Hindawi
Journal of Clinical Pharmacy and Therapeutics
Volume 2023, Article ID 2388845, 9 pages
https://doi.org/10.1155/2023/2388845

Research Article

A Survey of the UK Pharmacy Profession's Educational Needs on Pharmacogenomics

Victoria Rollinson, Neil French, Richard Turner, and Munir Pirmohamed

Wolfson Centre for Personalised Medicine, Institute of Systems, Molecular and Integrative Biology, University of Liverpool, Liverpool, UK

Correspondence should be addressed to Victoria Rollinson; victoria.rollinson4@nhs.net

Received 4 November 2022; Revised 16 April 2023; Accepted 13 May 2023; Published 10 July 2023

Academic Editor: Chad A. Bousman

Objective. The aim of this exploratory study was to ascertain the current educational status of pharmacogenomics (PGx) within the present and future UK pharmacy profession, in addition to ascertaining future educational and infrastructure needs of pharmacists to adopt PGx into practice. *Methods*. A 35-question survey was sent electronically to practicing pharmacists, preregistration pharmacists, and Master of Pharmacy (MPharm) students throughout the UK between April 2018 and May 2019. Responses were anonymous and analysed using GraphPad Prism 8 and SPSS statistics 26. *Results*. In total, 264 participants, where data could be used for analysis, responded to the survey. This comprised 196 practicing pharmacists and 68 preregistration pharmacists/MPharm students. The findings demonstrated variation in undergraduate level exposure to PGx between those who had qualified within the past 10 years and those who had qualified over 10 years ago. Over 60% of qualified pharmacists did not feel confident in identifying drugs that require PGx testing. Nearly three quarters of respondents cited that PGx guidelines were needed to help facilitate a PGx service, although 63.6% also stated that they had previously never looked for a PGx recommendation. Most respondents cited PGx as a low or medium learning priority. *Conclusion*. Our survey suggests that further education is required to prepare the UK pharmacy workforce for the advent of PGx. A focus on the provision of, and education around, PGx guidelines is needed. In addition, the disparity identified between pharmacists at different stages of their career will need to be addressed with tailored and targeted educational packages.

1. Introduction

Pharmacogenomics (PGx) refers to genetic variation in drug response (efficacy and safety) and was first coined by geneticist Friedrich Vogel in 1959 [1]. The terms pharmacogenomics and pharmacogenetics are often used interchangeably within the literature. The science of PGx has been extensively studied with an increasing number of publications since the completion of the human genome project, and greater emphasis on implementation of pharmacogenomics into clinical practice.

Current estimates indicate that around 98-99% of people carry a pharmacogenetic variant [2]. The presence of such a variant, termed a genetic polymorphism [3] if found at a frequency over 1%, may have a resulting impact on the pharmacokinetics (PK) or pharmacodynamics (PD) of a medication resulting in the potential for an ineffective treatment or adverse drug reaction (ADR).

The effectiveness of PGx testing in determining and reducing the incidence of ADRs for some medications has been so compelling that it has resulted in mandatory testing prior to prescribing. Perhaps the most well-known is the nucleoside reverse-transcriptase inhibitor, abacavir, used in the treatment of human immunodeficiency virus (HIV). Originally, it was estimated that around 5% of patients treated with abacavir would experience hypersensitivity reactions manifested as cutaneous eruptions, lung, and gastrointestinal manifestations, which increased in reaction severity on rechallenge [4]. However, in the early 2000s, a series of studies identified an association between abacavir

hypersensitivity and the presence of the HLA-B ∗ 57 : 01 allele [5–7] and an interventional trial was able to demonstrate that prescreening for HLA-B ∗ 57 : 01 resulted in elimination of immunologically confirmed hypersensitivity reactions [5]. This resulted in mandatory or recommended testing instructions in the drug labels in addition to recommendations within international prescribing guidelines [8].

Despite such successes, the transition of PGx into routine clinical practice has, overall, been slow. In the UK and internationally, availability of PGx testing has remained largely in the remit of specialist care settings (e.g., HIV and cancer). However, in the past decade the landscape of PGx testing has been changing with an increasing emphasis on implementation, as well as the availability of direct-to-consumer tests (DTC) for the public.

The aim of this exploratory study was to ascertain the current educational status of PGx within the present and future UK pharmacy profession, in addition to ascertaining future educational and infrastructure needs of pharmacists to adopt PGx into practice.

2. Methods

This study used a questionnaire-based, cross-sectional methodology to prospectively gather anonymised data from registered, preregistration, and student pharmacists in the UK. Due to the absence of any comparative UK data, an inductive research approach was adopted.

