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An objective evaluation of fundamental pharmacogenomics knowledge among pharmacists and pharmacy students

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ABSTRACT

Introduction: Possessing a correct and comprehensive foundation on the science of pharmacogenomics (PGx) is an important prerequisite for pharmacists to successfully apply pharmacogenomic testing to patient care. While some work has addressed general PGx knowledge among pharmacists, little research has specifically focused on PGx foundational knowledge. This study examines the level of foundational knowledge of PGx and interest in learning about PGx among community pharmacists and first-year pharmacy students at Beirut Arab University (BAU), Beirut, Lebanon.

Methods: A cross-sectional survey was self-administered to community pharmacists within a random sample of community pharmacies in Beirut, Lebanon, and to first-year BAU pharmacy students. The knowledge component of the instrument consisted of 25 items, each worth one point, addressing fundamental PGx information. The validity and internal consistency of the designed instrument were tested among the study population. Correlation analysis was carried out between aggregate knowledge and key variables for participating pharmacists.

Results: Of 150 approached pharmacists, 137 (91 %) participated and of 132 pharmacy students, 131 (99 %) participated. The average knowledge score for community pharmacists was 15 (Standard Deviation = 4) out of a possible total of 25 with the total number of correct answers ranging from 8 to 24 out of 25 questions. The average score for pharmacy students was 17 (Standard Deviation = 5) out of a possible total of 25 with the total number of correct answers ranging from 5 to 24. Pharmacists' age and years of practice were associated with a lower aggregate knowledge score ($r = -0.20$; $p < 0.05$ and $r = -0.21$; $p < 0.05$), respectively. Pharmacists' interest in learning about PGx varied whereas 62 % were either interested or very interested in learning about PGx. Students' interest, however, was higher with 70 % being either interested or very interested. Specific PGx topics of interest to participants were highlighted.

Conclusion: This study identified areas where PGx foundational knowledge was acceptable and others where significant opportunities for improvement exist. These results add to the rapidly expanding field of pharmacogenomics education and practice in relation to pharmacy. In particular, these findings have significant implications for planning pharmacogenomics-related educational activities targeting current and future pharmacists.

1. Introduction

As a science, pharmacogenomics (PGx) constitutes a key part of personalized medicine by which the best medication and/or dose are chosen using patient-specific genomic biomarkers. It is defined as "the study of the gene involved in response to a drug" (Kisor et al., 2014). With PGx in practice, the appropriate drug in the right dosage is prescribed to the patients with genetic factors in consideration before medication initiation improving both safety and efficacy. To that end, the United States Food and Drug Administration (FDA) recently launched a table of pharmacogenetic associations

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that considers PGx associations with sufficient evidence to aid health professionals in their decision making (US Food and Drug Administration, 2020). Examples of information covered by the FDA table include how a poor metabolizer of a commonly used drug combination such as Sulfamethoxazole and Trimethoprim may result in higher-than-average adverse reaction risk. The table also covers how ultrarapid metabolizers of a drug such as tramadol may experience higher systemic and breast milk active metabolite concentrations, increasing the chances of respiratory depression and death.

According to the American Society of Health-System Pharmacists (ASHP), pharmacists should encourage the use of PGx testing, provide an accurate interpretation of test results, improve therapy outcomes according to the PGx test results, educate other health care professionals and patients on the implementation of PGx, and engage with organizations housing sites of practice that integrate PGx testing (Haidar et al., 2015). To that end, previous studies addressed attitude towards pharmacogenetic testing, confidence in applying this test in their practice sites, and reasons for not ordering PGx tests (Roederer et al., 2012; Tuteja et al., 2013; Yau et al., 2015). The results generally showed low confidence in their ability to apply this test despite a favorable attitude. Few studies compared these characteristics of pharmacists versus clinicians (Albassam et al., 2018; Elewa et al., 2015). Results showed that both pharmacists and other clinicians have positive attitudes regarding the clinical implication of PGx despite their suboptimal level of awareness towards this topic.

