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RESEARCH ARTICLE

A quantitative exploration of the knowledge of pharmacy and medical students about Pharmacogenetics: Findings from a public university in Malaysia

Harini Thiagarajan, Shazia Jamshed, Azyyati Mohd Suhaimi, Pei Lin Lua, Umar Idris Ibrahim
Faculty of Pharmacy, Universiti Sultan Zainal Abidin, Besut Campus, Terengganu, Malaysia

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Correspondence
Umar Idris Ibrahim
Faculty of Pharmacy
University Sultan Zainal Abidin
Terengganu
Malaysia
umaribrahim@unisza.edu.my

Abstract

Background: Having a strong foundation in the science of pharmacogenetics is a significant prerequisite for both pharmacy and medical students to apply this knowledge in patient care once they enter into the healthcare setting. This study examines the level of foundational knowledge of pharmacogenetics and interest in learning about pharmacogenetics among third and fourth-year pharmacy and final-year medical students of the University Sultan Zainal Abidin (UniSZA) in Malaysia. **Method:** A total of 95 students participated in the study. A descriptive, cross-sectional study was conducted using a validated questionnaire from a previously published research paper. It was an electronic-based survey shared among the targeted population**.** **Results**: The average knowledge score for pharmacy students was 15.58 (SD $\pm$ 0.49) while final-year medical students had an average score of 14.56 (SD $\pm$ 0.32). A major percentage of the fourth-year pharmacy students were able to obtain scores higher than their junior counterparts and final-year medical students. Although the overall average knowledge score of the medical students was lower than that of the pharmacy students, nevertheless, they had a greater interest in learning about pharmacogenetics. **Conclusion:** There is a need to introduce up-to-date curricula for both pharmacy and medical students to enhance student comfort levels in pharmacogenetics practice.

Introduction

The use of pharmacogenetics has grown enormously in recent years along with the rapid advancement of healthcare, paving the door for personalised treatment based on each patient's genetic profile. More than 350 medications have been added to the Food and Drug Administration's (US-FDA) repository of medications tagged before administration, according to a pharmacogenetics study (Arafah *et al*., 2022). This association has created a pharmacogenetics table that takes into account pharmacogenetics relationships with enough data to help medical professionals make judgements about medications. The table also discusses how a drug's ultrarapid metabolizers can have negative consequences on the body (Arafah *et al*., 2022).

In some developed countries, pharmacogenetics practice has been implemented to maximise drug therapies. In a study conducted in Malaysia, it was concluded that the adoption rate of pharmacogenetics was considered low but has higher hopes for future adoption among physicians and pharmacists (Bannur, 2014). Also, the majority of the professionals had poor knowledge and had not been exposed to pharmacogenomics (Albassam *et al*., 2018). While it is important to assess the healthcare professionals' knowledge regarding pharmacogenomics, it is also crucial to evaluate the level of knowledge the undergraduate students have about pharmacogenetics. Future practitioners should be well-

equipped with adequate knowledge and clinical training regarding pharmacogenetics to provide quality healthcare to their patients.

Despite the growing importance of pharmacogenetics in healthcare, there is limited research on the level of understanding and interest among pharmacy and medical students. To be precise, only a few studies have addressed the foundational knowledge of both pharmacy and medical students. This study hypothesises that pharmacy students, in their later years of study, will have a greater understanding of pharmacogenetics compared to medical students. The objective of this study was to assess the foundational knowledge and interest in pharmacogenetics among third and fourth year pharmacy and final-year medical students.

Understanding fundamental pharmacogenetic concepts is necessary for comprehending the application of pharmacogenetics is used in clinical settings and is referred to as foundational knowledge. Both pharmacy and medical schools would be able to alter their curricula to close knowledge gaps in pharmacogenetics by conducting thorough evaluations of students' knowledge of pharmacogenetics.

