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ORIGINAL RESEARCH

Knowledge And Attitudes Of Pharmacy Students Towards Pharmacogenomics Among Universities In Jordan And West Bank Of Palestine

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Background: Testing by pharmacogenomics (PGx) aims to reduce the side-effects of medicines and to optimize therapy.

Aim: To ascertain the knowledge and attitudes towards PGx among pharmacy students in Jordan and West Bank of Palestine (WBP).

Methods: This cross-sectional study focused on pharmacy students from five universities in Jordan and WBP. Students were asked to answer an online survey comprising 30-closed ended questions measuring the knowledge and attitudes towards PGx.

Results: The total number of respondents to the questionnaire was 466. Most (96.1%) respondents knew that genetic variations can affect the drug response. Most students stated that the total number of lectures mentioning PGx was fewer than three. Most (>80%) respondents answered that they knew that human genetics can affect the response, inter-individual variation, and ethnic variations in the drug response. However, their knowledge about US Food and Drug Administration recommendations regarding PGx testing of commonly used drugs was weak. Also, 60.3% of respondents stated that the information they received about PGx was insufficient. Most (>92.7%) students wished to know more about PGx and believed that PGx is helpful in choosing the appropriate drug.

Conclusion: Pharmacy students had fair knowledge and good attitudes towards PGx. These factors could aid application of PGx in clinical practice in Jordan and WBP.

Keywords: pharmacogenomics, Jordan, West Bank of Palestine, knowledge, pharmacy students

Introduction

Pharmacogenomics (PGx) combines pharmacology and genomics to study the effect of genetic variants on the response to drug treatment.[1] These genetic variants can influence the pharmacokinetics and interactions between the drug and molecular targets, thereby influencing the efficacy and unwanted side-effects induced by drug therapy.[2]

PGx aims to reduce the inter-individual variation in drug response by providing the appropriate drug at the correct dose.[1] Use of the anticoagulant warfarin is an example of PGx testing. To avoid excessive bleeding, it is recommended to reduce the warfarin dose in patients with genetic variants, such as cytochrome (*CYP*) *2C9*2, *3* in Caucasians, *CYP2C9*5, *6, *8*, and **11* in Africans,[3] and vitamin K epoxide reductase (*VKORC1)-1639G>A*.[4]

In addition to warfarin, the Food and Drug Administration (FDA) in the USA has provided clinical evidence supporting the importance of PGx testing in the labeling of

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many drugs.[5] The Clinical PGx Implementation Consortium supported by the Pharmacogenomics Knowledge Base has developed a database for guiding clinicians to make pharmacotherapy decisions based on PGx information.[6,7]

However, PGx testing is not practiced widely in pharmacotherapy. One of the major barriers against implementation of PGx in clinical practice is the weak knowledge of PGx among medical-health professionals (including pharmacists).[8] Therefore, the emergence of developing medical education on PGx has been highlighted. The International Society of Pharmacogenomics recommends ≥4 credit ours of PGx teaching to be offered to medical students.[9]

In the USA, several pharmacy training programs have implemented PGx in their curricula after the American Council on Pharmacy Accreditation set PGx as a requirement in the pharmacy curriculum.[10] In Europe, PGx testing is implemented and practiced in clinical treatment.[11] In addition, many universities and conferences have introduced educational programs in PGx, such as the summer schools of the European Society of Pharmacogenomics and Personalized Therapy (https://esptnet.eu/). In Bosnia and Herzegovina, Mahmutovic et al found positive attitudes towards genetic testing and "personalized" medicine in students enrolled in biomedicine courses.[12]

In developing countries, including Middle Eastern countries, PGx is not practiced in pharmacotherapy. Some studies have shown that Middle Eastern Arab populations have different genetic variants in their drug-metabolizing enzymes when compared with neighboring African, European and Asian populations.[13,14]

The first step in PGx awareness among medical professionals is to evaluate the current knowledge, attitudes, and practice toward PGx. Then, strategies can be put into place to improve the awareness and implementation of PGx in clinical treatment. Jarrar et al.[15] investigated the perception of primary-health physicians in Jordan towards PGx. They found that internists had fair knowledge and a positive attitude toward PGx, but that it is not practiced due to a small number of validated PGx biomarkers and absence of simple and inexpensive PGx testing.

