's degree or higher, higher family income, healthcare workers, and individuals with a family history of genetic conditions or who experienced medication side effects or related hospitalizations showed higher PGx knowledge levels at ($p < 0.001$ for each) (Table S4).

TABLE 3 | Participants' perceptions and attitudes toward pharmacogenomics.

Question	Strongly agree/ Agree N (%)	Neutral N (%)	Strongly disagree/ Disagree N (%)	Mean $\pm$ SD
I believe pharmacogenomics test results will help me in my health choices in the future.	363 (85.4)	52 (12.2)	10 (2.4)	2.83 $\pm$ 0.434
If I have an alarming pharmacogenetic test result, I will inform my family members.	348 (81.9)	53 (12.5)	24 (5.6)	2.76 $\pm$ 0.543
The pharmacogenomics test results Might reveal health information I would rather not know.	290 (68.2)	78 (18.4)	57 (13.4)	2.55 $\pm$ 0.719
The privacy and confidentiality of the pharmacogenomics test results might concern me.	232 (54.6)	93 (21.9)	100 (23.5)	2.31 $\pm$ 0.828
The financial costs of pharmacogenomic tests will concern me if I pay it myself.	216 (50.8)	74 (17.4)	135 (31.8)	2.19 $\pm$ 0.890
The pharmacogenomics test results Might lead to unfair treatment in insurance coverage	156 (36.7)	130 (30.6)	139 (32.7)	2.04 $\pm$ 0.833
The pharmacogenomics test results Might lead to people viewing me differently.	153 (36)	114 (26.8)	158 (37.2)	1.99 $\pm$ 0.856
The pharmacogenomics test results Might lead to unfair treatment in healthcare.	76 (17.9)	133 (31.3)	216 (50.8)	1.67 $\pm$ 0.762