Methods

Study design and setting

A descriptive cross-sectional study, investigating the knowledge of third and fourth year pharmacy and final-year medical students about pharmacogenetics was conducted from March 2023 to June 2023.

Study sample

The study population consists of third and fourth year pharmacy students and final-year medical students of the University Sultan Zainal Abidin (UniSZA), Terengganu, Malaysia. The pharmacy and medical students were from the Faculty of Pharmacy and the Faculty of Medicine respectively. All students in the third and fourth year pharmacy and final year medical students of UniSZA were included in the study.

Sampling technique

Convenience sampling was utilised. The target population was selected based on the subject's accessibility and proximity to the researcher.

Instrument

An internet-based survey tool, Google Form was used for data collection, and the questionnaire was added to the Google Form. The questionnaire was adapted from a previously published journal article (Mehtar *et al*., 2022). The permission to use this pre-validated tool was obtained from the principal author and no changes were made to the tool. Knowledge items within the survey consisted of four sections. Section A had the demographic information, Section B, consisted of 18 multiple choice questions, Section C had s seven "*true or false*" questions, and Section D had questions relating to the specific pharmacogenetics topics the students would like to learn about.

Data collection

The questionnaire was designed specifically to be completed by respondents without the intervention of the researchers. The prepared questionnaires were added to the Google Form and shared with the targeted sample via WhatsApp. The respondents were notified of their anonymity regarding the information supplied. No identification information was collected from respondents. Respondents were asked to fill out a consent form before proceeding with the survey. Responses were sent only once using their university e-mails. Periodic reminders were also sent to improve the response rate.

Data analysis

Data was analysed using Statistical Package for Social Sciences (IBM SPSS Statistics for Windows, version 23, Armonk, NY:IBM Corp). Descriptive statistics such as percentages, frequencies and mean scores were used to present the demographic variables. The Pearson correlation coefficient was used to test for a significant association between the knowledge of pharmacogenetics among medical and pharmacy students. The study was set to be statistically significant at $p < 0.05$. (Mehtar *et al*., 2022).

Ethics approval and informed consent

To conduct this study, full ethical approval was sought from the University Sultan Zainal Abidin (UniSZA) Ethical Committee (UniSZA/UHREC/2023/482). The respondents' participation was voluntary and consent was implied by attempting the questionnaire.

Results

The findings support the hypothesis that pharmacy students in their later years of study will have a greater understanding of pharmacogenetics compared to medical students. A total of 95 students consented and completed the questionnaire between March 2023 and May 2023. All responses were coded and analysed using SPSS version 23. Majority of the respondents were female, 60 (63.2%). The mean average score of pharmacy students was 15.58 compared to the medical students' (14.56).

Both the collective pharmacy and medical students' interest in pharmacogenetics were also compared. It was observed that the pharmacy students were highly interested, 11 (18.6%) in learning about pharmacogenetics-related topics compared to the medical students who were eight (8.42%). Furthermore, 5.1% (n = 3) of pharmacy students were not interested while only 3.7% (n = 1) of medical students showed no interest in learning pharmacogenetics-related topics in their curriculum. For details, see Tables I, II and III.

Table I: Demographic characteristics of respondents

Characteristics	Results			
Gender				
Female			60 (63.2%)	
Male			35 (36.8 %)	
Year				
Year 3 pharmacy			32 (100%)	
Year 4 pharmacy			27 (100%)	
Final year medicine			36 (53.73%)	
Interest in learning pharmacogenetics	**Year three pharmacy**	**Year four pharmacy**	**Pharmacy students**	**Final-year medical students**
Very interested	5 (15.6%)	7 (25.9%)	12 (18.8 %)	8 (22.2%)
Interested	15 (46.9 %)	13 (48.2%)	28 (57.6 %)	16 (44.4%)
Slightly interested	10 (31.3%)	6 (22.3%)	16 (18.6 %)	11 (30.6 %)
Not at all interested	2 (6.3%)	1 (3.7 %)	3 (5.1%)	1 (2.8%)

