Pharmacy Education (2024) 24(1) 718 - 729
https://doi.org/10.46542/pe.2024.241.718729

RESEARCH ARTICLE

Assessment of healthcare students' knowledge, attitudes, and perceptions towards pharmacogenomics at Olabisi Onabanjo University, Sagamu Campus, Ogun State, Nigeria

Olusegun Ayo Ade-adekunle[1], Precious Adebowale Dada[1], Feranmi Olalekan Adekunle[1], Adeola Elizabeth Abiola[1], David Gbenga Babalola[1], Ifeoluwapo Johnson Soderu[1], Toluwalase Gbenga Onafuwa[1], Odunayo Olamide Ade-adekunle[2], Femi Johnson Adebayo[1], Zulaikha Omayoza Idris[1], Aishat Oluwatomiwa Mohammed[1]

[1] Faculty of Pharmacy Olabisi Onabanjo University, Ogun State, Nigeria
[2] Faculty of Basic Medical Sciences, University of Medical Sciences, Ondo State State, Nigeria

Keywords
Attitude
Healthcare student
Knowledge
Perception
Pharmacogenomics

Correspondence
Olusegun Ayo Ade-adekunle
Faculty of Pharmacy
Olabisi Onabanjo University
Ogun State
Nigeria
adeshegs46@gmail.com

Abstract

Background: Pharmacogenomics explores how genetic variations affect drug responses, crucial for personalised medicine. Understanding healthcare students' perspectives is vital for advancing awareness in this field. This study aimed to assess healthcare students' knowledge, attitudes, and perceptions towards pharmacogenomics at Olabisi Onabanjo University, Sagamu Campus, Ogun State. **Methods:** A cross-sectional survey was conducted among healthcare students (medicine, pharmacy, and nursing) at Olabisi Onabanjo University Teaching Hospital, Sagamu Campus, Ogun State, using purposive sampling. **Results:** Respondents from medicine, nursing, and pharmacy demonstrated a moderate level of confidence in pharmacogenomics knowledge (38.1%, 75.9%, and 42.6%, respectively). They also indicated that their curricula inadequately cover pharmacogenomics ($p < 0.001$), highlighting the need for curriculum revisions to incorporate pharmacogenomics training. **Conclusion:** Healthcare students exhibited fair knowledge and favourable attitudes towards pharmacogenomics, yet further education is essential for a comprehensive understanding of its fundamentals and clinical implications.

Introduction

Pharmacogenomics (PGx) examines the relationship between genomics and pharmacology, with an emphasis on comprehending and assessing how genetic variations affect how well medication therapy works (T P *et al.,* 2009). Pharmacogenetics is the field that examines the diversity in responses to drugs resulting from genetic variations (Hundertmark *et al.,* 2020). Gene variations affect how medications interact with their molecular targets, which affects both their efficacy and the confirmation of undesirable side effects. PGx has become increasingly popular as healthcare advances, paving the way for individualised therapy based on each patient's unique genetic profile (Hippman & Nislow, 2019). According to the PGx report, over 350 drugs have been included in the Food and Drug Administration's (FDA) database of medications with labelled instructions prior to administration (Koutsilieri *et al.,* 2020). These medications primarily encompass drugs with a narrow therapeutic index and a potential for toxicity, such as antineoplastic, anticoagulant, and anticonvulsant agents (Lowitt & Shear, 2001; Davies, 2006; Leong *et al.,* 2019).

Clinical PGx testing aims to inform physicians about prescribed medications with identified genetic variants linked to adverse drug reactions and drug

effectiveness (Yau *et al.,* 2015), emphasising the importance of an interdisciplinary strategy that includes physicians, pharmacists, and nurses to achieve this goal. The completion of the Human Genome Project in 2003 accelerated the development of personalised medicine and increased physicians' interest in it, thereby encouraging the use of genomics education (McCullough *et al.,* 2011; Giri *et al.,* 2018; Karas Kuželički *et al.,* 2019).

Cytochromes P450 (CYP) are the primary factor in variations in drug pharmacokinetics and reactions. Only over a dozen of the 57 human CYP enzymes able to function—mainly from the CYP1, 2, and 3 families—are in charge of metabolising the majority of foreign substances, including 70–80% of all pharmaceuticals used in clinical settings (Zanger & Schwab, 2013). The expression of CYP enzymes is influenced by genetic polymorphisms, xenobiotic induction, and factors like cytokines, hormones, disease states, sex, and age. CYPs such as 2D6, 2C19, and 3A5 are highly affected by ethnicity-dependent multiallelic polymorphisms, leading to distinct metaboliser phenotypes (poor, moderate, extensive, and ultrarapid). These differences are becoming more and more clinically significant in terms of adverse drug reactions (ADRs), dosage requirements, and drug efficacy. Many of the earliest examples of personalised medicine were connected to genetically mediated pharmacokinetic characteristics of medications, partly due to the biomedical research community's understanding of drug-metabolising enzymes and how they affect the body's response to drugs (Goetz & Schork, 2018).