A 35-question survey was designed by a multidisciplinary team of researchers including expert PGx clinicians and a clinical pharmacist. The survey comprised a mixture of question types including 5-point Likert scale, multiple option, and free-text questions (supplementary material (available herer)). Questions were based on other studies from the field [9–12] covering topics including confidence and familiarity with genetics and PGx, addressing barriers to implementation, and understanding the needs surrounding further education. Testing of underlying PGx knowledge was also undertaken in the survey but is not discussed within the context of this paper. Our approach enabled respondents' opportunities to provide qualitative data on their thoughts around PGx topics in addition to the more restrictive quantitative questions.

The survey was hosted using the website "Survey monkey," participation was voluntary and consent for involvement obtained during the first question. Responses collected were anonymous. Whilst it was not possible to skip any questions, not all participants completed the survey and so in this instance of missing data, the "unknown" category was assigned.

The survey went live in April 2018, and the access link was sent out nationally via "gate-keepers" (i.e., chief pharmacists or heads of pharmacy schools) into a variety of sectors of the pharmacy profession including community, hospital, and academia.

In June 2018, three months after the survey had gone live, it was noted that a high proportion of the respondents were based in hospital pharmacy. To counter this, and provide a broader perspective of the profession, the survey was further disseminated to pharmacists and pharmacy student groups using the social media platform Facebook.

Data were analysed using GraphPad Prism 8 and SPSS statistics 26, and for the purposes of the analysis, the respondents were broadly subdivided into two categories: "qualified pharmacists" and "in training,". These were further subdivided into pharmacists qualified over 10 years, less than 10 years, preregistration pharmacists, and pharmacy undergraduate students. Statistical significance in findings between any two groups was assessed using the Pearson χ^2 test. The threshold for statistical significance throughout this study was set at $p \leq 0.05$.

An XY scatter plot was created to assess any correlation between two sets of data which had a 0–100 scoring system. This scatter plot was created using responses from participants who provided answers to both questions and r^2 (goodness-of-fit of simple linear regression) calculated using GraphPad Prism 8.

2.1. Ethics Statement. The University of Liverpool Ethics Committee approved the survey on 05/04/2018 prior to implementation of the European General Data Protection Regulation (GDPR). An amendment was submitted to include dissemination via social media on 29/06/2018 and approved on 10/07/2018.

3. Results

3.1. Demographics. A total of 268 participants commenced the survey. It was not possible to calculate an accurate denominator due to the uncertainty regarding the reach of social media and therefore it was not possible to determine response rate.

Of the respondents, one person did not complete the survey demographics, or any subsequent questions and a further three participants were registered and practicing outside the UK. Data from these individuals were not included in the analysis, leaving 264 participants eligible for analysis. 196 of these were qualified pharmacists and 68 were considered "in-training" (preregistration or undergraduate). Full demographics of included participants are shown in Table 1.

3.2. Confidence and Familiarity with Genetics and PGx. Over 97% of respondents in both the qualified and in-training groups reported that they had received prior education in genetics (Question 11), but this dropped to 76.7% when asked about PGx specifically (Question 15). Within the qualified pharmacist group, there was a statistically significant difference between those qualified ≤10 years and >10 years with no previous PGx education, rising from 16.9% to 30.1% respectively (Pearson $\chi 2 = 4.71$, $p = 0.03$).

Undergraduate studies were cited as the most common place respondents received education on both PGx and genetics (Questions 10 and 14) across both qualified and in-training groups (as shown in Figure 1).

Table 1: Demographics of survey respondents.

	Qualified pharmacists ($n = 196$)		*In training* ($n = 68$)		Total
	Qualified ≤10 years $n = 83$ (%)	Qualified >10 years $n = 113$ (%)	Preregistration $n = 32$ (%)	Undergraduate $n = 36$ (%)	$n = 264$ (%)
Gender					
Male	31 (37.3)	42 (37.1)	9 (28.1)	13 (36.1)	95 (36.0)
Female	52(62.7)	69 (61.1)	23 (71.9)	23 (63.9)	167 (63.3)
Other	0 (0)	1 (0.9)	0 (0)	0 (0)	1 (0.4)
Prefer not to say	0 (0)	1 (0.9)	0 (0)	0 (0)	1 (0.4)
Age (years)					
Age range	23–35	33–76	22–42	18–25	18–76
Sector					
Community pharmacists	21 (25.4)	33 (29.8)	—	—	54 (20.5)
Hospital pharmacists (private and NHS)	51 (61.4)	48 (41.6)	—	—	99 (37.5)
GP practice pharmacists	3 (3.6)	13 (11.5)	—	—	16 (6.1)
Academic pharmacists	4 (4.8)	8 (7.1)	—	—	12 (4.5)
Preregistration pharmacists	—	—	32 (100)	—	32 (12.1)
Pharmacy students	—	—	—	36 (100)	36 (13.6)
Retired	0 (0)	1 (0.9)	—	—	1 (0.4)
Unknown/other	4 (4.8)	10 (8.8)	—	—	14 (5.3)
Prescriber Status ($N = 196$)					
Nonprescriber	64 (77.1)	59 (52.2)	—	—	123 (62.8)
Supplementary prescriber	0 (0)	1 (0.9)	—	—	1 (0.5)
Independent prescriber	19 (22.9)	53 (46.9)	—	—	72 (36.7)