Several studies addressed pharmacists' knowledge of PGx, interest in future education, and preferred resources to learn about PGx (Mccullough et al., 2011; Roederer et al., 2012; Yau et al., 2015). These studies were also done on other clinicians (Lee et al., 2019; Nair et al., 2019). Most of these studies showed gaps in PGx knowledge among health care providers and the need to get more training in this topic (Albassam et al., 2018; Mccullough et al., 2011; Roederer et al., 2012; Yau et al., 2015). Quite often, participants note that, despite being hopeful to integrate PGx in their field, they continue to be facing challenges in making this transition. Other studies assessed the role of pharmacists in PGx testing, emphasizing the importance of the pharmacist's role to use this testing and interpret the results after getting a suitable education for better patient outcomes (Suppiah et al., 2018; Tuteja et al., 2013). In addition, pharmacists are generally enthusiastic about receiving PGx training and are interested in taking action in PGx clinical application and related patient education (Albassam et al., 2018; Elewa et al., 2015). Worth noting is that most of this research was done in the US and Europe (Crown et al., 2020; Frigon et al., 2019; Hundertmark et al., 2020; Mccullough et al., 2011; Tuteja et al., 2013), with some being done in the Middle East (Albassam et al., 2018; Algahtani, 2020; Elewa et al., 2015).

Little work has addressed the foundational knowledge of PGx among pharmacists. In the context of this study, the term foundational knowledge refers to the understanding of key and common pharmacogenomic terms that serves as a prerequisite for understanding clinical applications of PGx. This comprehensive evaluation of current and future pharmacists' knowledge of PGx principles will help in making sure that future Continuous Education (CE) activities and training will be tailored to their needs and that schools of pharmacy can update their curricula to cover specific areas where gaps exist.

This study aimed to 1) assess the level of foundational knowledge of PGx among community pharmacists in Beirut and compare it to that of first-year pharmacy students at Beirut Arab University (BAU), a group with interest in pharmacy but no formal training on the topic, 2) explore the relationship between aggregate knowledge and key variables of conceptual relevance for participating pharmacists and 3) assess the interest in learning about PGx among pharmacists and pharmacy students.

2. Methods

2.1. Study design and ethical approval

This study followed a cross-sectional, descriptive survey design. The Beirut Arab University Institutional Review Board approved the study (2020-H-060-P-M-0392). Oral and online survey consents were obtained from participating pharmacists and pharmacy students, respectively.

2.2. Sample

Pharmacists: Community pharmacists in Beirut were the target population of this study. The sampling frame for community pharmacists in Beirut consisted of a list provided by the Order of Pharmacists of Lebanon (OPL) which included 230 pharmacies. The calculated sample size desired was 125 pharmacies, which was computed with the following assumptions: population size of 230 pharmacies as indicated by the OPL list, a hypothesized % frequency of outcome factor (aggregate PGx knowledge) in the population of 50 % ± 5, Confidence limits of 5 %, a design effect of 1 %, and a confidence interval: 90 %. With findings from a previous study done in another Middle Eastern country taken into consideration(Amin and Chewning, 2016), several factors that could impact the survey response rate such as absenteeism of the pharmacists, incomplete surveys, and refusal to participate were accounted for. Accordingly, the sample size was increased from 125 to 150 pharmacies to account for those possibilities when collecting data. Those 150 pharmacies were chosen using a random number generator. Only one community pharmacist from each pharmacy was requested to fill out the survey. In case more than one pharmacist was present during the data collectors' visit, the pharmacist who was about to interact with the next patient was asked to participate in the study. Pharmacy students and technicians were not included in this part of the study.