Table II: Assessment of pharmacogenetics knowledge of third and fourth year pharmacy students

Question		Year three pharmacy		Year four pharmacy	
		Correct	Incorrect	Correct	Incorrect
1.	The relationship between drug exposure and pharmacologic response Correct answer: Pharmacodynamics	22 (68.8%)	10 (31.3%)	25 (86.2%)	2 (6.9%)
2.	The study of a gene involved in response to a drug Correct answer: Pharmacogenetics	6 (18.8%)	26 (81.3%)	11 (37.9%)	16 (55.2%)
3.	The study of many genes involved in response to a drug : Correct answer: Pharmacogenomics	6 (18.8%)	26 (81.3%)	14 (48.3%)	13 (44.8%)
4.	The relationship of time and drug absorption, distribution, metabolism, and excretion Correct answer: Pharmacokinetics	7 (21.9%)	25 (78.1%)	26 (89.7%)	1 (34.7%)
5.	Alternate sequences or versions of the same gene inherited from each parent Correct answer: Allele	11 (34.4%)	21 (65.6%)	23 (79.3%)	4 (13.6%)
6.	Three adjacent nucleotide bases that ultimately encode a specific amino acid Correct answer: Codon	9 (28.1%)	23 (71.9%)	19 (65.5%)	8 (27.6%)
7.	A nucleotide sequence that codes information for protein synthesis Correct answer: Exon	21 (65.6%)	11 (34.4%)	10 (34.5%)	17 (58.6%)
8.	The entire DNA of an organism Correct answer: Genome	21 (65.6%)	11 (34.4%)	18 (62.1%)	18 (62.1%)
9.	The specific set of alleles inherited at a locus on a given gene Correct answer: Genotype	8 (25 %)	24 (75%)	19 (65.5%)	8 (27.6%)
10.	A series of polymorphisms that are inherited together Correct answer: Haplotype	16 (50%)	16 (50%)	9 (31%)	18 (62.1%)
11.	Characteristics derived from a single gene Correct answer: Monogenic trait	18 (56.3%)	14 (43.8%)	18 (62.1%)	9 (31%)

Question		Year three pharmacy		Year four pharmacy	
		Correct	Incorrect	Correct	Incorrect
12.	One of the structural components (building blocks) of DNA or RNA, including adenine (A), cytosine (C), guanine (G), thymine (T) and uracil (U)1 Correct answer: Nucleotide	19 (59.4%)	13 (40.6%)	14 (48.3%)	13 (44.8%)
13.	An individual's expression of a physical trait or physiologic function due to genetic makeup and environmental and other factors Correct answer: Phenotype	9 (28.1%)	23 (71.9%)	11 (37.9%)	16 (55.2%)
14.	Regions of the genome (DNA) that contain the instructions to make protein Correct answer: Gene	14 (43.8%)	18 (56.3%)	13 (44.8%)	14 (48.3%)
15.	The use of specific patient information and biomarkers to make more informed choices regarding the optimal therapeutic treatment regimen for a given patient Correct answer: Personalised medicine	29 (90.6%)	3 (9.4%)	20 (69%)	7 (24.1%)
16.	Insertion or deletion of DNA either as single nucleotides or spanning regions of DNA involving many nucleotides Correct answer: Indel	16 (50%)	16 (50%)	15 (51.7%)	12 (41.4%)
17.	A nucleotide sequence in DNA that does not code information for protein synthesis and is removed before translation or messenger RNA Correct answer: Intron	9 (28.1%)	23 (71.9%)	7 (24.1%)	20 (69%)
18.	Change in DNA sequence between individuals Correct answer: Mutation	25 (78.1%)	7 (21.9%)	22 (75.9%)	5 (17.2%)
19.	A mutation in DNA in a given population that may be observed at greater than 1% frequency is a polymorphism Correct answer: True	24 (75%)	8 (25%)	25 (86.2%)	2 (6.9%)
20.	An indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention is the definition of Biomarker Correct answer: True	27 (84.4%)	5 (15.6%)	20 (69%)	7 (24.1%)
21.	A variant DNA sequence in which a single nucleotide has been replaced by another base is the definition of single nucleotide polymorphism Correct answer: True	24 (75%)	8 (25%)	18 (62.1%)	9 (31%)
22.	Heterozygous is possessing an identical allele for the same trait Correct answer: True	24 (75%)	8 (25%)	8 (27.6%)	19 (65.5%)
23.	A protein around which DNA coils to form chromatin, thus ''*packaging*" DNA is the definition of Histone Correct answer: False	23 (71.9%)	9 (28.1%)	17 (58.6%)	10 (34.5%)
24.	Topoisomerase is a class of enzymes that alter the supercoiling of single-stranded DNA Correct answer: True	27 (84.4%)	5 (15.6%)	17 (58.6%)	10 (34.5%)
25.	Xenobiotics are substances introduced into the body but not produced by it Correct answer: False	22 (68.8%)	10 (31.3%)	21 (72.4%)	6 (20.7%)