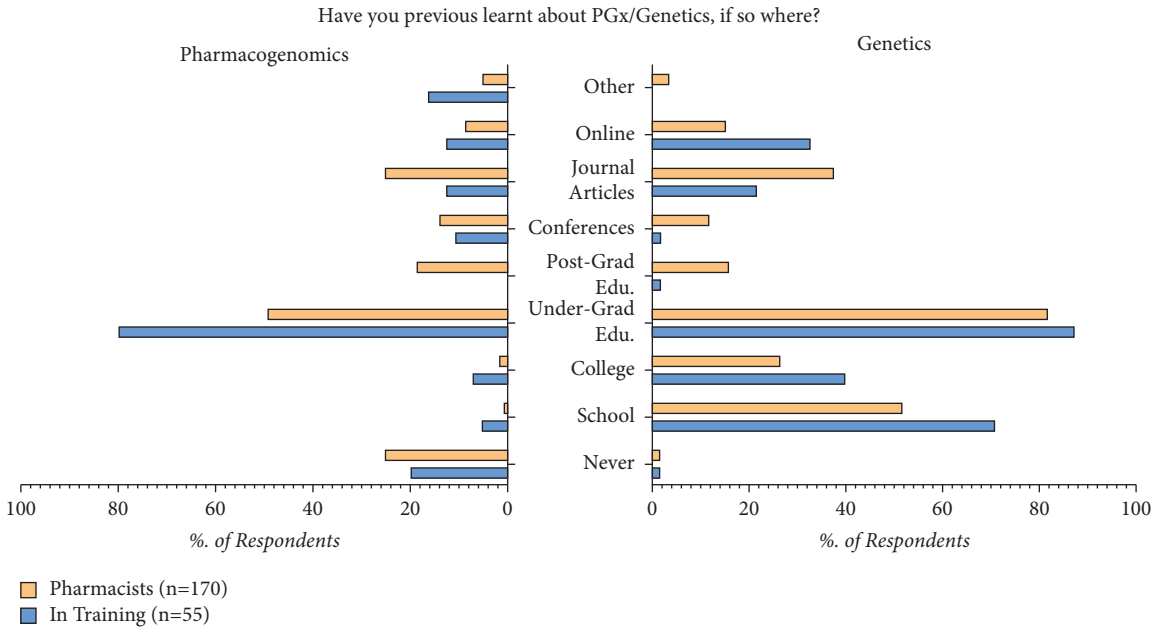

Figure 1: Outline of responses to a question regarding previous genetics/PGx education. Respondents were asked to rate their confidence in their knowledge and understanding of genetics and PGx (Questions 10 and 14) using a 0–100 scale wherein 0 equated to "not confident" and 100 "very confident." The overall level of confidence was lower for PGx than genetics for all respondents; in addition, the in-training cohort demonstrated a higher average confidence level than qualified pharmacists for both genetics and PGx.

When asked if they felt confident in their knowledge of which drugs required genetic testing prior to prescribing (Question 18), 65.3% of qualified pharmacists and 63.3% of the in-training cohort cited "strongly disagree" or "disagree" as shown in Figure 2.

In addition, in response to the question "in the past 12 months, how often have you requested/recommended a pharmacogenetic test be performed?" (Question 17) 86.7% of qualified pharmacists and 85.3% of the in-training cohort cited that they had never requested or recommended a test.

One qualified pharmacist (0.5%) reported requesting or recommending a test over 15 times. This individual cited their specialism as rheumatology where drugs which require TPMT testing, such as azathioprine, are frequently used. A further 7 pharmacist respondents (3.6%) reported requesting or recommending a test 1–5 times in the preceding 12 months. Of these, 6 were practicing in an NHS hospital within specialities including critical care, respiratory, and oncology. The final respondent was working as a community pharmacist.

Respondents were also asked to rate their confidence "to make/advise a drug or dose change based on a pharmacogenetic test result" using the same 0–100 scale (Question 21). Over 90% of respondents in both cohorts rated their confidence level at 50 or below.