Warfarin is a common blood thinner that targets the gene VKORC1, which is partially metabolised by the gene CYP2C9. If dosed incorrectly, this medication could result in potentially fatal adverse drug reactions, such as bleeding and haemorrhage, which can occur at almost any body site. Examples of such reactions include intracranial haemorrhage, gastrointestinal bleeding, haematemesis, intraocular bleeding, and haemarthrosis (Goetz & Schork, 2018; Patel *et al.,* 2024). Therefore, the U.S. FDA has advised that one's genotype must be accounted for while administering warfarin. This recommendation means that the dose of the medication should be customised for each individual based on the unique genetic variants that each person possesses in the VKORC1 and CYP2C9 genes (Lee & Klein, 2013).

Primaquine (PQ) is another well-known example of a medication that ought to be administered exclusively to people who match a specific genetic profile. In regions where malaria is endemic, PQ has been used to treat the disease with some degree of success. Yet, military physicians in the past noticed that some of the troops they treated for malaria using this medication eventually developed jaundice, anaemia, and signs of what was later known as acute haemolytic anaemia (AHA). Subsequent research revealed that those with AHA following PQ treatment have G6PD gene variations (Luzzatto & Seneca, 2014).

Previous research on the knowledge, attitudes, and perceptions of PGx among healthcare students revealed that 88% had moderate knowledge and above among Zimbabwe Pharmacy students (Muzoriana *et al.,* 2017). A similar study conducted among Nigerian medical students found high awareness of genomic medicine terminology at 92.0%. However, responses to knowledge and ability questions revealed notable gaps (Ogamba *et al.,* 2023). The primary barriers identified by some healthcare students in the United Arab Emirates for the implementation of genomic medicine and PGx were insufficient training or education (59.7%) and the absence of clinical guidelines (58.7%). Concerns about confidentiality and discrimination were also raised. While most medical and health science students demonstrated positive attitudes, their level of knowledge was only moderate (Rahma *et al.,* 2020).

Despite the growing importance of personalised medicine (PM), PGx, and genetic testing, there is a notable absence of local studies that examine public awareness and perceptions of these fields. Additionally, there is limited research on the extent of PGx and PM education at both undergraduate and graduate levels (Israt Khanom *et al.,* 2023). Although there is significant emphasis and supporting evidence for the importance of genomic medicine and PGx in clinical practice, many healthcare professionals report lacking confidence in effectively integrating PGx into their routine practice (McCullough *et al.,* 2011; Abdela *et al.,* 2017). This issue is primarily attributed to insufficient education, a commonly recognised factor contributing to knowledge gaps and challenges in effectively interpreting and communicating PGx results (Abdela *et al.,* 2017). Medical and health science students are the future of healthcare professionals, and their perspectives are crucial for raising awareness about personalised medicine and PGx. Specifically, pharmacists, esteemed as drug experts, are deemed essential for the clinical integration of PGx owing to the nature of their education and expertise (McCullough *et al.,* 2011; AlEjielat *et al.,* 2016; Muzoriana *et al.,* 2017). Assessing medical and health science students' knowledge, attitudes, and practices regarding genomic medicine and PGx is imperative to improve their awareness and proficiency in these fields.

This study aimed to evaluate healthcare students' knowledge, attitudes, and perceptions towards pharmacogenomics at Olabisi Onabanjo University, Sagamu Campus, Ogun State.

Methods

Study design and settings

A cross-sectional study was conducted among medicine, pharmacy, and nursing students in Olabisi Onabanjo University Teaching, Sagamu Campus, Ogun state. The data were collected from September 2023 to October 2023.

Study population

The study population consisted of all consenting penultimate and final-year students in the abovementioned faculties and departments in Olabisi Onabanjo University, Sagamu campus.

Sample size

The sample size was computed using Yamane's formula.

$$n = \frac{N}{1+N(e)^2} \quad n = \frac{448}{1+448(0.05)^2} = 211.32$$

n = Sample size; N = Size of population; e = assumed error of 0.05

Although the calculated sample size was initially 211 students, the number of recruited participants was increased to 268 (medicine = 155, pharmacy = 198, and nursing = 95). This decision was made to account for potential attrition and non-compliance, ensuring that the final sample size maintained sufficient statistical power. This over-recruitment also aimed to enhance the findings' generalisability by increasing the diversity of the population. All recruitment efforts adhered to the ethical guidelines approved by the HREC board.