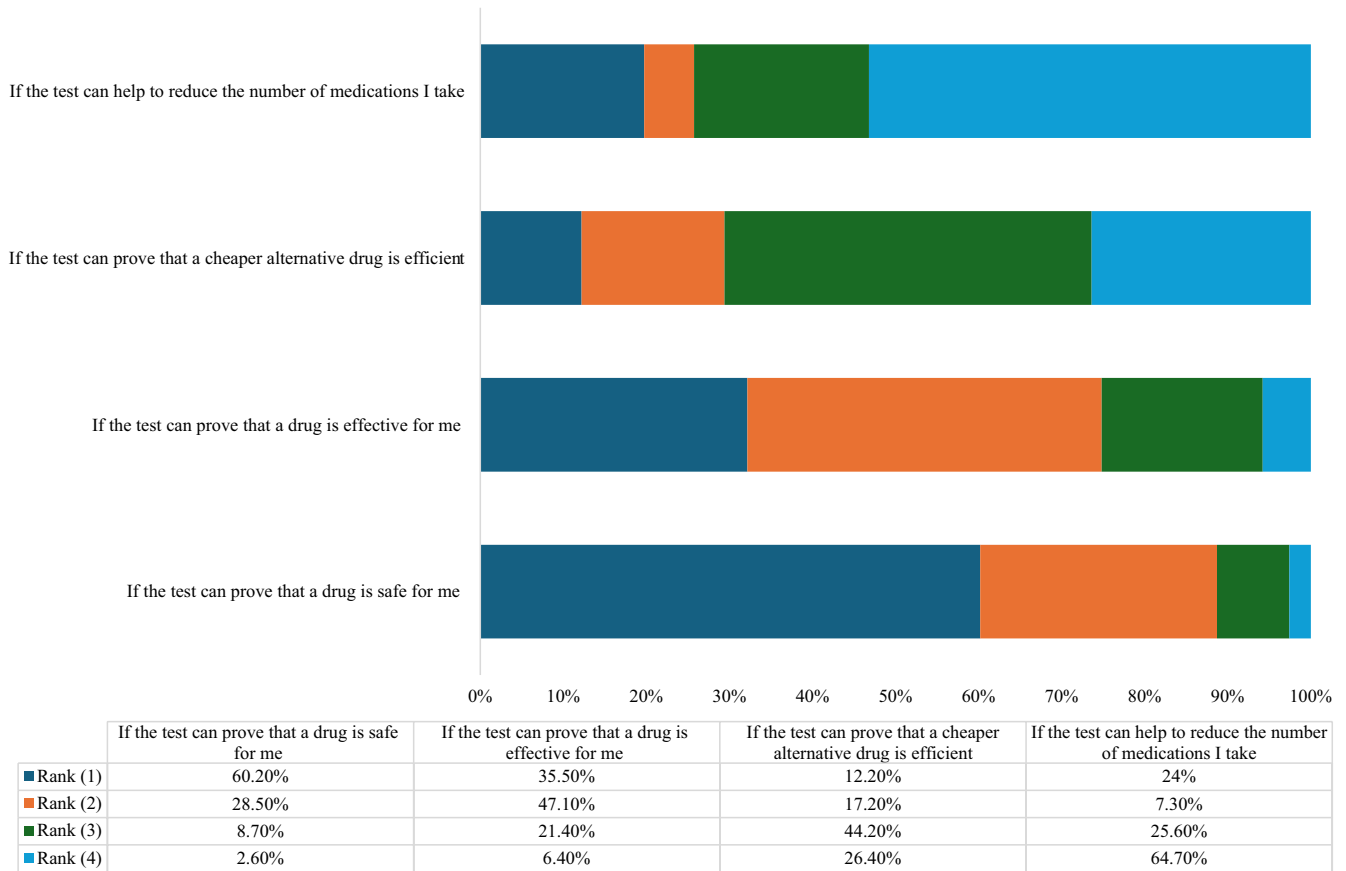


FIGURE 1 | Participants' priorities for pharmacogenomics testing: A stacked bar chart illustrates the ranked priorities of 425 cardiovascular patients regarding the potential benefits of PGx testing. Participants were asked to rank four possible benefits of PGx testing: (1) proving drug safety, (2) proving drug effectiveness, (3) identifying cheaper alternatives, and (4) reducing the number of medications taken. The graph shows the percentage of participants assigning each rank (1 = highest priority, 4 = lowest) to each benefit. Data were collected using a structured survey, and descriptive statistics were applied. Results show that drug safety was the top priority (60.2% ranked it first), while medication reduction was the least prioritized (64.7% ranked it fourth).

Multivariable analysis revealed significant associations with PGx knowledge. Females had higher odds ($OR = 2.746$, $p < 0.001$), as did those not working ($OR = 1.867$, $p = 0.05$), non-trial site participants ($OR = 2.930$, $p = 0.032$), and individuals with a genetic disease ($OR = 5.050$, $p = 0.004$). Hospitalization due to medication side effects ($OR = 2.692$, $p = 0.002$) and taking more than ten medications daily ($OR = 4.456$, $p = 0.003$) were also associated with greater knowledge. Additionally, those preferring PGx testing before medical issues arise had significantly higher knowledge ($OR = 11.4$, $p < 0.001$) (Figure 4 and Table S5).

A subgroup analysis using the Mann-Whitney U test revealed a statistically significant difference in PGx knowledge scores between EmHeart trial participants and those from hospital clinics ($p < 0.001$), with trial participants showing higher knowledge levels.

The potential for multicollinearity among independent variables was evaluated using Variance Inflation Factors (VIF). All VIF values were below the commonly accepted threshold of 5, indicating that multicollinearity is unlikely to affect this model.

3.12 | Sensitivity Test Analysis

A backward elimination method with a p -value threshold of 0.1 retained key predictors for PGx knowledge, including genetic history, experience with medication side effects, occupation type, participation site, gender, and hospitalization due to side effects, all of which contributed meaningfully to the model, which showed moderate explanatory power with a Cox & Snell R Square value of 0.288, indicating a stable fit.

4 | Discussion

This study assessed PGx knowledge and perceptions among CVD patients in the UAE, revealing a notable knowledge gap, with over half of the participants unfamiliar with PGx. However, higher awareness was observed among females, individuals with genetic conditions, those who had experienced medication side effects, and patients on complex medication regimens, suggesting that personal health experiences and proactive attitudes, including a preference for pre-emptive PGx testing, are linked to higher awareness. The frequent occurrence of medication side effects, with nearly half resulting