To ascertain if confidence in knowledge translated into confidence in utilisation, an XY scatter graph was created (Figure 3) using the self-rated confidence scores from the abovementioned question and "how confident do you feel in your current knowledge and understanding of pharmacogenomics?" (Question 16). The plot demonstrated a small positive correlation between the two data sets with an R^2 value of 0.23 ($p = < 0.0001$).

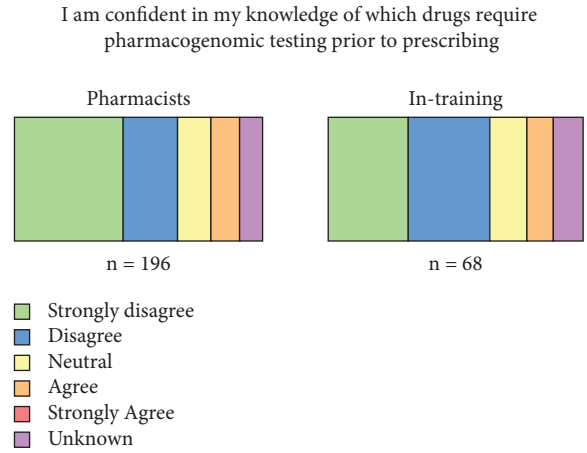

Figure 2: Confidence in knowledge of drugs which require PGx testing prior to prescribing.

In response to the question about how many times they had "reviewed a PGx test result" (Question 20) in the past 12 months, the number of pharmacist responders who answered "never" was lower for this at 156 (91.8%) compared with 162 (95.3%) when asked about recommending/requesting a test. The same pharmacist who requested a test over 15 times also said they had reviewed a result over 15 times in a 12-month period.

Furthermore, respondents were asked to cite where, if applicable, they had previously searched for PGx based recommendations (Question 19). Across all respondents, 63.6% stated that they had never looked for PGx recommendations.

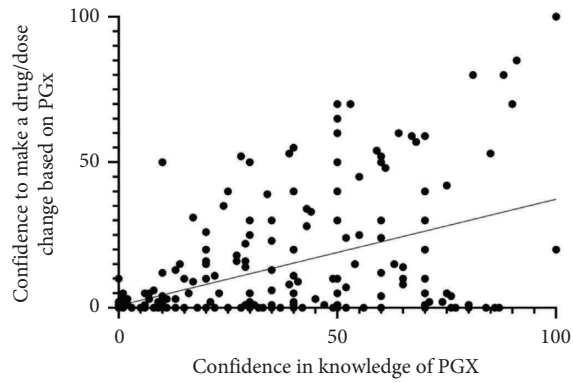

Figure 3: XY scatter graph and line of Pearson correlation coefficient between confidence in PGx knowledge and confidence in making drug/dose changes using PGx (R^2 0.23; $p < 0.0001$).

Of those who had searched for PGx recommendations, over 70% cited using more than one reference source, with the most popular choices being the British National Formulary (BNF) and the Summary of Product Characteristics (SPCs). Although overall usage of PGx specific reference sources was low, the Clinical Pharmacogenetics Implementation Consortium (CPIC) guidelines were the most utilised with 4.1% of pharmacists and 4.4% of those in-training citing this. Other sources cited included NICE guidelines, experts, and local protocols.

3.3. Barriers to PGx Implementation into Clinical Practice. When asked if they would utilise "point of care" PGx testing if it were available (Question 23), for example in a community pharmacy, a greater number of the in-training cohort than the qualified pharmacist cohort responded with extremely likely or likely, at 59% and 39.8%, respectively. Respondents also gave a free-text answer when asked to outline reasons why they would be likely or unlikely to utilise this technology (see Table 2).

A recurring theme in the responses related to who has responsibility for requesting a genetic test. Predominantly, the consensus from these responses was that the role of requesting and performing a test should lie with the prescriber, although there was also frequent reference made to the fact that pharmacists should still have access to the results.

Lack of knowledge of PGx also featured heavily. In addition, the cost or resources needed to provide a PGx service was also raised directly by 19 respondents. Of these, 89.4% of the comments were related to the cost or resource implications to the pharmacy or NHS.

In addition to this feedback, respondents were asked if there was anything additional that they felt they would require to suggest amendments based on a PGx result (Question 22). By far the most common response was for PGx guidelines with 74.5% of qualified pharmacists and 75% of in-training pharmacists highlighting this. After guidelines, an increased knowledge of genetics and PGx were cited by over 60% of respondents in both cohorts.

Financial remuneration was the least cited response with only 14.3% of the pharmacist cohort and 19.1% of the in-training cohort feeling it would be necessary to be able to offer a service.