Data collection procedure

Participants were selected using purposive sampling. Anonymous, self-administered questionnaires were distributed to consenting healthcare students in their lecture rooms. Before completing the questionnaires, students provided informed consent by signing consent forms to ensure that they were fully aware of the nature of the study, their rights as participants and the confidentiality of their responses. The questionnaire, which was self-developed and pretested, included 43 items distributed across five sections A, B, C, D and E.

Section A (5 items) collected respondents' demographic data. Section B (3 items) evaluated the source of information about PGx. Section C assessed respondents' knowledge of PGx with 18 true or false questions, with an additional "*not sure*" option to minimise guessing. Section D consisted of 11 items measuring participants' perceptions and awareness towards PGx. Lastly, Section E assessed respondents' attitudes regarding pharmacogenomics using 6 items.

Data analysis

The data were organised and analysed using SPSS software (version 23).

Descriptive statistics were presented using frequency distribution tables with percentages, with a margin of error of ± 0.1 to ensure accuracy. Measures of central tendency were calculated to summarise the data distribution. The relationships between variables were examined using chi-square tests of independence, with statistical significance set at $p < 0.05$

Results

Sociodemographic characteristics of respondents

Table I outlines the demographic details of the study participants. Out of 211 eligible individuals, a total of 268 were recruited in the study. The largest group of participants was 400-level pharmacy students, constituting 24.3% (65 individuals), while the smallest group was 400-level nursing students, at 10.4% (28 respondents). In Medicine, the majority were aged 20-23 (73.8%, 62 individuals), whereas Nursing had a significant proportion under 19 (9.6%, 8 individuals) and between 20-23 (90.4%, 75 respondents). Pharmacy showed diverse age distribution, with 20-23 years old forming a notable percentage (52.5%, 53 individuals), followed by those over 30 (19.8%, 20 respondents). More females participated (54.5%, 146 individuals) compared to males (45.5%, 122 individuals). Regarding religion, Medicine had a majority of Islam followers (56%, 47 individuals), while Nursing and Pharmacy were predominantly Christians (78.3%, 65 individuals; 67.3%, 68 individuals, respectively).

Table I: Sociodemographic characteristics of respondents

Variable	Medicine N=84(%)	Nursing N=83(%)	Pharmacy N=101(%)
Age range			
19 years and below	0(0)	8(9.6%)	4(4%)
20-23 years	62(73.8%)	75(90.4%)	53(52.5%)
24-26 years	20(23.8%)	0(0)	22(21.8%)
27-30 years	2(2.3%)	0(0.0)	2(2%)
Above 30 years	0(0.0)	0(0.0)	20(19.8%)
Gender			
Male	40(47.6%)	36(43.4%)	46(45.5%)
Female	44(52.4%)	47(56.6%)	55(54.5%)
Religion			
Islam	47(56%)	18(21.7%)	31(30.7%)
Christianity	35(41.7%)	65(78.3%)	68(67.3%)
Others	2(2.4%)	0(0.0)	2(2%)
Level			
400 level	0(0.0)	28(33.7%)	65(64.4%)
500 level	52(61.9%)	55(66.3%)	36(35.6%)
600 level	32(38.1%)	0(0.0)	0(0.0)

Source of information of respondents

Most medical students (n = 82, 97.6%) reported prior familiarity with PGx, while a minimal proportion (2.4%, n = 2) admitted being unfamiliar with the term. The primary sources of information on PGX varied among medicine, nursing, and pharmacy participants, with educational institutions (70.2%, 77.1%, 44.6%), internet sources (13.1%, 13.3%, 2%), and friends/family (10.7%, 2.4%, 18.8%) being the most reported across all fields (Table II).

Regarding the perceived knowledge, pharmacy students rated their understanding of PGx as very high (n = 22, 21.8%). In contrast, none of the medicine students and only one nursing student (1.2%) rated their knowledge as very high. A significant proportion of medicine students reported very low knowledge of PGx (n = 32, 38.1%), while the majority of respondents across medicine, nursing, and pharmacy rated their understanding as average (n = 32, 38.1%; n = 63, 75.9%; n = 43, 42.6%, respectively).