Table III: Assessment of pharmacogenetics knowledge of pharmacy and final year medical students

Question		Total pharmacy students		Final year medicine	
		Correct	Incorrect	Correct	Incorrect
1.	The relationship between drug exposure and pharmacologic response Correct answer: Pharmacodynamics	47 (78.3%)	12 (20%)	31 (86.1%)	5 (13.9%)
2.	The study of a gene involved in response to a drug Correct answer: Pharmacogenetics	37 (61.7%)	22 (36.7%)	22 (61.1%)	14 (38.9%)
3.	The study of many genes involved in response to a drug Correct answer: Pharmacogenomics	40 (66.7%)	19 (31.7%)	26 (72.2%)	10 (27.8%)
4.	The relationship between time and drug absorption, distribution, metabolism, and excretion Correct answer: Pharmacokinetics	51 (85%)	8 (13.3%)	26 (72.2%)	10 (27.8%)
5.	Alternate sequences or versions of the same gene inherited from each parent Correct answer: Allele	44 (73.3%)	15 (25%)	22 (61.1%)	14 (38.9 %)

Question		Total pharmacy students		Final year medicine	
		Correct	Incorrect	Correct	Incorrect
6.	Three adjacent nucleotide bases that ultimately encode a specific amino acid Correct answer: Codon	42 (70%)	17 (28.3%)	24 (66.7%)	12 (33.3%)
7.	A nucleotide sequence that codes information for protein synthesis Correct answer: Exon	21 (35%)	38 (63.3%)	15 (41.7%)	21 (58.3%)
8.	The entire DNA of an organism Correct answer: Genome	18 (62.1%)	30 (50%)	17 (47.2%)	19 (52.8%)
9.	The specific set of alleles inherited at a locus on a given gene Correct answer: Genotype	43 (71.7%)	16 (26.7%)	21 (58.3%)	15 (41.7%)
10.	A series of polymorphisms that are inherited together Correct answer: Haplotype	25 (41.7%)	34 (56.7%)	16 (44.4%)	20 (55.6%)
11.	Characteristics derived from a single gene Correct answer: Monogenic trait	36 (60%)	23 (38.3%)	24 (66.7%)	12 (33.3%)
12.	One of the structural components (building blocks) of DNA or RNA, including adenine (A), cytosine (C), guanine (G), thymine (T) and uracil (U)1 Correct answer: Nucleotide	33 (55%)	26 (43.3%)	20 (55.6%)	16 (44.4%)
13.	An individual's expression of a physical trait or physiologic function due to genetic makeup and environmental and other factors Correct answer: Phenotype	20 (33.3%)	39 (65%)	21 (58.3%)	15 (41.7%)
14.	Regions of the genome (DNA) that contain the instructions to make protein Correct answer: Gene	27 (45%)	32 (53.3%)	15 (41.7%)	21 (58.3%)
15.	The use of patient-specific information and biomarkers to make more informed choices regarding the optimal therapeutic treatment regimen for a given patient Correct answer: Personalised medicine	49 (81.7%)	10 (16.7%)	30 (83.3%)	6 (16.7%)