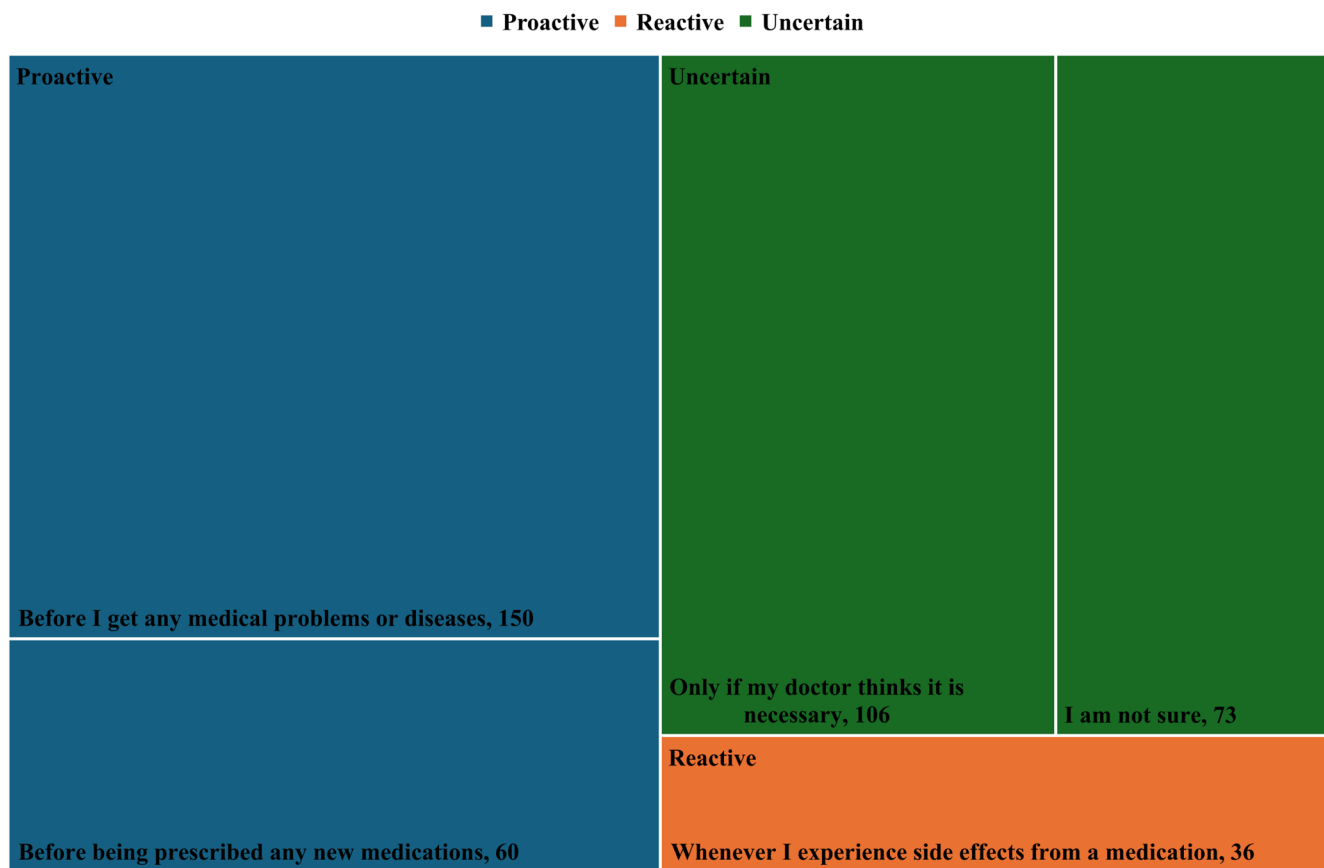


FIGURE 2 | Participants' preferred timing for pharmacogenomics testing: Treemap visualizing the preferences of 425 cardiovascular patients regarding the timing of PGx testing. Participants selected from six options, grouped into three categories: Proactive (e.g., before illness or new prescriptions), reactive (e.g., after side effects), and uncertain. Data were collected using a structured survey and analyzed descriptively. The most preferred timing was proactive testing before developing any medical conditions ($n = 150$), while the least selected was reactive testing after experiencing side effects ($n = 36$). A notable proportion ($n = 73$) were unsure when testing should occur.

in hospitalization, underscores PGx's potential to mitigate adverse drug reactions. Privacy, confidentiality, and cost were prominent concerns, while safety and effectiveness emerged as the primary motivators for testing, reflecting participants' strong prioritization of medication safety. These findings are timely, especially in the light of the recent launching the Emirati Genome Project with the mission "to advance preventive and personalized healthcare services for the UAE's present and future generations" [30]. Globally, awareness and adoption of PGx vary significantly, reflecting disparities in healthcare infrastructure, education, and cultural acceptance [31, 32]. In the Middle East and UAE, PGx knowledge has been extensively studied among healthcare providers, such as medical doctors, health sciences students, and pharmacists [24, 33, 34], while patients, as primary stakeholders in medical innovation, remain largely unexplored. Modern healthcare emphasizes a patient-centred approach, with patients increasingly shifting from passive recipients to active decision-makers [35]. Patient engagement is crucial for implementing innovations like PGx, as awareness and trust in genetic information can drive adoption and enhance drug safety and efficacy, highlighting the need for patient-focused education [36, 37].

The low level of PGx knowledge observed in this study reflects a widespread lack of awareness among patients, as reported globally. Studies such as Truong and coworkers (2019) and Pearce and coworkers (2024) have shown that while general awareness of genomics exists, understanding of PGx, particularly its role in drug efficacy and safety, remains limited [31]. Similarly, Edris and coworkers (2022) reported that only a minority in Flanders recognized the relevance of PGx, with genetics perceived as having a moderate influence on drug response [26]. These consistent findings feature the urgent need for targeted educational interventions to enhance patient understanding and support informed decision-making regarding PGx and its integration into healthcare.

Factors influencing PGx knowledge included demographics, medical history, and testing attitudes. Women and unemployed individuals showed higher knowledge, likely due to greater engagement with health information [38, 39]. At the same time, healthcare workers exhibited gaps, as proven in the literature [24, 33], reflecting the need for improved PGx education and professional training. Personal health experiences, such as having genetic diseases, being hospitalized due to medication side effects, or managing complex medication regimens, were associated with higher awareness of PGx, likely because such