Over 50% of qualified pharmacists had no ethical concerns regarding using PGx, this dropped to 39.7% for the in-training cohort, though the percentage that would not use PGx due to ethical concerns remained consistent at 1.5% in both groups.

4. Furthering PGx Education for Pharmacists

When asked if respondents "felt that PGX was/is an important part of their undergraduate education" (Question 32), there was a clear divide between the qualified and in-training cohorts, with 6.3% of the qualified cohort answering agree/strongly agree compared with 32.7% of their in-training counterparts as shown in Table 3.

Most respondents across both cohorts cited PGx as a low/medium learning priority. When the data for the learning priorities for qualified pharmacists was broken down further (Table 4) and correlated with previous PGx education it was noted that those who had stated that PGx education was not a priority for them had a lower percentage of previous exposure comparative to those who did consider it a priority.

Finally, respondents were asked via which mediums they would like to learn more about PGx. The most popular choice was online CPD, with over half of respondents from all cohorts selecting this option. Other media suggested included podcasts and lunchtime meetings. One respondent highlighted that PGx was not currently integrated into the curriculum of the non-medical prescriber course in the UK.

5. Discussion

This survey aimed to provide an assessment of the current understanding of PGx by UK pharmacists and pharmacy students in addition ascertaining the future educational and infrastructure needs of pharmacists to adopt PGx into practice. The findings of this survey indicate that there is a substantial amount of work to be carried out to prepare the UK pharmacy profession for the advent of PGx into routine clinical practice.

Some variation in PGx exposure was expected based on sector of work, years qualified or year of study (for students) as, in the UK, the Master of Pharmacy (MPharm) degree only implemented PGx as a mandatory component of the required undergraduate curriculum in 2011. The results of this survey demonstrate a clear generational divide in exposure to PGx education which will need rectifying prior to nationwide PGx implementation. These findings mirror those of a 2013 study which utilised semistructured interviews with UK pharmacogenetics and pharmacy stakeholders and practitioners [13] and a 2020 US survey investigating the role postgraduate education and training in pharmacist's knowledge and attitudes of pharmacogenomic testing [14].

Table 2: Extracts related to utilisation of "point of care" PGx technologies.

Themes	Extract
Time, cost, and resources	"*In community practice I think that there is not enough time, resources or staff to carry out this.*"-Preregistration pharmacist "*Believe would be financially not feasible, and also possibly very demanding of my already stretched time*"-Qualified Pharmacist (>10 years) "*. . .Only limitation might be limited resources to do the tests-remuneration*?"-Qualified Pharmacist (≤10 years) "*In principle I think it may be the way forward and improve safer, more rationale prescribing however funding may be an issue*"-Qualified Pharmacist (>10 years) "*Could save time and resources by screening for the most effective/least side effect profile for a given individual better for the patient and NHS*"-Undergraduate "*I think we should be making use of advancements in technology to optimise patient's regimens. Only limitation might be limited resources to do the tests-remuneration*?"-Qualified Pharmacist (>10 years)
Responsibility for testing	"*. . . decision should lie with prescriber*"-Qualified Pharmacist (>10 years) "*Pharmacists with the correct amount of clinical training are the drug experts and on that basis are more qualified to advise on these issues than other members of the primary care team, including GPs.*"-Qualified Pharmacist (>10 years) "*The genetic test and appropriateness should be at prescribing level-more so now so much dispensing is remote internet pharmacy etc*"-Qualified Pharmacist (>10 years) "*Such testing should be done at the point of prescribing and the result communicated to the pharmacist. Performing such a test would, in my opinion, constitute part of the prescribing process, not the dispensing/clinical check process. The result should definitely be accessible to the dispensing pharmacy to allow them to confirm that the prescription is clinically appropriate for the patient.*"-Qualified Pharmacist (≤10 years) "*Community setting is perfectly positioned to offer this service as pharmacists have the most time to spend with patients compared to other clinicians*"-Qualified Pharmacist (>10 years)
Data integrity/secondary findings	"*. . .I would be concerned on the repercussions of this technology as ultimately this data could harm patient confidentiality.*"-Undergraduate "*I would [use POC PGx testing] if it was supported by a decent evidence base and the test was cost effective. My one major concern is that we will introduce screening for genetic mutations and expose people to the harms that you get with every screening programme. I dont think this has been considered widely enough as people just assume a genetic test means personalised treatment which they always assume is better (I think)*"-Qualified Pharmacist (≤10 years)
Education and guidelines	"*After increasing knowledge within this new area and specific training I can see an opportunity for community pharmacy to provide this service. I do see a place in the future for this in the UK*"-Qualified Pharmacist (>10 years) "*If I was given more support and increased my knowledge of the subject I feel it would be appropriate to do in a healthcare setting as a pharmacist although I do feel more legislation is needed before I can do so.*"-Preregistration Pharmacist "*Don't know enough about it to make decision based on results*"-Qualified Pharmacist (≤10 years)

When asked about confidence in knowledge of the ethical and legal considerations surrounding PGx ((0 = not confident, 100 = very confident)), all groups had an average under 15 with those qualified under 10 years having the highest average confidence at 13.7 and students the lowest at 9.4.