Table II: Sources of information of respondents

Variable	Medicine N=84(%)	Nursing N=83(%)	Pharmacy N=101(%)
Have you heard about pharmacogenomics?			
Yes	82(97.6%)	72(86.7%)	81(80.2%)
No	2(2.4%)	11(13.3%)	20(19.8%)
Where did you first hear about pharmacogenomics?			
Friends and family	9(10.7%)	2(2.4%)	19(18.8%)
School	59(70.2%)	64(77.1%)	45(44.6%)
Internet	11(13.1%)	11(13.3%)	2(2%)
Textbook	3(3.6%)	3(3.6%)	2(2%)
Journal	0(0.0)	2(2.4%)	3(3%)
Others	2(2.4%)	1(1.2%)	30(29.7%)
Rate your knowledge of pharmacogenomics			
Very low	32(38.1%)	8(9.6%)	13(12.9%)
Low	15(17.9%)	8(9.6%)	8(7.9%)
Average	32(38.1%)	63(75.9%)	43(42.6%)
High	5(6%)	3(3.6%)	15(14.9%)
Very high	0(0.0)	1(1.2%)	22(21.8%)

Students' knowledge of pharmacogenomics

Most respondents across the three disciplines agreed that PGx aims to tailor therapy based on an individual's genetic profile (medicine = 100%, nursing = 78.3%, and pharmacy = 80.2%). A significant portion recognised that genetic variations could lead to adverse drug reactions, with 100% of medicine respondents, 85.5% of nursing respondents, and 72.3% of pharmacy respondents acknowledging this risk. Warfarin was presented as an established example of PGx application in clinical settings, with a focus on whether its package insert includes a warning about altered metabolism in individuals with specific genetic variants. Only a moderate number of respondents acknowledged this (61.9% from medicine, 61.4% from nursing, and 65.3% from pharmacy), as shown in Table III.

Table III: Students' knowledge of pharmacogenomics

Variable	Medicine N=84(%)	Nursing N=83(%)	Pharmacy N=101(%)	X^2	*P*-Value
Pharmacogenomics seeks to individualise therapy based on patient's profile					
True	84(100%)	65(78.3%)	81(80.2%)		
False	0(0)	3(3.6%)	3(3%)	20.376	<0.01
Not sure	0(0)	15(18.1%)	17(16.8%)		
Genetics changes can cause adverse reaction					
True	84(100%)	71(85.5%)	73(72.3%)		
False	0(0.0)	6(7.2%)	16(15.8%)	27.992	<0.01
Not sure	0(0.0)	6(7.2%)	12(11.9%)		
The package insert for warfarin includes a warning about altered metabolism in individuals who have specific genetic variant					
True	52(61.9%)	51(61.4%)	66(65.3%)		
False	3(3.6%)	3(3.6%)	3(3%)	0.385	0.984
Not sure	29(34.5%)	29(34.9%)	32(31.7%)		
Some patients have a high risk of drug toxicity due to inherited genetic variant					
True	84(100%)	76(91.6%)	86(85.1%)		
False	0(0.0)	2(2.4%)	7(6.9%)	14.257	0.007
Not sure	0(0.0)	5(6%)	8(7.9%)		
Genetic variations in drug targets, metabolizing enzymes and transporters affect drug therapy					
True	84(100%)	70(84.3%)	78(77.2%)		
False	0(0.0)	6(7.2%)	15(14.9%)	22.651	<0.01
Not sure	0(0.0)	7(8.4%)	8(7.9%)		
Subtle differences in person's genome can have a major impact on how the person responds to medications					
True	84(100%)	70(84.3%)	81(80.2%)		
False	0(0.0)	6(7.2%)	14(13.9%)	20.539	<0.01
Not sure	0(0.0)	7(8.4%)	6(5.9%)		
Inter-individual variation in pharmacokinetic parameters may be due to genetic variations					
True	84(100%)	59(71.1%)	76(75.2%)		
False	0(0.0)	6(7.2%)	11(10.9%)	30.771	<0.001
Not sure	0(0.0)	18(21.7%)	14(13.9%)		
Genetic variants can account for 95% of the variability in drug disposition and effects					
True	58(69%)	38(45.8%)	76(75.2%)		
False	12(14.3%)	13(15.7%)	9(8.9%)	20.870	<0.001
Not sure	14(16.7%)	32(38.6%)	16(15.8%)		
Pharmacogenomics testing is currently available for most medications					
True	4(4.8%)	51(61.4%)	76(75.2%)		
False	30(35.7%)	14(16.9%)	17(16.8%)	99.165	<0.001
Not sure	50(59.5%)	18(21.7%)	8(7.9%)		
Pharmacogenomics testing is recommended by FDA for certain drugs					
True	55(65.5%)	38(45.8%)	65(64.4%)		
False	5(6%)	7(8.4%)	25(24.8%)	11.633	0.020
Not sure	24(28.6%)	38(45.8%)	11(10.9%)		
The study of a gene involved in response to a drug is pharmacogenomics					