In Jordan and West Bank of Palestine (WBP), PGx testing is not practiced except in few cases (though medication errors and the prevalence of the adverse effects of drugs are high in these two countries).[16,17] Pharmacists also have a major role in personalized pharmacotherapy in Jordan and WBP.[18] However, PGx as a course is not included in the curricula of pharmacy schools, except in the Master of Science of Pharmacology at the University of Jordan (http://medicine.ju.edu.jo). Undergraduate pharmacy students may learn about some base concepts of PGx during pharmacology lecturers, but whether this knowledge is sufficient for implementation in clinical practice is questionable. Many pharmacy schools in Jordan and WBP provide two sub-programs: Pharmaceutical Science (PS) and Doctor of Pharmacy (DoP). The major difference between these two programs is that the DoP program provides more clinical courses with medical cases discussing the inter-individual variation in the drug response.[19]

The current knowledge and attitudes of pharmacy students toward PGx have not been evaluated in Middle Eastern Arab countries, a knowledge gap that we tried to fill in the present study.

Materials And Methods

This was a questionnaire-based cross-sectional study done online. The online copy is available as a Google™ document (https://docs.google.com/forms/d/1wO_ncL0mqHK9GbltHkLmAkm12PhEgCeRzXVkvXPTyJc/edit).

The response to the questionnaire was opened between 1 February and 29 April 2019. Eligible participants were students in PS or DoP from Jordan or WBP.

Nine-hundred students were asked to complete the online questionnaire, which was announced by the participant researchers in five universities: University of Jordan, Al-Zaytoonah University of Jordan, and Isra'a University in Jordan; An-Najah National University and Birzeit University in WBP.

The sample size was calculated according to the Daniel formula.[20] The confidence interval (CI) was 95% and the significance level was set as $\alpha = 0.05$. The expected prevalence in the sample with a characteristic of interest was 0.5. The total number of pharmacy students in the five universities was 6000. We estimated that a sample size of 360 was representative of the pharmacy students from Jordan and WBP. We recruited a sample size of 466 pharmacy students to increase the statistical robustness of our study. To ensure that we received >360 responses, we asked 900 students to complete the online questionnaire. In addition, the five universities selected are the top-ranked and major universities in Amman (capital of Jordan) and WBP. These universities have pharmaceutical academic programs and agreed to participate in our study. Among the selected universities, only the University of Jordan and An-Najah National University has two pharmacy programs: PS and DoP. In addition, the number of

students in the PS program was twofold higher than the number of DoP students among University of Jordan and An-Najah National University. Accordingly, we estimated that the number of DoP students was ~15% of the total number of pharmacy students among the selected universities. Participation was voluntary and participants were informed that they had the option to not answer questions.

At the beginning of the questionnaire, there was an introductory section describing the purpose and objectives of our study. The survey consisted of 30 close-ended questions with answers of yes/no/I am not sure, categorized into four parts: (i) demographic characteristics of the student; (ii) basic and clinical PGx knowledge; (iii) exposure to PGx education; (iv) attitudes towards PGx. Some of these questions were adopted from similar studies that were undertaken in the USA,[21] Zimbabwe[22] and Bosnia and Herzegovina,[12] with some modifications being made to make the questionnaire easier to understand by pharmacy students. In addition, we developed other questions which could help assessment of PGx knowledge, such as exposure to PGx education and PGx knowledge. "The effect of genetic variants on pharmacotherapy" was used instead of "PGx" in some of the questions to ensure that the participant dealt with the actual meaning rather than the terminology of PGx.

Before the questionnaire was sent to students, it was reviewed by three experts in pharmacogenomics and pharmacy education in Jordan and WBP. Then, the questionnaire was sent to 30 students (as a pilot study) for identification errors and misunderstood questions. The Cronbach alpha of PGx knowledge was 0.72, which indicated consistency in the questionnaire.