Table 3: Learning priorities for PGx and previous exposure at undergraduate level.

Would you like to learn more about pharmacogenomics in the future?	Qualified ≤10 years $n = 83$ (%)	Qualified >10 years $n = 113$ (%)	Preregistration $n = 32$ (%)	Undergraduate $n = 36$ (%)
No, it is not a learning priority for me	3 (3.6)	3 (2.7)	2 (6.3)	2 (5.6)
Yes, it is a low learning priority	27 (32.5)	25 (22.1)	7 (21.9)	2 (5.6)
Yes, it is a medium learning priority	27 (32.5)	39 (34.5)	11 (34.4)	9 (25.0)
Yes, it is a high learning priority	6 (7.2)	17 (15.0)	4 (12.5)	7 (19.4)
Yes, it is an essential learning priority	5 (6.0)	13 (11.5)	2 (6.3)	6 (16.7)
Unknown	15 (18.1)	16 (14.2)	6 (18.8)	10 (27.8)
Pharmacogenomics was/is an important part of my undergraduate pharmacy education				
Strongly disagree	21 (25.3)	54 (47.8)	6 (18.8)	3 (8.3)
Disagree	22 (26.5)	23 (20.4)	5 (15.6)	11 (30.6)
Neutral	11 (13.3)	7 (6.2)	8 (25.0)	2 (5.6)
Agree	10 (12.0)	5 (4.4)	7 (21.9)	6 (16.7)
Strongly agree	4 (4.8)	8 (7.1)	0 (0.0)	4 (11.1)
Unknown	15 (18.1)	16 (14.2)	6 (18.8)	10 (27.8)

Table 4: Breakdown of pharmacist demographics associated with learning priority responses.

	N	(%) NHS hospital	(%) Community pharmacy	(%) Another sector	(%) With previous PGx education	Mean confidence in PGx (±SD)
PGx is not a learning priority for me	6	33.3	33.3	33.3	66.6	34.7 (32.9)
Yes, it is a low learning priority	52	50.0	30.8	19.2	73.1	23.4 (23.4)
Yes, it is a medium learning priority	66	54.5	24.2	21.3	74.2	28.1 (22.5)
Yes, it is a high learning priority	23	52.2	17.4	30.4	78.3	43.6 (33.5)
Yes, it is an essential learning priority	18	50.0	27.8	22.2	72.2	33.1 (32.8)
Unknown*	31	38.7	38.7	22.6	61.3*	29.9 (29.6)*

*For those who responded "unknown" data was missing for confidence score and education for 6 respondents.

The statistically significant difference in previous education levels within the qualified pharmacist cohort itself is of particular interest. From this finding, it can be ascertained that a variety of educational materials will need to be developed which range from introductory materials to more advanced PGx applications to accommodate the heterogeneity of previous exposure. As this study offers quantitative data on this generational gap, it would be possible to repeat the survey following the implementation of wide-reaching post-graduate PGx education to ascertain if this has been successful reducing the diversity in PGx exposure opportunities.

When considering if PGx education correlated to confidence, the results suggest that despite over 75% of all respondents having previous education, only 15.7% of these either agreed or strongly agreed when asked about their confidence in which drugs required PGx testing. This finding is not unique to the UK; a survey of pharmacists practicing in the Netherlands also identified that while approximately half of the 727 respondents had experienced prior PGx training, only 14.1% felt adequately informed about availability and application in practice [12]. In addition, over 60% of the qualified pharmacists did not feel confident in identifying drugs that require PGx testing, a finding which is similar to those identified in a 2011 US survey of 303 pharmacists which noted that just under 75% of respondents could not identify medications which required PGx testing [11].

When it comes to facilitating PGx implementation, over 80% of respondents stated that guidelines on the use of PGx would assist them in implementing PGx based recommendations in addition to further education. This echoes the findings of the survey of the US pharmacists which identified the need for further education as a barrier to PGx implementation [14]. Financial remuneration was cited the least and this finding is similar to those identified within the Ubiquitous PGx European survey of healthcare professionals [10].