Variable	Medicine N=84(%)	Nursing N=83(%)	Pharmacy N=101(%)	X^2	*P*-Value
True	82(97.6%)	58(69.9%)	87(86.1%)		
False	2(2.4%)	17(20.5%)	10(9.9%)	25.359	<0.001
Not sure	0(0.0)	8(9.6%)	4(4%)		
The study of many genes involved in response to a drug is pharmacogenetics					
True	81(96.4%)	49(59%)	81(80.2%)		
False	3(3.6%)	17(20.5%)	9(8.9%)	35.832	<0.001
Not sure	0(0.0)	17(20.5%)	11(10.9%)		
The intensity of adverse events of some medications may depend on a person's genetic make-up					
True	84(100%)	67(80.7%)	88(87.1%)		
False	0(0.0)	6(7.2%)	5(5%)	16.787	0.002
Not sure	0(0.0)	10(12%)	8(8%)		
An indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention is the definition of biomarker					
True	72(85.7%)	46(55.4%)	85(84.2%)		
False	5(6%)	2(2.4%)	0(0.0)	37.416	<0.001
Not sure	7(8.3%)	35(42.1%)	16(15.8%)		
Genetic variation affects pharmacological action of isoniazid					
True	55(65.5%)	25(30.1%)	85(84.2%)		
False	6(7.1%)	6(7.2%)	0(0.0)	60.127	<0.001
Not sure	23(27.4%)	52(62.7%)	16(15.8%)		
Genetic variation influences occurrence of hemolytic anemia in G6PD deficiency					
True	76(90.5%)	39(47%)	85(84.2%)		
False	3(3.6%)	2(2.4%)	0(0.0)	55.337	<0.001
Not sure	5(6%)	42(50.6%)	16(15.8%)		
Genetic variations may contribute to inter-individual variation in pharmacodynamics and drug-molecular target interaction					
True	76(90.5%)	60(72.3%)	83(82.2%)		
False	5(6%)	4(4.8%)	2(2%)	14.913	0.005
Not sure	3(3.6%)	19(22.9%)	16(15.8%)		
There is a racial variation in drug response					
True	77(91.7%)	51(61.4%)	85(84.2%)		
False	7(8.3%)	11(13.3%)	2(2%)	33.670	<0.001
Not sure	0(0.0)	21(25.3%)	14(13.9%)		

Perception and awareness of pharmacogenomics

Most respondents agreed that PGx is critical and that healthcare providers should be knowledgeable in this field. However, opinions on the integration of PGx into their study curricula were more moderate, with 66.7% of medicine, 54.2% of nursing, and 31.7% of pharmacy students believing it should be an essential part of their education. Additionally, 20.2% of medicine, 43.4% of nursing, and 14.9% of pharmacy respondents were unsure if their curriculum adequately covers PGx. A majority also indicated they were unaware of any ethical concerns surrounding pharmacogenomic testing in patient care, with 70.2% from medicine, 50.6% from nursing, and 72.3% from pharmacy reporting this (Table IV).

Table IV: Perceptions and awareness of pharmacogenomics

Variable	Medicine N=84(%)	Nursing N =83(%)	Pharmacy N=101(%)	X^2	*P*-Value
Perception					
Pharmacogenomics is an important field and health providers must know it					
Strongly agree	74(88.1%)	49(59%)	66(65%)		
Agree	10(11.9%)	29(35%)	29(28.7%)	20.110	0.003
Neutral	0(0.0)	4(4.8%)	5(5%)		
Strongly disagree	0(0.0)	0(0.0)	0(0.0)		