The study protocol was approved by the ethics committee of An-Najah National University (Institutional Review Board number 16-02-2019). In addition, the Ethics Committee of Al-Zaytoonah University approved the study to be conducted among pharmacy students in Jordan. All students provided written informed consent to be involved in the study.

Categorical variables (demographics and knowledge and attitudes about PGx) are expressed as frequencies and percentages. Descriptive analysis was undertaken using^2 tests, Student's *t*-tests and ANOVA (if needed). The Spearman test was used to calculate the correlation coefficient between the categorical data. Corresponding 95% CIs were calculated using a significance level of 5% for all statistical tests. Missing data were excluded from the analysis. Statistical analyses were carried out using SPSS v25 (IBM, Armonk, NY, USA).

Results

Demographic Data Of Participants

We received 466 responses to the online questionnaire (52%). One-hundred and ninety (40.8%) responses were from WBP and 262 (56.2%) responses were from Jordan. The highest number of responses was received from Al-Zaytoonah University of Jordan, 140 (30%), followed by 131 (28.1%) from An-Najah National University, 76 (16.3%) from University of Jordan, 59 (12.7%) from Isra'a University and 49 (10.5%) from Birzeit University (Table 1). Also, 360 (77.3%) respondents were women and 78 (16.7%) respondents were men. Regarding the academic program, 82 (17.6%) respondents were DoP and 382 (82%) respondents were PS students.

The percentage of respondents according to the academic grade is shown in Table 1. Achievement of the average academic mark is also shown in Table 1.

Exposure To PGx Education

Most students (n = 342, 73.4%) knew about PGx through their university education, 94 (20.2%) respondents knew about PGx through social media, and 12 (2.6%) students heard about PGx through scientific conferences (Table 2). Most students (n = 372, 79.8%) answered that they studied about PGx during university lectures. One-hundred and eighty-five (39.7%) students answered that they learnt about PGx in one course, 85 (18.2%) students learnt about PGx in two courses, 80 (17.2%) students learnt about PGx in more than two courses, and 108 (23.2%) students did not learn about PGx in any course during pharmaceutical studies at university. Most students (n = 258, 55.36%) responded that the number of total lectures in which PGx was mentioned fewer than three, 104 (22.3%) students answered that they took 3–5 lectures in PGx, 53 (11.4%) students learnt PGx in 6–10 lectures, and 42 (9%) students learnt about PGx in >10 lectures.

Basic Knowledge Of PGx

A total of 448 (96.1%) respondents answered that they knew that human genetics can affect the drug response (Table 3). Many of the students (n = 433, 92.9%) answered that they knew that inter-individual variation in the drug response might be due to genetic factors. In addition, 410 (88%) responded that they knew that there were ethnic variations

Table 1 Demographic Data Of The Participating Students

Parameter	Frequency (Percentage)
Age (years)	
<20	59 (12.7%)
20–24	347 (74.5%)
>24	53 (11.4%)
Missing	7 (1.5%)
Total	466 (100%)
Country	
Jordan	262 (56.2%)
West Bank of Palestine	190 (40.8%)
Missing	14 (3%)
Total	466 (100%)
Sex	
Male	78 (16.7%)
Female	360 (77.3%)
Missing	28 (6%)
Total	466 (100%)
University	
Al-Zaytoonah University of Jordan	140 (30%)
Al-Isra'a University	59 (12.7%)
University of Jordan	78 (16.7%)
An-Najah National University	131 (28.1%)
Birzeit University	49 (10.5%)
Missing	9 (1.9%)
Total	466 (100%)
Pharmacy educational program	
Pharmaceutical Science	382 (82%)
Doctor of Pharmacy	82 (17.6%)
Missing	2 (0.4%)
Total	466 (100%)
Average mark achieved in the university	
50–59	9 (1.9%)
60–69	66 (14.2%)
70–79	144 (30.9%)
80–89	161 (34.5%)
90–100	78 (16.7%)
Missing	8 (1.7%)
Total	466 (100%)
Academic year	
First	14 (3%)
Second	68 (14.6%
Third	84 (18%)
Fourth	151 (32.4%)
Fifth	119 (25.5%)
Master of Science	21 (4.5%)
Missing	9 (1.9%)
Total	466 (100%)