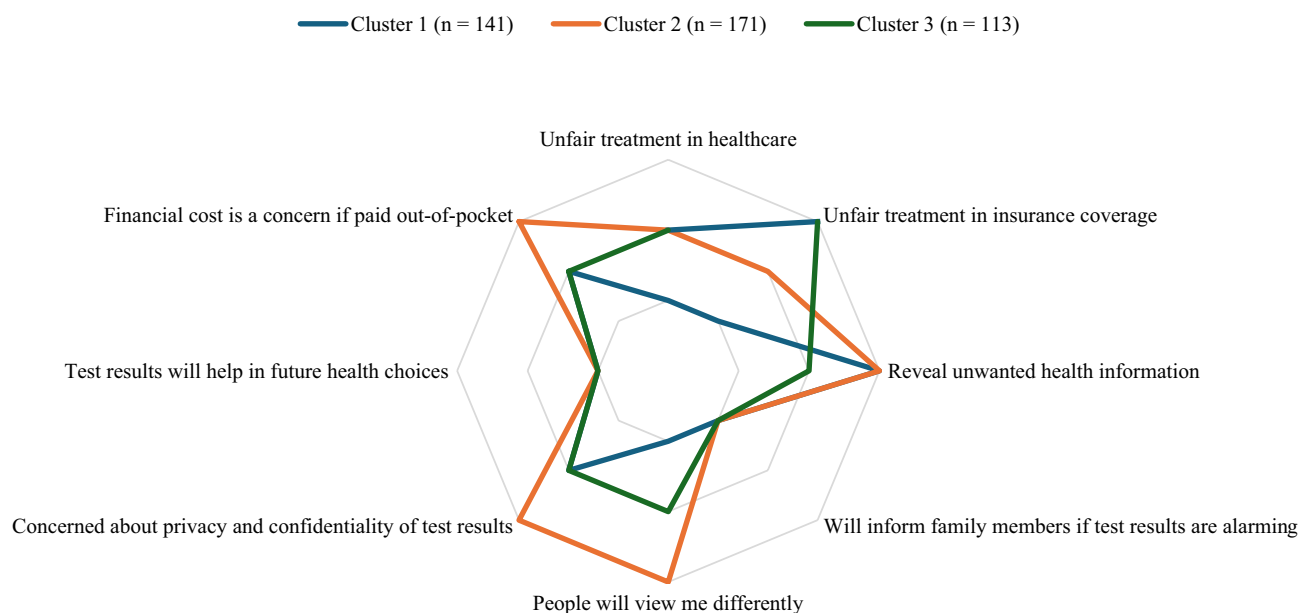


FIGURE 3 | Radar chart of participant attitudes toward PGx testing by cluster: radar chart displaying attitudinal profiles of 425 cardiovascular patients clustered into three groups based on their responses to eight perception items related to PGx testing. Clusters were derived using K-means analysis: Cluster 1 ($n = 141$), Cluster 2 ($n = 171$), and Cluster 3 ($n = 113$). Each axis represents one attitude item, measured on a 5-point Likert scale and recoded into three categories: (1 = disagree/strongly disagree, 2 = neutral, 3 = agree/strongly agree). The chart illustrates differing levels of concern across clusters. For example, Cluster 2 showed the highest concern for privacy and cost, whereas Cluster 3 displayed strong confidence in the health benefits of PGx.

experiences highlight the importance of individual variability in drug response and motivate patients to consider more personalized approaches to treatment [40]. For instance, individuals who have experienced medication side effects may become more actively engaged in understanding the reasons behind their reactions and in seeking ways to prevent similar events in the future [41]. This curiosity and concern can lead them to explore concepts like PGx, especially in healthcare environments such as the UAE, where routine clinical application of PGx remains limited. In such contexts, patients likely acquire knowledge through self-directed efforts, including online resources, social media, or informal conversations with peers, rather than through structured education from healthcare providers [42]. Likewise, patients taking many medications may develop heightened awareness due to the complexity of managing multiple therapies and the increased risk of adverse events [43]. While in some healthcare systems, polypharmacy prompts structured interventions or education from pharmacists and clinicians [44]. In the UAE this association may also reflect independent information-seeking behavior. Although our survey did not capture the specific source of PGx knowledge or whether it led to actual testing behavior, the patterns observed suggest these patient subgroups could serve as valuable entry points for future educational and clinical integration efforts.

Although part of our cohort was recruited from the EmHeart clinical trial, which included PGx testing and treatment adjustments in some arms, subgroup analysis revealed no significant difference in PGx knowledge between trial and non-trial participants. This suggests that trial participation alone, in the absence of dedicated education or counseling, may not enhance patient knowledge, underlining the need for structured awareness interventions.

Recent studies showed a growing openness toward health technologies, with most participants in this study viewing PGx testing positively for its potential to enhance health decisions. This aligns with findings that familiarity with PGx benefits promotes acceptance and confidence in its utility [32, 45, 46]. However, cost remains a significant barrier to PGx adoption worldwide. Studies from the U.S., China, and Germany, as well as this study, report that many are unwilling to pay out-of-pocket for the PGx test, emphasizing the need for insurance coverage or subsidies that can facilitate the implementation of PGx, particularly among underserved populations [40, 45, 47]. While the majority of our participants reported having medical insurance, PGx tests are not yet routinely reimbursed by insurers in the UAE. Therefore, concerns about out-of-pocket costs remain highly relevant and were reflected in participant responses.

Nearly half of the participants expressed concerns over data privacy and confidentiality, consistent with previous studies in which privacy apprehensions were prevalent [45, 48]. These concerns point to the need for strong privacy protections and transparent communication regarding the legal safeguards of patient data.

Participants in this study prioritized PGx testing for its safety, effectiveness, affordability, and ability to reduce medication needs, aligning with other studies where patients valued its role in enhancing medication safety and personalization [45, 47]. However, a Flemish study found participants focused more on PGx's potential for early prevention, with less emphasis on affordability, reflecting shared priorities and regional differences that highlight the need for tailored approaches [26].