16.	Insertion or deletion of DNA either as single nucleotides or spanning regions of DNA involving many nucleotides Correct answer: Indel	31 (51.7%)	28 (46.7%)	21 (58.3%)	15 (41.7%)
17.	A nucleotide sequence in DNA that does not code information for protein synthesis and is removed before translation or messenger RNA Correct answer: Intron	16 (26,7%)	43 (71.7%)	16 (44.4%)	20 (55.6%)
18.	Change in DNA sequence between individuals Correct answer: Mutation	47 (78.3%)	12 (20%)	24 (66.7%)	12 (33.3%)
19.	A mutation in DNA in a given population that may be observed at greater than 1% frequency is a polymorphism Correct answer: True	49 (81.7%)	10 (16.7%)	28 (77.8%)	8 (22.2%)
20.	An indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention is the definition of Biomarker Correct answer: True	47 (78.3%)	12 (20%)	21 (58.3%)	15 (41.7%)
21.	A variant DNA sequence in which a single nucleotide has been replaced by another base is the definition of single nucleotide polymorphism Correct answer: True	42 (70%)	17 (28.3%)	20 (55.6%)	16 44.4%)
22.	Heterozygous is possessing an identical allele for the same trait Correct answer: True	16 (26.7%)	43 (71.7%)	11 (30.6%)	25 (69.4%)
23.	A protein around which DNA coils to form chromatin, thus ''packaging" DNA is the definition of Histone Correct answer: False	40 (66.7%)	19 (31.7%)	20 (55.6%)	16 (44.4%)
24.	Topoisomerase is a class of enzymes that alter the supercoiling of single-stranded DNA Correct answer: True	44 (73.3%)	15 (25%)	20 (55.6%)	16 (44.4%)
25.	Xenobiotics are substances introduced into the body but not produced by it Correct answer: False	43 (71.7%)	16 (26.7%)	13 (36.1%)	23 (63.9%)

Figure 1 shows the distribution of scores between the pharmacy (third and fourth year) and final-year medical students. Pharmacy students (n = 3) obtained the highest score (22), while the highest score among medical students was 20 (n = 2). The lowest score, which is eight, was by a medical student. The average scores obtained

by the pharmacy students ($\bar{x} = 15.58$) were slightly higher than the final year medical students ($\bar{x} = 14.56$).

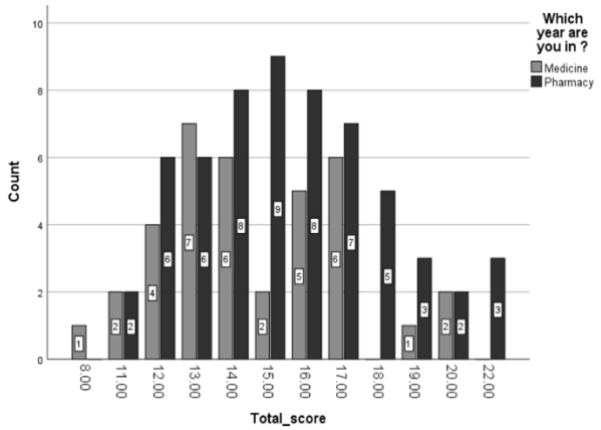

Figure 1: Aggregate knowledge of medicine and pharmacy students

Figure 2 shows the distribution of scores among third and fourth year pharmacy students. The highest score of 22 (n = 3) was obtained by year four pharmacy students while the highest score among the fourth-year pharmacy students was 19 (n = 2).