Variable	Medicine N=84(%)	Nursing N =83(%)	Pharmacy N=101(%)	X^2	*P*-Value
Disagree	0(0.0)	1(1.2%)	1(1%)		
Pharmacogenomics should be an important part of study curriculum					
Strongly agree	56(66.7%)	45(54.2%)	32(31.7%)		
Agree	28(33.3)	27(32.5%)	60(59.4%)	32.418	<0.001
Neutral	0(0.0)	10(12%)	8(7.9%)		
Strongly disagree	0(0.0)	0(0.0)	0(0.0)		
Disagree	0(0.0)	1(1.2%)	1(1%)		
Curriculum is well designed to understand pharmacogenomics					
Strongly agree	18(21.4%)	11(13.3%)	35(34.7%)		
Agree	19(22.6%)	13(15.7%)	50(49.5%)		
Neutral	17(20.2%)	36(43.4%)	15(14.9%)	77.931	<0.001
Strongly disagree	8(9.5%)	10(12%)	0(0.0)		
Disagree	22(26.2%)	13(15.7%)	1(1%)		
Healthcare professionals must know pharmacogenomics					
Strongly agree	51(60.7%)	43(51.8%)	42(41.6%)		
Agree	33(39.2%)	27(32.5%)	45(44.6%)		
Neutral	0(0.0)	10(12%)	11(10.9%)	17.504	0.025
Strongly disagree	0(0.0)	1(1.2%)	1(1%)		
Disagree	0(0.0)	2(2.4%)	2(2%)		
Training will help healthcare students identify medicines requiring pharmacogenomics testing					
Strongly agree	49(58.3%)	41(49.4%)	35(34.7%)		
Agree	35(41.7%)	30(36.1%)	56(55.4%)		
Neutral	0(0.0)	6(7.2%)	4(40.0)	21.314	0.002
Strongly disagree	0(0.0)	0(0.0)	0(0.0)		
Disagree	0(0.0)	6(7.2%)	6(5.9%)		
Pharmacogenomics is relevant to my current practice					
Strongly agree	49(58.3%)	44(53%)	28(27.7%)		
Agree	26(31%)	28(33.7%)	69(68.3%)		
Neutral	9(10.7%)	7(8.4%)	4(4%)	40.859	<0.001
Strongly disagree	0(0.0)	1(1.2%)	0(0.0)		
Disagree	0(0.0)	3(3.6%)	0(0.0)		
In future, health care professionals should use PG tests for medication therapy management					
Strongly agree	50(59.5%)	42(50.6%)	36(35.6%)		
Agree	23(27.4%)	20(24.1%)	51(50.5%)		
Neutral	11(13.1%)	13(15.7%)	7(6.9%)	27.603	<0.001
Strongly disagree	0(0.0)	4(4.8%)	4(4%)		
Disagree	0(0.0)	4(4.8%)	3(3%)		
Curriculum is not well designed to understand pharmacogenomics					
Strongly agree	51(60.7%)	26(31.3%)	32(31.7%)		
Agree	19(22.6%)	40(48.2%)	52(51.5%)		
Neutral	14(16.7%)	3(3.6%)	6(5.9%)	46.080	<0.001
Strongly disagree	0(0.0)	7(8.4%)	4(4%)		
Disagree	0(0.0)	7(8.4%)	7(6.9%)		
Awareness					
Are you aware of any pharmacogenomic-related guidelines or policies in your healthcare curriculum or institution					
Yes	64(76.2%)	31(37.3%)	31(30.7%)		
No	20(23.8%)	52(62.7%)	70(69.3%)		
Are you aware of any ethical concerns related to pharmacogenomic testing in patient care					
Yes	25(29.8%)	41(49.4%)	28(27.7%)		
No	59(70.2%)	42(50.6%)	73(72.3%)		
Are you aware of any cost related barriers to implementing pharmacogenomics in healthcare					
Yes	60(71.4%)	41(49.4%)	31(30.7%)		
No	24(28.6%)	42(50.6%)	70(69.3%)		

Attitudes towards pharmacogenomics

The results revealed a generally favourable attitude towards PGx across the three disciplines, with the majority of respondents expressing interest in learning more about it (84.4% of medicine, 71.1% of nursing, and 75.2% of pharmacy). Furthermore, most respondents (88.1% in medicine, 88% in nursing, and 89.1% in pharmacy) agreed that PGx would enhance their ability to select the right drug and dosage for patients in their future careers. When asked whether pharmacogenomic testing should be part of routine patient assessments, the support was moderate, with 51.2% in medicine, 50.6% in nursing, and 58.4% in pharmacy favouring its adoption. A similar trend was seen regarding the belief that PGx would become standard practice soon, with 51.2% of medicine, 50.6% of nursing, and 59.4% of pharmacy students agreeing with this statement. Notably, the majority believed that pharmacogenomic testing could reduce the incidence of adverse drug reactions (72.6% in medicine, 72.3% in nursing, and 76.2% in pharmacy) (Table V).