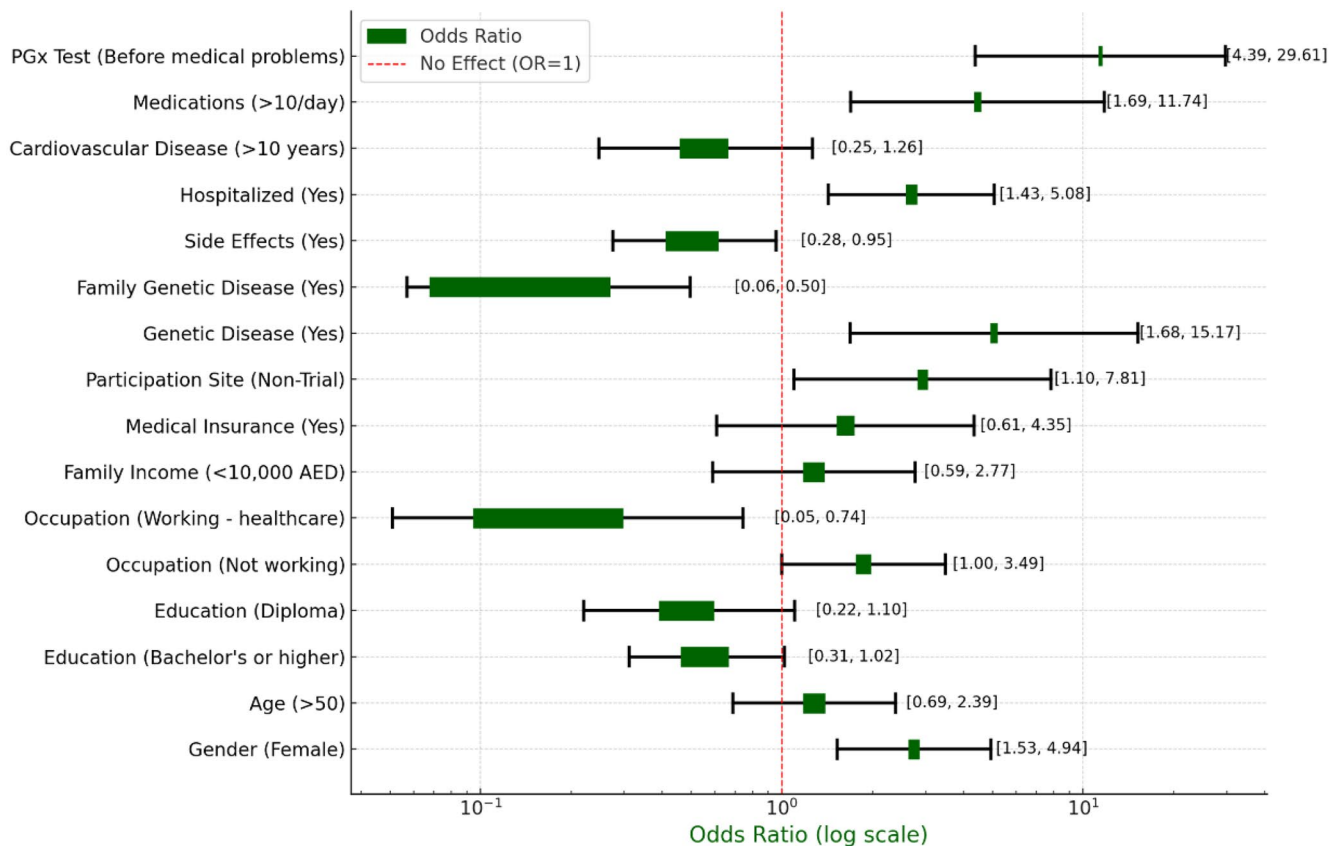


FIGURE 4 | Factors Associated with Pharmacogenomic Knowledge: Forest plot showing odds ratios and 95% confidence intervals from a multi-variable logistic regression model assessing factors associated with higher PGx knowledge among 425 cardiovascular patients. The horizontal axis represents odds ratios on a logarithmic scale (OR=1 indicates no effect). Variables examined included demographic (e.g., gender, age, education), health-related (e.g., side effects, hospitalization), and behavioral factors (e.g., preference for preemptive testing). Statistically significant predictors included being female (OR = 2.74), having a genetic disease (OR = 5.05), prior hospitalization due to side effects (OR = 2.69), and willingness to undergo PGx testing before illness onset (OR = 11.4).

Moreover, this study revealed a strong preference for preemptive PGx testing, supported by evidence of its feasibility and effectiveness in significantly reducing adverse drug reactions across diverse healthcare settings [49], which implies the need to study and investigate the possibility of integrating preemptive PGx testing into routine clinical practice in the UAE.

5 | Strengths and Limitations

This study is the first to examine PGx awareness and attitudes among cardiovascular patients in the Middle East, including EmHeart Study participants, thereby addressing a critical gap in the literature. Targeting cardiovascular patients, those who may benefit most from PGx, provides actionable insights for clinical practice in the UAE. However, this study has limitations; its cross-sectional design limits causality, and self-reported responses may introduce bias. Recruitment from cardiac clinics and trial participants may exclude those without regular cardiovascular care, limiting broader applicability. The online format likely restricted participation to those with technological access, and only Arabic- or English-speaking individuals were included. Additionally, the predominance of insured participants may underrepresent the views of uninsured populations, introducing potential bias.

Future studies should examine PGx awareness and attitudes among patients beyond cardiovascular care, incorporating diverse demographics and health profiles. Qualitative research is recommended to gain deeper insights into patient experiences, beliefs, and perceived barriers regarding PGx.

6 | Conclusions and Recommendations

This study highlights key areas for improving the integration of PGx testing in cardiovascular care in the UAE. Findings indicate a substantial knowledge gap among cardiovascular patients regarding PGx, emphasizing the need for tailored education to enhance understanding of PGx. Additionally, concerns around privacy and the costs associated with PGx testing emerged as significant barriers, suggesting that successful implementation will require addressing these patient priorities and concerns to foster broader acceptance and trust.