Pharmacy Students: Similar to 0 to 6 programs in the US, the Faculty of Pharmacy at BAU accepts students immediately after they graduate from high school. First-year pharmacy students enrolled in the academic year 2020–2021 at BAU served as the sampling frame for the student sample. All 132 students enrolled in that cohort were sent an invitation to fill an online survey similar to the one administered to pharmacists. Those students were selected since they have not received any course materials on pharmacogenomics. Following data collection, however, students were debriefed about the topic including the correct answers for each item.

2.3. Study variables

The key study variable was the aggregate knowledge of PGx foundational principles. Survey items were adapted from definitions provided by a leading textbook on the topic (Kisor et al., 2014). Knowledge items within the survey comprised either multiple-choice questions with a single correct answer as well as true or false questions. The duration needed to fill this survey was about 10 min. Participants were instructed not to consult colleagues or external sources when answering the survey.

In the second part of the survey, demographic data such as age and gender were collected both from pharmacists and pharmacy students. Data collected from pharmacists included pharmacy credentials, year of graduation, the university from which the highest pharmacy practice degree was obtained, and the number of years

of practice after graduation. Final items in the survey addressed participants' interest in learning about PGx as well as specific PGx topics of interest to participants.

2.4. Pretesting measures

The survey was provided to participants in English and French, the languages of instruction in Lebanese pharmacy schools. Instrument validity was established in two main steps. First, cognitive interviewing (think-aloud) for each version of the instrument (English and French) was done with five community pharmacists in Beirut to ensure the proper comprehension of instrument items. The second step involved pilot testing, which included visiting a convenience sample of five community pharmacies and asking the five pharmacists on duty to fill the surveys.

2.5. Data collection

Pharmacists: Two data collectors visited the selected pharmacies and asked the selected pharmacist whether he/she would prefer to take the survey in English or French. They then provided the participant with a paper copy of the survey form to the selected pharmacist in their preferred language to be self-administered before collecting filled surveys following participant completion. Pharmacist data were collected in the period from November 2020 to December 2020.

Pharmacy Students: An electronic survey link followed by three reminders was sent to all first-year pharmacy students in BAU in spring 2021. A small paragraph explaining the purpose of the survey and the deadline to fill the survey was provided to students. Similar to the pharmacist survey, students were provided with survey items both in English and in French. As with pharmacists, students were informed that all their responses would be kept confidential. They were notified that while the survey would not contribute to their grade, they were expected to fill the survey as part of the pharmacy program's continuous quality improvement activity aiming to assess the knowledge of students of this topic to inform future curriculum modifications. No incentive was provided for students to fill out the survey. Pharmacy student data were collected in March 2021.

2.6. Data analysis

Descriptive statistics were used to describe the characteristics of participating pharmacists and pharmacy students, aggregate and item-specific knowledge scores, and level of interest in learning about PGx. The analysis generated frequencies, as well as means, ranges, or standard deviations as relevant. Possible aggregate scores for participants' knowledge ranged from zero to 25, with each question item being worth one point. The reliability of the knowledge items was assessed using Kuder-Richardson 20. Correlation analysis was carried out between aggregate knowledge and key variables of conceptual relevance for participating pharmacists. The statistical level of significance was set at $P < 0.05$. Data were analyzed using IBM SPSS (version 24). Lastly, participants' answers to the open-ended item addressing PGx topics of interest to participants were analyzed using qualitative content analysis (Holdford, 2008).

3. Results

3.1. Participant response and characteristics

Of 150 pharmacists approached, 137 (91 %) agreed to participate and 13 (9 %) refused. An analysis of sample demographics of participating pharmacists is presented in Table 1. The majority of pharmacists were females (55 %) and the mean age was 31 (SD = 9) ranging from 21 to 80 years with years of graduation ranging from 1965 to 2020. Pharmacists' years of practice after graduation ranged from 0 to 55 years with a mean of 7 years (SD = 9). Most had a Bachelor of Pharmacy degree (69 %) while 20 % and 10 % had Doctor of Pharmacy and Master degrees, respectively. Nearly-two-thirds graduated either from BAU or from the Lebanese International University (LIU). Nearly 9 in 10 were fully licensed to practice pharmacy while 11 % were recent pharmacy graduates who were yet to receive their pharmacy practice license.