Table V: Students' attitudes towards pharmacogenomics

Variable	Medicine N=84(%)	Nursing N=83(%)	Pharmacy N=101(%)	X^2	*P*-Value
Do you want to know more about pharmacogenomics					
No	3(3.6%)	3(3.6%)	3(3%)		
Not sure	7(8.3%)	21(25.3%)	22(21.8%)	9.069	0.059
Yes	74(88.1%)	59(71.1%)	76(75.2%)		
Do you think that pharmacogenomics testing can improve your future work in choosing the right drug and dose					
No	3(3.6%)	3(3.6%)	4(4%)		
Not sure	7(8.3)	7(8.4%)	7(6.9%)	0.201	0.995
Yes	74(88.1%)	73(88%)	90(89.1%)		
Do you believe pharmacogenomics testing should be a routine part of patient assessment					
No	5(6%)	5(6%)	5(5%)		
Not sure	36(42.9%)	36(43.4%)	37(36.6%)	1.439	0.837
Yes	43(51.2%)	42(50.6%)	59(58.4%)		
Do you think pharmacogenomics will become a standard practice in the near future					
No	13(15.5%)	13(15.7%)	13(12.9%)		
Not sure	28(33.3)	28(33.7%)	28(27.7%)	1.840	0.765
Yes	43(51.2%)	42(50.6%)	60(59.4%)		
How likely is it that pharmacogenomics testing will help to decrease the number of adverse drug reactions					
No	4(4.8%)	4(4.8%)	4(4%)		
Not sure	19(22.6%)	19(22.9%)	20(19.8%)	0.475	0.976
Yes	61(72.6%)	60(72.3%)	77(76.2%)		
How likely is it that pharmacogenomics testing will help to decrease the cost of developing new drugs					
No	21(25%)	21(25.3%)	22(21.8%)		
Not sure	47(56%)	43(51.8%)	44(43.6%)	6.542	0.162
Yes	16(19%)	19(22.9%)	35(34.7%)		

Discussion

Pharmacogenomics is an area of pharmacology that studies how genetic variation affects a patient's reaction to medication by establishing a link between a drug's toxicity or efficacy and gene expression or single-nucleotide polymorphisms (T P *et al*., 2009). It seeks to create logical ways to tailor medication regimens to each patient's genotype to maximise benefits and minimise side effects. These methods mark the arrival of customised medicine, in which medications and treatment combinations are tailored to the specific genetic composition of each patient. Understanding healthcare students' knowledge, perceptions, and attitudes towards pharmacogenomics (PGx) is essential to assess their readiness during undergraduate training for this rapidly advancing field. This insight is critical for ensuring that they are adequately prepared to integrate PGx into their future clinical practice.

The demographic breakdown of the study participants reveals some intriguing trends across the different healthcare disciplines. Pharmacy students formed the largest group, with 400-level students making up 24.3%

of the total, while nursing students at the same level represented the smallest group, at 10.4%, indicating that pharmacy students were the most represented in the study, which could influence the overall insights into PGx education.

Regarding age distribution, the majority of medical students fell within the 20 to 23 age range (73.8%), which aligns with typical age patterns observed in undergraduate healthcare programmes, as reported in a study assessing the demography and medical education of Nigerian final-year medical students (Mo, 2015). Nursing students displayed a narrower age range, with the vast majority (90.4%) between 20 and 23 and a small proportion (9.6%) under 19. Pharmacy, however, had a broader age spectrum, with 52.5% aged 20-23 and a notable 19.8% over 30 years old, reflecting a more diverse student body. The gender distribution leaned slightly towards females, who made up 54.5% of the participants, compared to 45.5% of males. The varied demographics in this study provide a comprehensive overview of the student population, which could affect perceptions and readiness towards PGx.

Among the participants, the primary source of information on PGx was their educational institution, with a proportion of 70.2% for medicine, 77.1% for nursing, and 44.6% for pharmacy, contrasting with previous findings, where textbooks followed by the internet were identified as the primary sources of PGx knowledge (Agrawal *et al.,* 2021). This contrast may be attributed to variations in curricula across different institutions and courses. A notable proportion of students (38.1% medicine, 75.9% nursing, and 42.6% pharmacy) rated their perceived knowledge of PGX as average. Students' understanding of genetic testing, precision medicine, and PGx may mainly stem from information and advertisements provided by the direct-to-consumer genetic testing (DTCGT) industry—which may include inaccuracies and exaggerations—rather than from more reliable information gained through their academic curricula (Zayts & Luo, 2017).