Healthcare institutions should prioritize clear, accessible communication on PGx's purpose, benefits, and safety to boost patient readiness. Policy improvements are also essential; establishing robust privacy protections and exploring insurance coverage or subsidies for PGx testing can mitigate financial and confidentiality concerns.

Author Contributions

M.O.A., F.A.-M., G.P.P., B.R.A., A.T.R., and I.E. wrote the manuscript; M.O.A., F.A.-M., A.T.R., I.E., and Z.A.-M. designed the research; F.N., A.O., A.S.A., R.K.A., and M.A. performed the research; M.O.A. and A.T.R. analyzed the data.

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Disclosure

Patients or the public were not involved in our research's design, conduct, reporting, or dissemination plans. The nature of this study, which focused on assessing the knowledge and perceptions of cardiovascular patients toward PGx, relied solely on patient participation as research participants.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

References

1. D. B. Goldstein, S. K. Tate, and S. M. Sisodiya, "Pharmacogenetics Goes Genomic," *Nature Reviews Genetics* 4, no. 12 (2003): 937–947.
2. E. Cecchin and G. Stocco, "Pharmacogenomics and Personalized Medicine," *Genes* 11, no. 6 (2020): 679, <https://doi.org/10.3390/genes11060679>.
3. J. R. Lewis, "Pharmacogenomics in Drug Metabolism Enzymes and Transporters," in *Drug Discovery and Evaluation: Safety and Pharmacokinetic Assays*, ed. F. J. Hock and M. K. Pugsley (Springer International Publishing, 2022), 1–47.
4. D. M. Roden, R. A. Wilke, H. K. Kroemer, and C. M. Stein, "Pharmacogenomics: The Genetics of Variable Drug Responses," *Circulation* 123, no. 15 (2011): 1661–1670.
5. R. M. Turner and M. Pirmohamed, "Pharmacogenomics in Cardiovascular Disease," in *Diagnostic Molecular Pathology*, 2nd ed., ed. W. B. Coleman and G. J. Tsongalis (Academic Press, 2024), 623–642.
6. A. Alchakee, M. Ahmed, L. Eldohaji, H. Alhaj, and M. Saber-Ayad, "Pharmacogenomics in Psychiatry Practice: The Value and the Challenges," *International Journal of Molecular Sciences* 23, no. 21 (2022): 13485, <https://doi.org/10.3390/ijms232113485>.
7. R. Singh, S. K. Chandi, S. Sran, et al., "Emerging Therapeutic Strategies in Cardiovascular Diseases," *Cureus* 16, no. 7 (2024): e64388.
8. E. F. Magavern, J. C. Kaski, R. M. Turner, A. Janmohamed, P. Borry, and M. Pirmohamed, "The Interface of Therapeutics and Genomics in Cardiovascular Medicine," *Cardiovascular Drugs and Therapy* 35, no. 3 (2021): 663–676.
9. M. S. Fayed, M. A. Saleh, N. A. Sabri, and A. A. Elkholy, "Adrenergic Receptor Polymorphisms: A Possible Genetic Predictor of Bisoprolol Response in Acute Coronary Syndrome," *Future Science OA* 9, no. 10 (2023): FSO895.
10. K. A. Malsagova, T. V. Butkova, A. T. Kopylov, et al., "Pharmacogenetic Testing: A Tool for Personalized Drug Therapy Optimization," *Pharmaceutics* 12, no. 12 (2020): 1240, <https://doi.org/10.3390/pharmaceutics12121240>.
11. H. Abdelhalim, A. Berber, M. Lodi, et al., "Artificial Intelligence, Healthcare, Clinical Genomics, and Pharmacogenomics Approaches in Precision Medicine," *Frontiers in Genetics* 13 (2022): 963896, <https://doi.org/10.3389/fgene.2022.963896>.