Concerning pharmacy student participants, of 132 first-year BAU students receiving the survey link, 131 (99 %) participated. Nearly-seven in ten were females (69 %) and the mean age was 19 (SD = 2) ranging from 17 to 30 years.

3.2. Participants' response to individual pharmacogenomics knowledge questions

The proportion of community pharmacists and pharmacy students who identified the correct answer for each of the knowledge questions is presented in Table 2. For pharmacists, the highest number of correct answers was provided to question 4 addressing the definition of pharmacokinetics (93 %) followed by question 1 addressing pharmacodynamics (88 %). On the other hand, the highest numbers of incorrect answers were provided to questions 16 and 24 addressing the definition of an indel and a topoisomerase where, for both, less than one in four pharmacists identified the correct answers. Concerning the answers of pharmacy students, 91 % and 89 % identified the correct answer for questions 6 and 12 addressing the definition of a codon and a nucleotide, respectively. On the contrary, only 31 % of the students recognized the correct answer to question 16 addressing the definition of an indel and 47 % to question number 7 addressing the definition of an exon.

Table 1
Characteristics of participating community pharmacists (n = 137).

Characteristics	Results
Gender	**n (%)**
Female	75 (55 %)
Male	62 (45 %)
Age	**Years**
Range	21–80
Mean (SD)	32 (±10)
Year of graduation	**Years**
Range	1965–2020
Years of practice after graduation	**Years**
Range	0–55
Mean (SD)	7 (±9)
Pharmacy credentials	**n (%)**
Bachelor of pharmacy	95 (70 %)
Doctor of pharmacy	28 (20 %)
Master degree	14 (10 %)
University of highest pharmacy practice degree	**n (%)**
Beirut Arab University	61 (45 %)
Lebanese International University	31 (23 %)
Lebanese University	13 (9 %)
Lebanese American University	10 (7 %)
Saint Joseph University	3 (2 %)
American University of Beirut	3 (2 %)
Foreign University	16 (12 %)
Licensed	**n (%)**
Yes	122 (89 %)
No	15 (11 %)

Table 2
Questions asked and the proportion of community pharmacists (n = 137) and pharmacy students (n = 131) who identified the correct answer of each question.