Table 2 Educational Exposure To PGx

Question	Frequency (Percentage)
Did you study, during your university education, that there are inter-individual and inter-ethnic variations in the drug response?	
Yes	372 (79.8%)
I am not sure	48 (10.3%)
No	41 (8.8%)
Missing	5 (1.1%)
Total	466 (100%)
How did you learn about PGx?	
University lectures	342 (73.4%)
Scientific conferences	12 (2.6%)
Social media	94 (20.2%)
Television programs	9 (1.9%)
Missing	9 (1.9%)
Total	466 (100%)
How many pharmaceutical courses mentioned and described PGx?	
0	108 (23.2%)
1	185 (39.7%)
2	85 (18.2%)
More than 2	80 (17.2%)
Missing	8 (1.7%)
Total	466 (100%)
How many lectures, from different courses, mentioned and described the effect of genetic variants on the drug response?	
<3	258 (55.4%)
3–5	104 (22.3%)
6–10	53 (11.4%)
>10	42 (9%)
Missing	9 (1.9%)
Total	466 (100%)
Did the PGx information you received during pharmaceutical courses enable you to understand the effect of genetic variants on the drug response?	
Yes	47 (10.1%)
I am not sure	125 (26.8%)
No	281 (60.3%)
Missing	13 (2.8%)
Total	466 (100%)
Did the lecturers describe the effect of genetic variants on the drug response clearly?	
Yes	183 (39.3%)
I am not sure	181 (38.8%)
No	93 (20%)
Missing	9 (1.9%)
Total	466 (100%)

in the drug response. Most pharmacy students (n = 383, 82.2%) knew that genetic variants can affect the pharmacokinetic parameters of the drug, and 365 (78.3%) students knew that the interaction between the drug and its target may be influenced by variants in drug-target genes. Furthermore, 374 (80.3%) of respondents answered that

some patients are at high risk of drug-induced toxicity due to inherited genetic variations, and 392 (84.1%) students responded that some patients do not respond to drug therapy due to certain genetic variants. Three-hundred and nineteen students (68.5%) responded that the drug response can be predicted through pharmacogenetic testing. When we compared the level of PGx knowledge among students, depending on the participating university, we found that An-Najah National University students had a significantly weaker knowledge of PGx ($p < 0.05$, ANOVA) in comparison with students from other universities (Table 4).

Knowledge About Specific Validated PGx Testing

The percentage of students who knew that *CYP2C9* variants affected the response to warfarin was 59.2% (Table 5). In addition, 184 (39.5%) students answered that the response to warfarin is affected by *VKORC1*. Only 149 (31.97%) students knew that the gene for the endothelial growth factor receptor influences the response to kinase inhibitors (e.g., erlotinib). Lastly, 79 (17%) students knew that the FDA provides clinical evidence for PGx testing in the labeling of many drugs.

Attitudes Towards PGx Education

We found that 281 (60.3%) of respondents thought that the PGx information they received during their university education was not sufficient to enable them to understand the effects of genetic variants on the drug response. Only 183 (39.27%) students stated that the lecturer delivered information on PGx in a clear way (Table 2). Four-hundred and twenty-one (92.2%) students believed that PGx was helpful for pharmacists in choosing the correct drug at the appropriate dose. Most students (n = 432, 92.7%) wanted to know more about PGx. In addition, 82.4% of students were willing to apply PGx testing in clinical practice. However, only 31.5% wanted to study, in a post-graduate program, the science underpinning PGx. The attitudes towards PGx testing are shown in Table 6.