12. S. Watson, O. Caster, P. A. Rochon, and H. den Ruijter, "Reported Adverse Drug Reactions in Women and Men: Aggregated Evidence From Globally Collected Individual Case Reports During Half a Century," *EClinicalMedicine* 17 (2019): 100188, <https://doi.org/10.1016/j.eclinm.2019.10.001>.
13. J. Bouget, F. Balusson, D. Viglino, et al., "Major Bleeding Risk and Mortality Associated With Antiplatelet Drugs in Real-World Clinical Practice: A Prospective Cohort Study," *PLoS One* 15, no. 8 (2020): e0237022, <https://doi.org/10.1371/journal.pone.0237022>.
14. S. Jayatilaka, K. Desai, S. Rijal, and D. Zimmerman, "Statin-Induced Autoimmune Necrotizing Myopathy," *Journal of Primary Care and Community Health* 12 (2021): 28710.
15. S. M. Altoum, Z. N. Al-Mahayri, and B. R. Ali, "Antihypertensives-Associated Adverse Events: A Review of Mechanisms and Pharmacogenomic Biomarkers in Multi-Ethnic Populations," *Frontiers in Pharmacology* 14 (2023): 1286494, <https://doi.org/10.3389/fphar.2023.1286494>.
16. E. F. Magavern, J. C. Kaski, R. M. Turner, et al., "The Role of Pharmacogenomics in Contemporary Cardiovascular Therapy: A Position Statement From the ESC Working Group on Cardiovascular Pharmacotherapy," *European Heart Journal - Cardiovascular Pharmacotherapy* 8, no. 1 (2022): 85–99.
17. J. P. Radich, E. Briercheck, D. T. Chiu, et al., "Precision Medicine in Low- and Middle-Income Countries," *Annual Review of Pathology* 17 (2022): 387–402.
18. Y. Jarrar and S. J. Lee, "Demand for Pharmacogenomics and Personalized Medicine in the United Arab Emirates," *Journal of Personalized Medicine* 12, no. 1 (2022): 104, <https://doi.org/10.3390/jpm12010104>.
19. L. Q. Khasawneh, H. Alsafar, H. Alblooshi, M. Allam, G. P. Patrinos, and B. R. Ali, "The Diversity and Clinical Implications of Genetic Variants Influencing Clopidogrel Bioactivation and Response in the Emirati Population," *Human Genomics* 18, no. 1 (2024): 2, <https://doi.org/10.1186/s40246-023-00568-3>.
20. Z. N. Al-Mahayri, G. P. Patrinos, S. Wattanapokayakit, et al., "Variation in 100 Relevant Pharmacogenes Among Emiratis With Insights From Understudied Populations," *Scientific Reports* 10, no. 1 (2020): 20220, <https://doi.org/10.1038/s41598-020-76531-6>.
21. Z. N. Al-Mahayri, L. Q. Khasawneh, M. N. Alqasrawi, et al., "Pharmacogenomics Implementation in Cardiovascular Disease in a Highly Diverse Population: Initial Findings and Lessons Learned From a Pilot Study in United Arab Emirates," *Human Genomics* 16, no. 1 (2022): 42, <https://doi.org/10.1186/s40246-022-00394-4>.
22. Z. N. Al-Mahayri, H. S. Al Jaibaji, Y. Saab, et al., "VKORC1 Variants as Significant Predictors of Warfarin Dose in Emiratis," *Pharmacogenomics and Personalized Medicine* 12 (2019): 47–57, <https://doi.org/10.2147/PGPM.S187350>.
23. M. Navarro, "Patients Empowerment and the Role of Patients Education," *Medical Research Archives* 8, no. 12 (2020): 2306, <https://doi.org/10.18103/mra.v8i12.2306>.
24. M. Khattab, M. Baguneid, B. R. Ali, et al., "A Review of Pharmacogenomics Studies Assessing the Knowledge and Attitudes of Physicians and Pharmacists Across the Arab and Middle Eastern Region," *Pharmacy Practice (Granada)* 21, no. 3 (2023): 2812, <https://doi.org/10.18549/PharmPract.2023.3.2812>.
25. A. T. Rahma, B. R. Ali, G. P. Patrinos, et al., "Knowledge, Attitudes, and Perceptions of the Multi-Ethnic Population of The United Arab