Question*	Correct answer	Pharmacists		Students	
		correct n (%)	incorrect n (%)	correct n (%)	incorrect n (%)
1- The relationship between drug exposure and pharmacologic response	Pharmacodynamics				
■ Pharmacogenomics		120	17	96	35
■ Pharmacodynamics		(88%)	(12%)	(73%)	(27%)
■ Pharmacokinetics					
■ Pharmacogenetics					
2- The study of a gene involved in response to a drug	Pharmacogenetics				
■ Pharmacogenomics		81	56	76	55
■ Pharmacodynamics		(59%)	(41%)	(58%)	(42%)
■ Pharmacokinetics					
■ Pharmacogenetics					
3- The study of many genes involved in response to a drug	Pharmacogenomics	85			
■ Pharmacogenomics		(62%)	52	80	51
■ Pharmacodynamics			(38%)	(61%)	(39%)
■ Pharmacokinetics					
■ Pharmacogenetics					
4- The relationship of time and drug absorption, distribution, metabolism, and excretion	Pharmacokinetics				
■ Pharmacogenomics		127	10	105	26
■ Pharmacodynamics		(93%)	(7%)	(80%)	(20%)
■ Pharmacokinetics					
■ Pharmacogenetics					
5- Alternate sequences or versions of the same gene inherited from each parent	Allele				
■ Allele		95	42	99	32
■ Chromosome		(69%)	(31%)	(76%)	(24%)
■ Gene					
■ Genome					
6- Three adjacent nucleotide bases that ultimately encodes a specific amino acid	Codon				
■ Codon		95	42	119	12
■ Exon		(69%)	(31%)	(91%)	(9%)
■ Intron					
■ Outron					
7- A nucleotide sequence that codes information for protein synthesis	Exon				
■ Codon		42	95	61	70
■ Exon		(31%)	(69%)	(47%)	(53%)
■ Intron					
■ Outron					
8- The entire DNA of an organism	Genome				
■ Nucleotide		88	49	99	32
■ Genome		(64%)	(36%)	(76%)	(24%)
■ Gene					
■ Allele					
9- The specific set of alleles inherited at a locus on a given gene	Genotype	90	47	107	24
■ Phenotype		(66%)	(34%)	(82%)	(18%)
■ Genotype					
■ Haplotype					
■ Endophenotype					
10- A series of polymorphisms that are inherited together	Haplotype				
■ Phenotype		52	85	89	42
■ Genotype		(38%)	(62%)	(68%)	(32%)
■ Haplotype					
■ Endophenotype					
11- Characteristics derived from a single gene	Monogenic trait				
■ Monogenic trait		99	38	91	40
■ Multigenic trait		(72%)	(28%)	(69%)	(31%)
■ Homozygous					
■ Heterozygous					
12- One of structural components (building blocks) of DNA or RNA, including adenine (A), cytosine (C), guanine (G),thymine (T) and uracil (U)	Nucleotide	102 (74%)	35 (26%)	116	15
■ Genome				(89%)	(11%)
■ Chromosome					
■ Nucleotide					
■ Allele					
13- An individual's expression of a physical trait or physiologic function due to genetic makeup and environmental and other factors	Phenotype				
■ Phenotype		82	55	89	42
■ Genotype		(60%)	(40%)	(68%)	(32%)
■ Biomarker					
■ Haplotype					
14- Regions of the genome (DNA) that contain the instructions to make protein	Gene				
■ Chromosome		64	73	89	42
■ Allele		(47%)	(53%)	(68%)	(32%)
■ Gene					
	Personalized				

Table 2 (*continued*)

Question*	Correct answer	Pharmacists		Students	
		correct n (%)	incorrect n (%)	correct n (%)	incorrect n (%)
15- The use of patient- specific information and biomarkers to make more informed choices regarding the optimal therapeutic treatment regimen for a given patient	medicine	67 (49%)	70 (51%)	104 (79%)	27 (21%)
■ Personalized medicine					
■ Pharmacogenomics					
■ Pharmacogenetics					
16- Insertion or deletion of DNA either as single nucleotides or spanning regions of DNA involving many nucleotides	Indel	31 (23%)	106 (77%)	40 (31%)	91 (69%)
■ Mutation					
■ Repair					
■ Indel					
17- A nucleotide sequence in DNA that does not code information for protein synthesis and is removed before translation or messenger RNA	Intron	53 (39%)	84 (61%)	80 (61%)	51 (39%)
■ Exon					
■ Intron					
■ Codon					
18- Change in DNA sequence between individuals	Mutation	105 (77%)	32 (23%)	93 (71%)	38 (29%)
■ Mutation					
■ Repair					
■ Indel					
19- A mutation in DNA in a given population that may be observed at greater than 1% frequency is a polymorphism	True	96 (70%)	41 (30%)	82 (63%)	49 (37%)
■ True					
■ False					
20- An indicator of normal biological processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention is the definition of Biomarker	True	105 (77%)	32 (23%)	97 (74%)	34 (26%)
■ True					
■ False					
21- A variant DNA sequence in which a single nucleotide has been replaced by another base is the definition of single nucleotide polymorphism	True	92 (67%)	45 (33%)	82 (63%)	49 (37%)
■ True					
■ False					
22- Heterozygous is possessing an identical allele for the same trait	False	113 (82%)	24 (18%)	109 (83%)	22 (17%)
■ True					
■ False					
23- A protein around which DNA coils to form chromatin, thus "packaging" DNA is the definition of Histone	True	100 (73%)	37 (27%)	104 (79%)	27 (21%)
■ True					
■ False					
24- Topoisomerase is a class of enzymes that alter the supercoiling of single-stranded DNA	False	31 (23%)	106 (77%)	71 (54%)	60 (46%)
■ True					
■ False					
25- Xenobiotics are substances introduced into the body but not produced by it	True	103 (75%)	34 (25%)	104 (79%)	27 (21%)
■ True					
■ False					