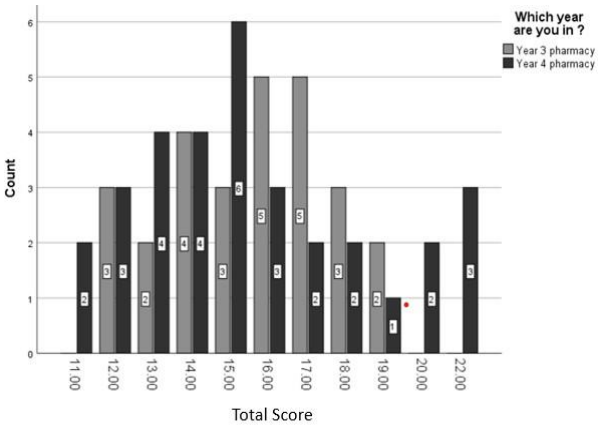

Figure 2: Aggregate knowledge of years three and four pharmacy students

The correlation matrix shown in Table IV reveals the simple correlation between key study variables. Pharmacy students in the third and fourth years were associated with a lower interest in learning pharmacogenetics. (r = -0.127, p < 0.05). Meanwhile, there is a weak positive association between pharmacy, medical students and their interest in learning pharmacogenetics. (r = 0.105, p < 0.005). Similarly, there is a weak positive association between pharmacy, medical students and their aggregate knowledge score. (r = 0.184, p < 0.05). For further clarification of the correlation between variables, Table IV is referred to.

Table IV: Correlation matrix

Characteristics	Gender	Years three and four pharmacy students	Pharmacy and medical students	Interest in learning pharmacogenetics	Aggregate knowledge score
Gender	1	-	-	-0.70	0.60
Years three and four pharmacy students	-	1	-	-0.127*	-0.007
Pharmacy and medical students	-	-	1	0.105*	0.184*
Interest in learning pharmacogenetics	-	-	-	1	-0.001

*Correlation is significant at the 0.05 level (2-tailed). Pearson correlation coefficient was used when its assumptions were met.

Discussion

The study found that pharmacy students demonstrated a higher level of knowledge in pharmacogenetics compared to medical students, indicating a potential gap in medical education. Similar the some reported findings (Agrawal, 2021; Albitar & Alchamat, 2021), the study indicates a deficiency in pharmacogenetics education among medical students.

The study aimed to evaluate the pharmacogenetics knowledge of third and fourth-year pharmacy students and final-year medical students. The participation rate among third and fourth-year pharmacy students was high, encompassing the entire target population, while slightly over half of the final-year medical students responded, likely due to their busy clinical schedules. The assessment primarily focused on foundational pharmacogenetics concepts and terminologies. Correct

responses indicated sufficient knowledge, while incorrect answers highlighted areas for improvement. The study also explored the correlation between students' pharmacogenetics knowledge and their interest in learning about the subject and specific pharmacogenetics topics.

Knowledge score of pharmacy and medical students

Pharmacy students demonstrated a stronger grasp of pharmacogenetics compared to their medical counterparts, evident in their higher mean scores. This can be attributed to the alignment of assessment items with the pharmacy curriculum. These findings corroborate Albitar & Alchamat's 2021 study, underlining the profession's influence on knowledge scores (Albitar & Alchamat, 2021). Additionally, Moen and Lamba's 2012 research indicated that pharmacy students are more inclined to recognise the importance of pharmacogenetics knowledge in their field (Moen & Lamba, 2012).

The significant difference in mean scores between medical and pharmacy students can be attributed to the variability in pharmacogenetics education across programs (Albassam *et al.*, 2018). Moen and Lamba in 2012 reported that a majority of responding pharmacy schools prioritise genetics-related education (Moen & Lamba, 2012). In contrast, less than a quarter of medical students in the USA had reported exposure to pharmacogenetics in their curriculum (Agrawal, 2021). Consequently, curriculum disparities explain why pharmacy students exhibit greater familiarity with scientific pharmacogenetics terms and achieve higher scores than final-year medical students.