Whilst some international PGx guidelines exist, such as those provided by the Clinical Pharmacogenetics Implementation Consortium (CPIC) and Dutch Pharmacogenomics Working Group (DPWG), the utilisation of these resources by the qualified pharmacist cohort was low. This finding correlated closely to those of a survey of Canadian Pharmacists and Nurse Practitioners which identified that only 4% of respondent had utilised CPIC and PharmGKB and only 2% had utilised DPWG [15]. Whilst utilisation was slightly higher in the in-training cohort, it is important that developed learning packages provide clear links to current guidelines either from international sources or an NHS/National Institute for Clinical Excellence (NICE) equivalent when available.

It is also possible, however, that part of the lack of guideline utilisation reflects that the majority pharmacist respondents had not yet encountered PGx in their professional practice due to limited testing availability within the NHS at present.

Most respondents across both cohorts cited PGx as a medium learning priority or lower. In part, this may be due to a lack of understanding as to where PGx may fit into their practice due to the NHS Genomic Medicine Service not being fully rolled out at the time of the survey [16]. The results of this survey demonstrated that pharmacists for whom PGx learning was not a priority had lower exposure to previous PGx education and those who cited it as a high priority had the highest levels of previous education. This trend indicates that introducing PGx education early in pharmacist training may foster further learning and, for those qualified pharmacists who had not yet encountered PGx, a brief introductory session may provide the basis for desired ongoing learning.

Presently, there is no formal training pathway for pharmacists following qualification with the exception of fulfilment of self-directed CPD [17]. Often ongoing training varies considerably by sector with formal postgraduate clinical diplomas remaining largely within the remit of hospital pharmacy [17]. In 2014, the RPS began offering its "Foundation Pharmacy Framework" [18] which is open to all practicing pharmacists but, as a practice based framework, in certain sectors may not allow for exposure to PGx. It is therefore important to consider where PGx training falls in the scope of ongoing training for pharmacists.

A limitation of this work is that the largest proportion of pharmacist respondents were working in the hospital sector and so may be unable to fully represent the differences between pharmacy sectors in the UK. Due to the sample size, the study was also inadequately powered to detect statistically significant differences between sectors of the profession. In addition, the "undergraduate" cohort consisted of students across all 4 years of study (and therefore, PGx exposure) but due to the small sample size of the group, these were collated for analysis. Future work looking specifically at this group would be beneficial in understanding the nature of undergraduate PGx education over the coming years.

In addition, this survey only assessed the views of pharmacists and those training to be pharmacists. The UK pharmacy sector consists of other pharmacy professionals including technicians and assistants all of whom may have a variety of opinions and experience with PGx which were not captured within the scope of this study. Further potential work on this topic may also include focus groups of pharmacy professionals exploring what they feel their responsibilities within UK PGx provision could include. For example, a study undertaken in the US demonstrated that over 50% of community pharmacists felt that their role should include counselling patients on PGx information [19]. Such work undertaken within the UK, with both pharmacists and other healthcare professionals, could provide a basis for the structure of PGx provision in the UK.

In conclusion, the data encapsulated within this study indicate a generational divide in PGx knowledge within the UK pharmacy profession and that most qualified pharmacists have not yet encountered PGx within their practice. The UK pharmacy sector is not alone in these findings and faces much the same challenges as other parts of the world in the implementation of PGx into clinical practice. Providing introductory PGx training may increase interest in ongoing learning and that online learning was the preferred medium for PGx education. Furthermore, our findings are important in providing a baseline understanding of the UK pharmacy workforces awareness of and skills gap in pharmacogenomics, which should help in developing appropriate undergraduate curricula and post-graduate continued learning packages. Further work needs to be undertaken to better understand intersectional differences in PGx exposure in the UK pharmacy setting, and the opinions of other members of the pharmacy profession and the full extent of the role pharmacists expect to deliver in clinical PGx provision.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

VR received PhD funding through the European Community's Horizon 2020 Programme under grant agreement no. 668353 (Ubiquitous Pharmacogenomics). MP has received partnership funding for the following: Medical Research Council (MRC) Clinical Pharmacology Training Scheme (cofunded by MRC and Roche, Union Chimique Belge [UCB] Pharma, Eli Lilly, and Novartis), and a PhD studentship jointly funded by Engineering and Physical Sciences Research Council and Astra Zeneca. He has also received unrestricted educational grant support for the UK Pharmacogenetics and Stratified Medicine Network from Bristol-Myers Squibb. He has developed a human leukocyte antigen genotyping panel with MC Diagnostics but does not benefit financially from this.

Supplementary Materials

Survey questions. (*Supplementary Materials*)

References

[1] F. Vogel, "Moderne probleme der Humangenetik," in *Ergebnisse der Inneren Medizin und Kinderheilkunde*, Springer Berlin Heidelberg, Berlin, Heidelberg, 1959.