*Before the multiple-choice items were introduced, the following statement was added "For each of the following items, please select the term that matches the correct definition".

3.3. Scale reliability and aggregate pharmacogenomics knowledge scores

The value generated for Kuder Richardson 20 indicated that the created PGx knowledge scale had adequate internal consistency (KR20 = 0.75). See Appendix B.

Fig. 1 shows the aggregate number of correct items selected by community pharmacists and students. The average knowledge score for community pharmacists was 15 (SD = 4) out of a possible total of 25. The total number of correct answers ranged from 8 (2 participants) to 24 (1 participant) out of 25 questions. With student participants, the average knowledge score was slightly higher, but the range of correct answers was wider than that of pharmacists. The average student score for pharmacy students was 17 (SD = 5) out of a possible total of 25, with the total number of correct answers ranging from 5 (2 participants) to 24 (6 participants).

3.4. Correlations

Table 3 shows the correlation matrix with simple coefficients of correlation between key study variables. Pharmacists' age and the number of years of practice after graduation were associated with a lower aggregate knowledge score ($r = -0.20$; $p < 0.05$ and $r = -0.21$; $p < 0.05$), respectively.

3.5. Interest in learning about pharmacogenomics

Pharmacists' interest in learning about PGx varied where 62 % were either interested or very interested in learning about pharma-

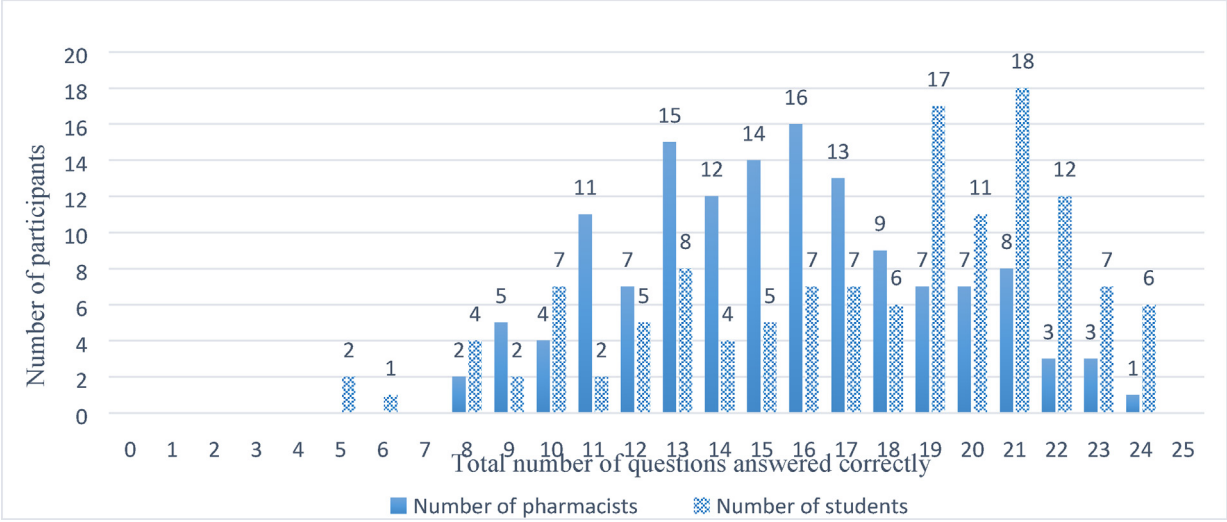

Fig. 1. Aggregate knowledge scores for community pharmacists (n = 137) and pharmacy students (n = 131).