- Emirates on Genomic Medicine and Genetic Testing,” *Human Genomics* 17 (2023): 63, <https://doi.org/10.1186/s40246-023-00509-0>.
26. A. Edris, E. Callier, and L. Lahousse, “Precision Medicine From a Citizen Perspective: A Survey of Public Attitudes Towards Pharmacogenomics in Flanders,” *BMC Medical Genomics* 15, no. 3 (2022): 64, <https://doi.org/10.1186/s12920-022-01295-0>.
 27. G. Lee, L. A. Varughese, L. Conway, et al., “Attitudes Toward Pharmacogenetics in Patients Undergoing CYP2C19 Testing Following Percutaneous Coronary Intervention,” *Peritoneal Medicine* 19, no. 2 (2022): 93–101, <https://doi.org/10.2217/pme-2021-0101>.
 28. R. B. Carver, J. Castéra, N. Gericke, N. A. Evangelista, and C. N. el-Hani, “Young Adults’ Belief in Genetic Determinism, and Knowledge and Attitudes Towards Modern Genetics and Genomics: The PUGGS Questionnaire,” *PLoS One* 12, no. 1 (2017): e0169808, <https://doi.org/10.1371/journal.pone.0169808>.
 29. L. Naing, R. B. Nordin, H. Abdul Rahman, and Y. T. Naing, “Sample Size Calculation for Prevalence Studies Using Scalex and ScalaR Calculators,” *BMC Medical Research Methodology* 22, no. 1 (2022): 209, <https://doi.org/10.1186/s12874-022-01750-0>.
 30. Emirati Genome Program, “Emirati Genome Program,” (2025), (accessed May 13, 2025), <https://emiratigenomeprogram.ae/en/index.html>.
 31. A. Pearce, L. A. Mitchell, S. Best, et al., “Publics Knowledge of, Attitude to and Motivation Towards Health-Related Genomics: A Scoping Review,” *European Journal of Human Genetics* 32, no. 7 (2024): 747–758, <https://doi.org/10.1038/s41431-024-01598-3>.
 32. B. E. Gawronski, E. J. Cicali, C. W. McDonough, et al., “Exploring Perceptions, Knowledge, and Attitudes Regarding Pharmacogenetic Testing in the Medically Underserved,” *Frontiers in Genetics* 13 (2023): 1085994, <https://doi.org/10.3389/fgene.2023.1085994>.
 33. A. T. Rahma, M. Elsheik, B. R. Ali, et al., “Knowledge, Attitudes, and Perceived Barriers Toward Genetic Testing and Pharmacogenomics Among Healthcare Workers in The United Arab Emirates: A Cross-Sectional Study,” *Journal of Personalized Medicine* 10, no. 4 (2020): 216, <https://doi.org/10.3390/jpm10040216>.
 34. A. T. Rahma, M. Elsheik, I. Elbarazi, et al., “Knowledge and Attitudes of Medical and Health Science Students in The United Arab Emirates Toward Genomic Medicine and Pharmacogenomics: A Cross-Sectional Study,” *Journal of Personalized Medicine* 10, no. 4 (2020): 191, <https://doi.org/10.3390/jpm10040191>.
 35. R. Janssens, E. Overbeek, L. Verswijvel, et al., “Patient Involvement in the Lifecycle of Medicines According to Belgian Stakeholders: The Gap Between Theory and Practice,” *Frontiers in Medicine* 5 (2018): 307, <https://doi.org/10.3389/fmed.2018.00307>.
 36. K. Nguyen and K. Wiisanen, “Patient-Facing Clinical Decision Support for Pharmacogenomic Precision Medicine,” in *Clinical Decision Support for Precision Medicine*, ed. B. Devine, R. D. Boyce, and K. Wiisanen (Academic Press, 2022), 203–225.
 37. K. Souliotis, “Patient Participation in Contemporary Health Care: Promoting a Versatile Patient Role,” *Health Expectations* 19, no. 2 (2016): 175–178, <https://doi.org/10.1111/hex.12442>.
 38. H. Y. Lee, J. Lee, and N. K. Kim, “Gender Differences in Health Literacy Among Korean Adults: Do Women Have a Higher Level of Health Literacy Than Men?,” *American Journal of Men’s Health* 9, no. 5 (2015): 370–379, <https://doi.org/10.1177/1557988315589312>.
 39. F. Samkange-Zeeb, H. Singh, M. Lakeberg, et al., “Health Literacy Needs Among Unemployed Persons: Collating Evidence Through Triangulation of Interview and Scoping Review Data,” *Frontiers in Public Health* 10 (2022): 798797, <https://doi.org/10.3389/fpubh.2022.798797>.
 40. V. Atemnkeng Ntam, T. Huebner, M. Steffens, et al., “The Influence of Age, Gender and Pharmacogenetic Profiles on the Perspective on Medicines in the German EMPAR Study,” *PLoS One* 19, no. 10 (2024): e0311267, <https://doi.org/10.1371/journal.pone.0311267>.
 41. H. Enlund, K. Vainio, S. Wallenius, and J. W. Poston, “Adverse Drug Effects and the Need for Drug Information,” *Medical Care* 29, no. 6 (1991): 558–564, <https://doi.org/10.1097/00005650-199106000-00014>.
 42. E. Wahlstedt and B. Ekman, “Patient Choice, Internet-Based Information Sources, and Perceptions of Health Care: Evidence From Sweden Using Survey Data From 2010 and 2013,” *BMC Health Services Research* 16 (2016): 325, <https://doi.org/10.1186/s12913-016-1581-5>.
 43. T. H. Mikkelsen, J. Sendergaard, N. K. Kjaer, et al., “Handling Polypharmacy: A Qualitative Study Using Focus Group Interviews With Older Patients, Their Relatives, and Healthcare Professionals,” *BMC Geriatrics* 23 (2023): 477, <https://doi.org/10.1186/s12877-023-04131-6>.
 44. A. H. W. Alkhamsan, A. H. Y. Al Khamsan, M. M. Zabarrah, et al., “Pharmacist-Led Interventions for Reducing Polypharmacy and Improving Patient Outcomes: A Systematic Review,” *Journal of Ecohumanism* 3, no. 8 (2024): 860–869, <https://doi.org/10.62754/joe.v3i8.4773>.
 45. L. Zhang, P. A. Jacobson, A. N. K. Johnson, et al., “Public Attitudes Toward Pharmacogenomic Testing and Establishing a Statewide Pharmacogenomics Database in the State of Minnesota,” *Journal of Personalized Medicine* 12, no. 10 (2022): 1615, <https://doi.org/10.3390/jpm12101615>.
 46. C. Mukherjee, K. M. Sweet, J. A. Luzum, et al., “Clinical Pharmacogenomics: Patient Perspectives of Pharmacogenomic Testing and the Incidence of Actionable Test Results in a Chronic Disease Cohort,” *Personalized Medicine* 14, no. 5 (2017): 383–388, <https://doi.org/10.2217/pme-2017-0016>.
 47. J. Tamaiev, Z. Bergson, X. Sun, et al., “Patient Attitudes Toward Pharmacogenetic Testing in Psychiatric Treatment,” *Current Behavioral Neuroscience Reports* 10, no. 2 (2023): 30–40, <https://doi.org/10.1007/s40473-023-00244-3>.
 48. A. A. Lemke, L. M. Amendola, J. Thompson, et al., “Patient-Reported Outcomes and Experiences With Population Genetic Testing Offered Through a Primary Care Network,” *Genetic Testing and Molecular Biomarkers* 25, no. 2 (2021): 152–160, <https://doi.org/10.1089/gtmb.2020.0275>.
 49. S. Chenchula, S. Atal, and C. R. S. Uppugunduri, “A Review of Real-World Evidence on Preemptive Pharmacogenomic Testing for Preventing Adverse Drug Reactions: A Reality for Future Health Care,” *Pharmacogenomics Journal* 24, no. 2 (2024): 9, <https://doi.org/10.1038/s41397-024-00326-1>.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.