A majority of respondents across disciplines recognised that the goal of PGx is to personalise therapy based on an individual's genetic profile. Among them, 100% of medicine, 85.5% of nursing, and 72.3% of pharmacy students agreed that genetic variations can lead to adverse effects. These findings align with a similar study, where the majority (81%) believed that PGx is a valuable tool for pharmacists and medical professionals to enhance medication effectiveness and reduce the risk of adverse events (Coriolan *et al.,* 2019). When asked whether the package insert for warfarin includes a warning about altered metabolism in individuals with specific genetic variants, only 61.9% of medicine, 61.4% of nursing, and 65.3% of pharmacy students could confirm that such a warning exists. This finding suggests curricular gaps, a lack of familiarity with drug inserts, or limited exposure to PGX among the remaining participants.

In terms of perception and awareness, the majority of respondents strongly agreed that pharmacogenomics is a vital field healthcare providers should be knowledgeable about, and most of them also believed it should be an integral part of their curriculum. However, this result contrasts with findings from pharmacy students in Bosnia and Herzegovina, where the majority disagreed that pharmacogenomics should be an essential aspect of their curriculum (Mahmutovic *et al.,* 2018). Only an average number of respondents agreed that their curriculum is adequately designed to facilitate the understanding of PGx, highlighting significant curricular gaps among the study population and setting. When asked about their awareness of ethical concerns related to pharmacogenomic testing in patient care, the majority—70.2% from medicine, 50.6% from nursing, and 72.3% from pharmacy—reported not being aware of any ethical considerations. This result aligns with previous conclusions, showing that only 45% of all surveyed students were aware of various ethical aspects of genetic testing, with awareness ranging from 27% among students at the Faculty of Health Studies to 54% among pharmacy students (Mahmutovic *et al.,* 2018).

Overall, favourable attitudes towards PGx were observed, with the majority of respondents expressing interest in learning more about the field (88.1% medicine, 71.1% nursing, and 75.2% pharmacy), aligning with previous findings showing the desire of students to further their reading on PGX after graduation (Coriolan *et al.,* 2019). Most respondents also believed that pharmacogenomic testing could improve their future practice, particularly in selecting the right drugs and dosages for their patients. This result is consistent with that of another study in which respondents recognised the potential benefits of PGx for various aspects of drug management, albeit to varying degrees (Siamoglou *et al.,* 2021).

A crucial step in developing a comprehensive roadmap for the full adoption of genomic medicine and pharmacogenomics in Nigeria is assessing the attitudes, knowledge, and perceptions of healthcare students regarding pharmacogenomics. This evaluation provides valuable insights for stakeholders to identify and address knowledge gaps and overcome implementation challenges. By assessing the perspectives of healthcare students at Olabisi Onabanjo University, stakeholders gain a vital resource for shaping an effective strategy toward the seamless integration of these fields in Nigeria.

Recommendations

Given the rise of genomic technologies and their potential clinical applications, it is imperative to bridge the knowledge gap for precision medicine by educating healthcare students. Moreover, customising this training to suit the local context is essential. This training could take various forms, such as professional development courses or integrating PGx into students' curricula. The survey also highlighted a widespread consensus across different healthcare fields that possessing knowledge of pharmacogenomics is essential. This knowledge is crucial for recommending PGx testing, accurately interpreting and applying PGx test results to drug therapy decisions, and understanding the ethical considerations in pharmacogenomic testing. Such preparedness would empower healthcare professionals to actively contribute to shaping the future of pharmacogenomics, particularly in Nigeria and other low- and middle-income countries facing similar challenges, such as limited resources and expertise.

Limitations

This study's findings are limited by the specific demographic and educational context of Olabisi Onabanjo University in Ogun State, Nigeria. The responses and attitudes observed among students may not necessarily reflect those of healthcare students in other regions or institutions due to potential cultural, educational, or institutional variations. This limitation underscores the importance of recognising that while the study offers valuable insights into attitudes and perceptions within this particular setting, caution should be exercised when extrapolating these findings to broader populations or diverse educational environments.

Conclusion

This research uncovered varying levels of awareness and knowledge regarding the importance of pharmacogenomics among healthcare students at Olabisi Onabanjo University. While a significant portion expressed eagerness to enhance their understanding, the absence of perceived emphasis on pharmacogenomics within curricula emerged as a potential obstacle. Recognising these attitudes and perceptions is crucial for the successful integration of pharmacogenomics education, ensuring that future healthcare professionals are sufficiently equipped to harness its advantages in personalised medicine.

Ethics approval and informed consent

An ethical approval with reference number OOUTH/HREC/721/2023 AP was obtained from the Health Research Ethics Committee (HREC) of Olabisi Onabanjo University Teaching Hospital, Sagamu Ogun State, Nigeria prior to the commencement of this study. We also requested and acquired consent from all participants.

Conflict of interest

The authors declare no conflict of interest.

Source of funding

The authors did not receive any funding.

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