Table 3
Correlation matrix for community pharmacists (n = 137).

	A	B	C	D	E
A	1				
B	0.103	1			
C	0.979*	−0.115	1		
D	−0.198*	0.053	−0.211*	1	
E	−0.103	0.084	−0.084	0.137	1

*Correlation is significant at the 0.05 level (2-tailed). Pearson correlation coefficient was used when its assumptions were met. For ordinal data, a Spearman rank correlation was used.
(A): Age; (B): Pharmacy credentials (1 = Bachelor of Pharmacy, 2 = Doctor of Pharmacy, 3 = Masters); (C): Years of practice after graduation, (D): Total number of correct answers, (E): Interest in learning about pharmacogenomics (Not or Slightly interested = 0, Interested or Very Interested = 1).

cogenomics and on the other hand, 12 % were not interested at all in learning about the topic. Students' interest in learning about pharmacogenomics was higher than that of pharmacists with 70 % being either interested or very interested, and only 4 % reporting they are not at all interested in learning about the topic. Specific PGx topics of interest are highlighted in Table 4.

Table 4
Quotes from participants representing pharmacogenomics topics of interest to community pharmacists and pharmacy students.

Pharmacists	Pharmacy students
■ New medications targeting genes ■ Cancer targeted and viral targeted biomarkers and modified genes treatment ■ Treatment of obesity in respect to a person's genetics ■ Relationship between orphan diseases and genes ■ PGx test applied on individuals to see the person's potential response to a therapeutic drug ■ Viral diseases related to PGx ■ Gene modification CRISPR, use of CRISPR in the treatment and in gene modification	■ A pharmacogenomics testing in cancer care "colorectal cancer " using Irinotecan, which is a type of chemotherapy the doctors common use to treat colon cancer. ■ How mutations occur ■ Biotechnology ■ Pharmaceutical science ■ Relation between time and drug distribution ■ Colorectal cancer ■ Cardiovascular diseases and Drugs ■ How pharmacogenomics can be applied to further help pharmacists and doctors choose the right drug and drug doses exclusively for each patient. ■ Pharmacogenomics for Diabetes and Obesity

4. Discussion

This study objectively evaluated the knowledge of community pharmacists and first-year pharmacy students about foundational aspects of PGx indicating positive areas where participants had adequate knowledge and other areas where significant opportunities for improvement exist. It also shed light on how PGx knowledge relates to years of community pharmacist's practice, interest in learning about PGx, and specific PGx topics of interest.

Pharmacy students were slightly more knowledgeable of the principles of PGx than community pharmacists. This was an interesting finding and would relate to the nature of items covered in this survey. Those items addressed fundamental PGx knowledge rather than applications. It is likely that this pattern would have been reversed if the study covered PGx applications, which would have been more familiar to pharmacists given their professional expertise.

Further, the level of knowledge was significantly associated with age and years of practice after graduation: community pharmacists who are younger and with the fewest years of practice after graduation having better knowledge than others who have been practicing pharmacy for longer intervals. Similar to our findings, Roederer et al. (2012) found that recent pharmacy graduates scored statistically significantly higher on all objective pharmacogenetics questions than those who were out of school for 5 years or more (Roederer et al., 2012). Further, Tuteja et al. (2013) indicated that pharmacists graduating in the past 10 years also had a higher objective knowledge score than those graduating >30 years ago (Tuteja et al., 2013). It is not surprising that participants' knowledge declined with the increase in the number of years of

practice. Even if some of those pharmacists had some exposure to PGx as a topic earlier, the retention would likely be low as they would have had little to no opportunity to apply this knowledge in practice.