Knowledge score of the third and fourth-year pharmacy students

The knowledge score increased from the third-year to the fourth-year pharmacy students. This result is comparable to a study by Arafah and colleagues, in which they noted a significantly rising knowledge score with each year of pharmacy degree coursework. One of the reasons was that fourth-year pharmacy students were exposed to more in-depth and extensive study material on the topic of pharmacogenetics and tended to learn more about it (Arafah, 2022). Hence, they understood the importance of cultivating interest and having a strong grasp of pharmacogenetics knowledge so that they can apply the same later during their clinical practices.

Interest in learning about pharmacogenetics among pharmacy and medical students

While the medical students had a slightly lower average knowledge compared to pharmacy students, they displayed a notably higher interest in learning about pharmacogenetics. This interest reflects their recognition of the clinical significance of pharmacogenetics in enhancing healthcare services, despite the subject's limited inclusion in their curriculum. The findings indicate that medical students, although slightly less knowledgeable than the study's overall target population, possess a stronger desire for instruction in pharmacogenetics. Consequently, there is a pressing need for a focused instructional approach, aiming to integrate pharmacogenetics concepts into medical curricula, provide ongoing education, and introduce pharmacogenetics applications in clinical practice (Alzoubi *et al*., 2021; Shah *et al*., 2022).

About the items in the questionnaire

In assessing the students' comprehension of various pharmacogenetics terms, the questionnaire presented challenging options, necessitating in-depth pharmacogenetics knowledge for accurate responses. The majority of participants demonstrated above-average knowledge, reflecting their understanding of the questions and the ability to identify correct answers, with only minor knowledge gaps. This aligns with Arafah and colleagues' findings, indicating a fair level of pharmacogenetics knowledge among Saudi University participants (Arafah *et al*., 2022). The educational landscape in both pharmacy and medical curricula within the studied faculties seems favourable for pharmacogenetics (Alzoubi *et al*., 2021).

The difficulty level of the questions varied depending on the participants' academic year and field. Pharmacy students scored higher on questions related to terms like "*pharmacokinetics*" and "*pharmacodynamics*" due to consistent exposure during their coursework, a trend supported by Mehtar and colleagues' study among pharmacists (Mehtar *et al*., 2022). Such terminology is routinely used in pharmacy practice. This exposure contributed to pharmacy students' superior scores compared to medical students. For the question concerning the definition of 'personalised medicine,' both pharmacy and medical students mostly answered correctly, likely because the alternatives, "*pharmacogenetics*" and "*pharmacogenomics*" could be ruled out, and the key phrase 'optimal treatment regimen for a given patient' guided their choice. However, understanding the term "*Indel*" proved more challenging, with only half of the students across both disciplines providing the correct definition. Mehtar's study also reported difficulties with "*Indel*" recognition,

possibly due to confusion with the term "*Mutation*" which is less commonly addressed in curricula (Mehtar *et al*., 2022).

In terms of the definitions of "*pharmacodynamics"* and "*pharmacokinetics"* medical students excelled in the former, as it aligns with their focus on how drugs affect patients, while pharmacy students predominantly excelled in the latter, as it comprises a substantial part of their curriculum. However, both pharmacy and medical students demonstrated limited knowledge regarding specific topics such as "*heterozygous gene*", "*nucleotide sequence*", and the definitions of "*exon*" and "*intron*", indicating these questions posed greater difficulty and required deep pharmacogenetics knowledge. These terms are less commonly explored in detail during students' learning, and they are not frequently used in their daily coursework, contributing to the limited understanding (Mehtar *et al*., 2022).