Factors Correlated With PGx Knowledge

We found that the number of courses and lectures in PGx correlated significantly ($p < 0.05$) with the level of PGx knowledge (Table 7). The academic year, university, and average marks achieved also correlated significantly (p value < 0.05) with the level of PGx knowledge. In addition, students who learnt about PGx from university courses had a significantly stronger level of PGx knowledge ($p < 0.05$, ANOVA) than students who learnt about PGx from scientific conferences and social media.

Factors Correlated With PGx Attitudes

The attitude towards PGx was strongly correlated ($p < 0.05$) with PGx knowledge. Regression analyses revealed that the academic program (PS or DoP) and PGx knowledge were significantly ($p < 0.05$) correlated with attitudes towards PGx (Table 8).

Discussion

There is a global trend to increase implementation of PGx testing in clinical practice. The acceptance of PGx testing among medical professionals is dependent upon the level of PGx knowledge.[23]

Table 3 PGx Knowledge Among Participant Pharmacy Students In Jordan And West Bank Of Palestine (n = 466)

Question	I Know	I Am Not Sure	I Do Not Know	Missing
Inherited genetic variants may influence the drug response	448 (96.1%)	7 (1.5%)	5 (1.1%)	6 (1.3%)
Inter-individual variation in response to drugs and toxicity may be due to inherited genetic variants	433 (92.9%)	14 (3%)	14 (3%)	5 (1.1%)
There is an inter-ethnic variation in the drug response	410 (88%)	31 (6.7%)	20 (4.3%)	5 (1.1%)
Inter-individual variation in pharmacokinetic parameters may be due to genetic variations	383 (82.2%)	47 (10.1%)	31 (6.7%)	5 (1.1%)
Inter-individual variation in pharmacodynamics, and the interaction between the drugs and molecular targets, may be due to genetic variations	365 (78.3%)	64 (13.7%)	31 (6.7%)	6 (1.3%)
Some patients have a high risk of drug toxicity due to inherited genetic variants	374 (80.3%)	57 (12.2%)	27 (5.8%)	8 (1.7%)
Some patients do not respond to medicines due to some inherited variants	392 (84.1%)	47 (10.1)	21 (4.5%)	6 (1.3%)
The drug response can be predicted using genetic biomarkers	319 (68.5%)	103 (22.1%)	35 (7.5%)	9 (1.9%)

Note: Data are presented as n (%).

Table 4 Comparison Of Basic PGx Knowledge Of Participating Students Depending On The Participating University, Sex And Academic Year

Parameter	Average of PGx Knowledge[a]	N	SD	*p*
University				
Al-Zaytoonah University	7.60	140	2.50	0.1
Al-Isra'a University	7.68	59	2.72	
University of Jordan	7.85	78	2.57	
An-Najah National University	6.61*	131	2.31	
Birzeit University	7.85	49	1.89	
Academic year				
First year	5.50	14	1.99	<0.001
Second year	6.34	68	2.01	
Third year	6.49	84	2.49	
Fourth year	7.66	151	2.41	
Fifth year	8.23	119	2.33	
Master of Science	9.19	21	2.01	
Sex				
Male	6.89	78	2.87	0.04
Female	7.52	360	2.41	
Pharmacy program				
Pharmaceutical Science	7.4	82	2.3	0.73
Doctor of Pharmacy	7.3	382	2.1	

Notes: [a]PGx knowledge was calculated based on the Likert scale: +1 for "I know", 0 for "I am not sure" and −1 for "I do not know". The Student's *t-test* was used to compare between two groups, whereas ANOVA was used to compare between more than two groups. *Indicates significant $p < 0.05$ for the comparison in PGx among An-Najah National University students with other university students.

Several academic and research centers for PGx are distributed among the continents. In addition, some universities provide a postgraduate program in PGx (e.g., Manchester University, Manchester, UK). Among Middle Eastern Arab countries, practice of PGx is very limited to some specialist cancer centers.[24] In addition, no academic or research centers specialize in PGx research/education. The situation in Jordan and WBP is not exceptional from other Middle Eastern countries.