[2] H. M. Dunnenberger, K. R. Crews, J. M. Hoffman et al., "Preemptive clinical pharmacogenetics implementation: current programs in five US medical centers," *Annual Review of Pharmacology and Toxicology*, vol. 55, no. 1, pp. 89–106, 2015.

[3] K. J. Karczewski, R. Daneshjou, and R. B. Altman, "Chapter 7: pharmacogenomics," *PLoS Computational Biology*, vol. 8, no. 12, Article ID e1002817, 2012.

[4] J. D. Ma, K. C. Lee, and G. M. Kuo, "HLA-B 5701 testing to predict abacavir hypersensitivity," *PLoS Curr*, vol. 2, Article ID RRN1203, 2010.
[5] S. Mallal, E. Phillips, G. Carosi et al., "HLA-B 5701 screening for hypersensitivity to abacavir," *New England Journal of Medicine*, vol. 358, no. 6, pp. 568–579, 2008.
[6] S. Mallal, D. Nolan, C. Witt et al., "Association between presence of HLA-B∗5701, HLA-DR7, and HLA-DQ3 and hypersensitivity to HIV-1 reverse-transcriptase inhibitor abacavir," *The Lancet*, vol. 359, no. 9308, pp. 727–732, 2002.
[7] A. R. Hughes, M. Mosteller, A. T. Bansal et al., "Association of genetic variations in HLA-B region with hypersensitivity to abacavir in some, but not all, populations," *Pharmacogenomics*, vol. 5, no. 2, pp. 203–211, 2004.
[8] British Hiv Association (Bhiva), "Guidelines for the treatment of HIV-infected adults with antiretroviral therapy," *HIV Medicine*, vol. 1, no. 2, pp. 76–101, 2000.
[9] P. C. Bank, J. J. Swen, and H. J. Guchelaar, "A nationwide cross-sectional survey of pharmacy students on pharmacogenetic testing in The Netherlands," *Pharmacogenomics*, vol. 19, no. 4, pp. 311–319, 2018.
[10] K. S. Just, M. Steffens, J. J. Swen, G. P. Patrinos, H. J. Guchelaar, and J. C. Stingl, "Medical education in pharmacogenomics-results from a survey on pharmacogenetic knowledge in healthcare professionals within the European pharmacogenomics clinical implementation project Ubiquitous Pharmacogenomics (U-PGx)," *European Journal of Clinical Pharmacology*, vol. 73, no. 10, pp. 1247–1252, 2017.
[11] K. B. McCullough, C. M. Formea, K. D. Berg et al., "Assessment of the pharmacogenomics educational needs of pharmacists," *American Journal of Pharmaceutical Education*, vol. 75, no. 3, p. 51, 2011.
[12] P. C. Bank, J. J. Swen, and H. J. Guchelaar, "A nationwide survey of pharmacists' perception of pharmacogenetics in the context of a clinical decision support system containing pharmacogenetics dosing recommendations," *Pharmacogenomics*, vol. 18, no. 3, pp. 215–225, 2017.
[13] K. Jamie, "Pharmacogenetics and pharmacy education in the UK: mind the generation gap pharmacy education," 2013, https://pharmacyeducation.fip.org/pharmacyeducation/article/view/253.
[14] M. E. Hundertmark, S. C. Waring, D. D. Stenehjem et al., "Pharmacist's attitudes and knowledge of pharmacogenomics and the factors that may predict future engagement," *Pharmacy Practice*, vol. 18, no. 3, p. 20, 2008.
[15] M. Hayashi and C. A. Bousman, "Experience, knowledge, and perceptions of pharmacogenomics among pharmacists and Nurse practitioners in alberta hospitals," *Pharmacy Times*, vol. 10, no. 6, p. 139, 2022.
[16] Genomics Education Program, "Pharmacogenomics: a new normal for the NHS?," 2019, https://www.genomicseducation.hee.nhs.uk/blog/pharmacogenomics-a-new-normal-for-the-nhs/.
[17] Health Education England, *Advancing pharmacy education and training: A review*, Health Education England, London, England, 2019.
[18] Royal Pharmaceutical Society of Great Britain, "Foundation," 2021, https://www.rpharms.com/development/credentialing/foundation.
[19] S. Tuteja, K. Haynes, C. Zayac, J. E. Sprague, B. Bernhardt, and R. Pyeritz, "Community pharmacists' attitudes towards clinical utility and ethical implications of pharmacogenetic testing," *Personalized Medicine*, vol. 10, no. 8, pp. 793–800, 2013.