Specific pharmacogenetics topics of interest of students

Responses from final-year medical students and third and fourth-year pharmacy students revealed their particular interests in pharmacogenetics topics. These interests encompassed specific subjects such as CYP450, renal CYP3A5, CYP2A6, and CYP3A4 inducers and inhibitors, indicating the students' recognition of the significance of these topics in comprehending drug interactions and making informed clinical decisions. Furthermore, students exhibited curiosity about cancer-related genes and personalised medicine, recognising the potential of pharmacogenetics in individualised cancer therapy. "*Personalised medicine*" entails utilising a patient's genetic makeup to guide treatment decisions, considering genetics alongside lifestyle, quality of life, and environmental factors. In contrast, students demonstrated less enthusiasm for subjects like polymorphism and mutation, possibly due to the limited emphasis placed on these topics in both pharmacy and medical curricula.

Ways to improve pharmacogenetics knowledge among pharmacy and medical students in future

The study findings, along with other research, reveal a shared interest among medical and pharmacy students in learning pharmacogenetics due to the recognised clinical benefits (Albassam *et al*., 2018; Agrawal, 2021). However, there exists a disconnect between the skills they acquire and those they perceive as necessary for enhanced patient care (Agrawal, 2021). A significant hurdle in the widespread adoption of pharmacogenetics in healthcare is the lack of information about the field. Therefore, it is imperative to integrate pharmacogenetics into academic curricula to ensure future pharmacists and physicians can effectively apply the knowledge of pharmacogenetics in their practice.

In clinical settings, healthcare providers' limited knowledge and awareness of pharmacogenetics have hindered its adoption (Arafah *et al*., 2022). Pharmacists, known as drug experts, play pivotal roles in patient education and can aid healthcare professionals in understanding and interpreting pharmacogenetics data for optimal treatment decisions. Physicians should be proficient in ordering relevant pharmacogenetics-related tests and making informed medication choices based on the results. Medical and pharmacy students represent the future of pharmacogenetics adoption, emphasising the importance of assessing their knowledge and interests. This study serves as a foundation for policymakers to address and rectify knowledge gaps in both pharmacy and medical students.

Collaboration between medical and pharmacy schools is crucial to tackle this issue. To enhance students' understanding of pharmacogenetics, the Ministry of Health, Ministry of Education, and professional organisations should update undergraduate curricula, a strategy supported by various studies (Moen & Lamba, 2012; Rahma *et al.*, 2020; Alzoubi *et al*. 2021; Mehtar *et al.* 2022). The faculties of medicine and pharmacy bear the responsibility of preparing future practitioners with a comprehensive grasp of pharmacogenetics, and the ability to apply it in patient care. The inclusion of pharmacogenetics in curricula, reinforced with practice-based training opportunities and faculty guidance, can nurture students' interest and knowledge in the field (Coriolan *et al*., 2019; Makrygianni, 2023). Various international organisations advocate for standard pharmacogenetics education in medical, pharmacy, and public health schools, emphasising the need for undergraduate teaching, case-based learning, and dedicated textbook chapters on the subject (Agrawal, 2021).

Limitations

This study had a few limitations. Firstly, the generalisability of the results raises concerns, as the sample was recruited solely from the third, fourth pharmacy and final-year medical students from UniSZA. The knowledge of the students may differ by geographic location (different universities) and different pharmacy and medical curricula. Secondly, while students were informed that the survey was ungraded and no identifying information was collected, it was not possible to verify that they did not use external resources when filling out the survey, especially since the survey version they took was administered

electronically. Future studies could explore the effectiveness of targeted educational interventions to improve pharmacogenetics knowledge.

Conclusion

The findings revealed that both pharmacy and medical students demonstrated moderate knowledge scores and exhibited a strong interest in gaining an in-depth understanding of pharmacogenetics. Notably, fourth-year pharmacy students exhibited a higher proficiency in basic pharmacogenetics knowledge compared to their third-year counterparts and final-year medical students. While final-year medical students scored lower in terms of knowledge compared to pharmacy students, they displayed greater enthusiasm for learning about pharmacogenetics

Conflict of interest

The authors declare no conflict of interest.

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