We investigated the current knowledge and attitudes towards PGx among pharmacy students attending elite universities in Jordan and WBP. In general, students had a strong basic knowledge (Table 3) and positive attitudes (Table 6) towards PGx, even though the number of PGx courses/lectures is lower than that recommended by the International Society of Pharmacogenomics.[9] Nevertheless, the knowledge among students towards certain commonly used drugs listed by the FDA and which require PGx testing was weak. These findings suggest that: (i) there is a strong desire to apply PGx in clinical practice in Jordan and WBP; (ii) the curricula of pharmacy departments in universities should be improved through implementation of more clinical cases which require PGx testing before and during drug treatment. Hopefully, improving PGx knowledge will prepare pharmacists to implement PGx testing in pharmacotherapy.

The level of PGx knowledge among pharmacy students in Jordan and WBP was stronger than that reported among medical-health students in Bosnia, where 45% of students were aware of different ethnicity-based aspects and only 50% had heard about PGx.[12] In the present study, >80% of students in Jordan and WBP were aware of inter-individual and ethnic variations in the drug response, though the background of the participating students in these countries was different. Furthermore, the results regarding knowledge towards PGx among pharmacy students in Jordan and WBP were close to the data found in a survey done by pharmacy students in the Netherlands: most of the students had high expectations toward PGx, but only 12.8% felt adequately informed.[25] Collectively, the PGx knowledge among pharmacy students in Jordan and WBP was strong in comparison with that in European and developed countries.

Most of the respondents in the present study were women. This sample was representative of current pharmacy

Table 5 Knowledge About PGx Testing Recommended By The US FDA (n = 466)

Question	I know	I am not sure	I do not know	Missing
CYP2C9 variants may affect metabolism and, hence, the warfarin response	276 (59.2%)	172 (36.9%)	13 (2.8%)	5 (1.1%)
VKORC1 variants may affect the pharmacodynamics and, hence, the warfarin response	184 (39.5%)	170 (36.5%)	106 (22.8%)	6 (1.3%)
Genetic variants in endothelial growth factor receptors affects the response to erlotenib	149 (31.97%)	303 (65.02%)	8 (1.71%)	6 (1.3%)
FDA provides clinical evidence for PGx testing in the labeling of many drugs	79 (17%)	172 (36.91%)	204 (44.4%)	8 (1.71%)

Note: Data are presented as n (%).
Abbreviations: *CYP2C9*, cytochrome 2C9 gene; *VKORC1*, vitamin K epoxide reductase gene; FDA, Food and Drug Administration.

Table 6 Attitudes Towards PGx Testing (n = 466)

Question	Yes	I Am Not Sure	No	Missing
Do you think that PGx testing can improve your future work in choosing the right drug and dose?	421 (90.3%)	23 (4.9%)	13 (2.8%)	9 (1.9%)
Do you want to know more about PGx?	432 (92.7%)	13 (2.8%)	15 (3.2%)	6 (1.3%)
Do you want to apply PGx testing in your future work?	384 (82.4%)	63 (13.5%)	14 (3%)	5 (1.1%)
Do you want to study the postgraduate program in PGx	147 (31.5%)	207 (44.4%)	105 (22.5%)	7 (1.5%)

Note: Data are presented as n (%).

Table 7 Factors Correlated With PGx Knowledge

Factor	Correlation coefficient	*p*
Age	0.30	<0.001*
Country	−0.08	0.69
Academic year	0.39	<0.001*
University	0.01	0.57
Sex	0.06	0.45
Achieved marks	0.24	0.01*
Academic program	0.01	0.73
Way of receiving PGx information	0.15	0.04*
Number of course subjects on PGx	0.28	<0.001*
Number of lectures on PGx	0.38	<0.001*
Clear PGx lectures	0.43	<0.001*

Note: *$p < 0.05$.