Items were not of equal difficulty to participants. Interestingly, the difficulty (or easiness) of items varied by whether the participant is a pharmacist or a student. With community pharmacists, the two items that were most likely to be identified correctly addressed the definition of "Pharmacokinetics" and "Pharmacodynamics". As medication experts, pharmacists have plenty and continuous exposure to such terms. Pharmacists need to use those terms in their daily practice as they receive and provide drug information such as those related to drug interactions. With first-year pharmacy students, the two items that were most likely to be identified correctly addressed the definitions of a "Codon" and a "Nucleotide". As the topic of genetics is stressed during the last years of high school in biology classes, first-year pharmacy students can still remember the definition of those common genetic terms. Although the word "Indel" was expected to be clear to participants, since it is composed of the combination of the two words insertion and deletion, a significant proportion of community pharmacists and students struggled with recognizing its correct definition. They were confused between the definitions of mutation and "Indel". It is possible that this confusion resulted from the fact that this was not a common word that has not been thoroughly or routinely addressed in high school or pharmacy curricula or during routine pharmacy practice.

Both community pharmacists and pharmacy students in this study showed significant interest in learning about pharmacogenomics with six to seven out of ten participants being either interested or very interested in learning about the topic. This finding is in agreement with several studies done that reported high interest among pharmacists to have more PGx training (McMahon and Tucci, 2011; Rahma et al., 2020; Yau et al., 2015); which could be done through workshops, seminars, and online activities. Overall, students were slightly more interested than community pharmacists in learning about PGx. It is possible that students who have yet to determine a career path may be considering a career involving more specialized knowledge of PGx within practice or research or could be more eager to learn at this level. Community pharmacists, on the other hand, may be overwhelmed with responsibilities that they may be reluctant to invest time in learning about a topic.

Findings from this study highlight the need for revisiting PGx foundational knowledge as a refreshment to community pharmacists, especially ones who graduated in earlier cohorts. This could be done through varying CE modes such as online training, seminars, conferences, ward rounds, and the provision of high-quality sources of PGx information(Alsaloumi et al., 2019; Yau et al., 2015). Importantly, CE activities should not take for granted that pharmacists possess all the necessary fundamental PGx information when introducing PGx applications. Foundational PGx knowledge should be revisited before introducing PGx related information that address specific medications. CE activities should also address PGx topics of interest of particular emphasis to the target pharmacist group.

Specific strengths related to the employed methodology included utilizing a probability sample of community pharmacists and achieving a high participation rate. In addition, the survey utilized an instrument was provided to participants in their language of preference with no interference from the data collector to improve the comprehension of questions and, consequently, the quality of data.

Limitations of this study merit discussion. This study drew its sample only from community pharmacies in Beirut, the Lebanese capital. It would be interesting to test the knowledge of pharmacists in other geographic and practice settings including, for instance, hospital pharmacists and those working in the pharmaceutical industry sector. Secondly, while students were informed that the survey was ungraded and no identifying information were collected, it was not possible to verify that they did not use external resources when filling the survey, especially since the survey version they took was administered electronically. To minimize the likelihood of this from happening, students were informed that there was no grade assigned for their performance in the survey. Finally, the item addressing interest in learning about PGx may be liable to social desirability bias. In an attempt to reduce this bias, the survey was self-administered and no identifying information were collected from participants.

5. Conclusions

Pharmacogenomics can help patients achieve improved health outcomes by knowing ahead of time whether a growing number of drugs are likely to be beneficial and safe when used with specific patients. Knowing this information can help health professionals, including pharmacists, in selecting medications judiciously while applying information from a rapidly growing field. As the concepts of pharmacogenomics and precision medicine continue to disseminate, it is essential for different stakeholders to build on findings from different studies, including the work described here, to make sure that current and future pharmacists are well equipped to serve as leading experts in PGx related services and to participate in interprofessional delivery of PGx testing in different settings. This will allow pharmacy professionals to expand their practice territory resulting in gains for the pharmacy profession and for public health as a whole.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsps.2022.10.005.

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