Table 8 Factors Correlated With Attitudes Toward PGx

Factor	Correlation coefficient	*p*
Age	0.02	0.77
Country	−0.02	0.71
Academic year	0.02	0.60
University	−0.09	0.11
Sex	−0.05	0.45
Achieved marks	0.05	0.45
Academic program	0.18	0.03*
Way of receiving PGx information	0.09	0.10
Number of course subjects on PGx	0.02	0.74
Number of lectures on PGx	0.06	0.59
Clear PGx lectures	0.02	0.74

Note: *$p< 0.05$.

students, whereby there are 3–4-times more women than men. This high women:men ratio has also been reported in pharmacy colleges in the USA.[26] We found that women had a significantly stronger ($p < 0.05$, Student's *t*-test) knowledge of PGx than men. This finding was because female students had significantly higher ($p < 0.05$, Student's *t*-test) average academic marks than male students. The average academic marks correlated significantly with PGx knowledge (Table 7).

In general, there was no significant difference in knowledge of and attitudes towards PGx between students from Jordan and WBP. However, students from An-Najah National University (which is located in WBP) had the lowest score for PGx knowledge (Table 4). This finding was because most students from An-Najah National University had fewer than three lectures on PGx. We found that number of lectures and courses on PGx correlated positively and significantly with PGx knowledge among pharmacy students (Table 7).

The different pharmacy curricula affected attitudes towards PGx. DoP students had significantly ($p < 0.05$) better attitudes towards PGx than PS students. This observation may have been because DoP students practice clinical pharmacotherapy and personalized therapy more than PS students (who concentrate more on the pharmaceutical industry and marketing).

Ejilat et al found that Jordanian pharmacists have strong knowledge and attitudes towards PGx.[27] We found that Jordanian pharmacy students had strong knowledge and good attitudes towards PGx. These results may indicate that pharmaceutical education in Jordanian universities had a major role in improving the knowledge and attitudes towards PGx among pharmacy students and, hence, pharmacists.

The academic year affected PGx knowledge ($p < 0.05$, ANOVA) and was found to correlate positively with PGx knowledge (Table 7). We found that Master of Science Students had significantly ($p < 0.05$) stronger PGx knowledge than undergraduate students. First-grade students had the weakest knowledge of PGx. This finding might have been because Master of Science Students as well as fifth- and fourth-grade students received more lectures and

courses regarding PGx, whereas more junior students were not fully exposed to the pharmacology of the drugs that require PGx testing.

Although students had, in general, strong knowledge and good attitudes towards PGx, their knowledge of FDA recommendations regarding PGx testing of commonly used drugs (e.g., warfarin) was weak. This finding may indicate that the pharmaceutical curricula of the participating universities in Jordan and WBP did not contain clinical examples of PGx testing, and that training programs in clinical pharmacotherapy do not include validated PGx biomarkers. These can be considered to be weak points in PGx education and hamper future strategies regarding implementation of PGx in clinical practice.

Most students learnt about PGx from their university education (Table 2). In addition, students who learnt about PGx during university had a significantly ($p < 0.05$, ANOVA) stronger knowledge of PGx than students who knew about PGx from other sources. This finding may indicate the important role of university education in improving knowledge of PGx.[28,29]

Pharmacy students in Jordan and WBP did not know about specific clinical cases in which PGx testing can be used to optimize therapy. Based on our findings, on 2–3 August/2019, we conducted a workshop in the Association of Pharmacy in Amman on clinical implementation of PGx testing in clinical practice. We hope to remove the major barrier in PGx implementation: weak knowledge about PGx testing.

Our study had four main limitations. First, we did not investigate other barriers against implementation of PGx testing in clinical practice. Second, we included universities from one city in Jordan. Third, we recruited only pharmacy students and excluded medical students, who can contribute to future PGx practice. Finally, we did not ask students about molecular principles in PGx testing and interpretation of such results.

Conclusion

Pharmacy students among five universities in Jordan and WBP had fair knowledge and positive attitudes toward PGx. The curricula of pharmacy education in the participating universities should be reviewed and improved through implementation of more clinical cases that require PGx testing.

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Disclosure

The authors report no conflicts of interest in this work.

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