Review Article

JYP

Knowledge, Attitude and Practice Concerning Pharmacogenomics among Pharmacists: A Systematic Review

Adamu Yau[1], Aniza Binti Abd Aziz[2], Mainul Haque[3*]

[1]*Masters Student, Faculty of Medicine and Health Sciences (FPSK), Universiti Sultan Zainal Abidin (UniSZA), 20400 Kuala Terengganu, Terengganu, Malaysia.*

[2]*Associate Professor, FPSK, UniSZA, Kampus Kota, Jalan Sultan Mahmud 20400, Kuala Terengganu, Malaysia.*

[3]*Professor and Head of the Unit of Pharmacology, FPSK, UniSZA, 20400 Kuala Terengganu, Terengganu, Malaysia.*

ABSTRACT

Background: Pharmacists are furnished with expert drug knowledge and have been considered as valuable resource of drug information, therefore, are well positioned to play a leading role in the application of pharmacogenomics (PG) in to clinical practice. This might prevent Chemotherapy related adverse events and improve patient outcomes, despite the ethical, privacy concerns and potential implications of lifelong genetic-data. **Methods:** This review is to evaluate and digest the various studies on Knowledge, Attitudes and Practice concerning pharmacogenomics among pharmacists and to suggest future research areas. 13 English published studies from 2004 to 2014 were selected. Studies involving Pharmacists of different area of practice and covering research from different continents were selected. Only studies on attitudes, knowledge and practice concerning pharmacogenetics among pharmacists from 2004 to 2014, and research articles published in English were selected. Non-research articles, studies done on general public; studies conducted among other healthcare professionals; studies on genetics of diseases or toxicogenetics were excluded. **Results:** Knowledge and practice regarding pharmacogenetics among pharmacists were poor despite good attitudes. There was knowledge advancement from 38% in 2005 to more than 50% 2013 in some countries. Some barriers to adoption of pharmacogenomics into patient care and interventional recommendations were highlighted. **Conclusion:** there is an urgent call for additional training of Pharmacogenomics among pharmacists and to incorporate pharmacogenomics into curriculum of pharmacy schools. Pharmacists and future pharmacists should be trained on how to critically evaluate the use, efficacy, and safety of available pharmacogenetic testing.

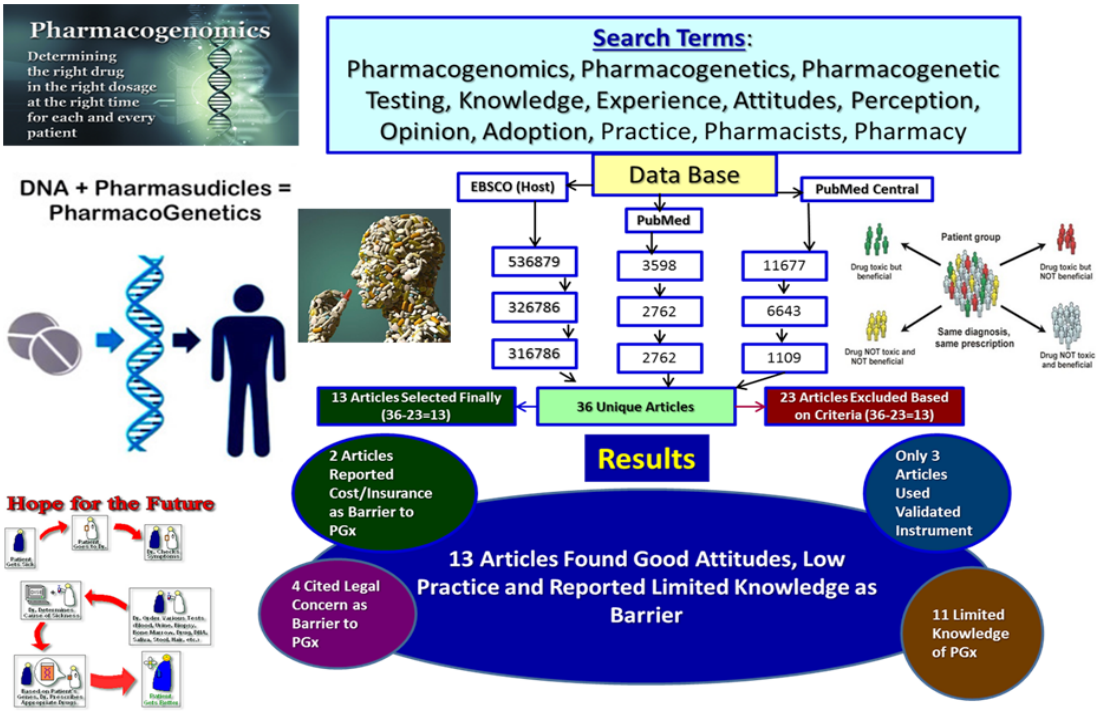
Key words: KAP, Pharmacogenomics, Pharmacogenetics, Pharmacists, Systematic Review.

Access this article online	
Journal Sponsor	Website: www.jyoungpharm.org
www.phcog.net	DOI: 10.5530/jyp.2015.3.3

INTRODUCTION

Inter-individual variability in the clinical response to drug treatments for acute and chronic diseases is one of public health concerns. This variability has been attributed largely to non-genetic factors, such as age, weight, disease conditions, and drug-drug interactions. The fraction of

Address for correspondence:
Prof. Mainul Haque, Professor and Head of the Unit of Pharmacology, Faculty of Medicine and Health Sciences, Jalan Sultan Mahmud-20400 Kuala Terengganu, Terengganu, Malaysia. E-mail : runurono@gmail.com



Graphical Abstract

patients who respond positively to their medications is approximately ranging from 25 to 60% only, therefore the remaining fraction is not receiving the proper medication or is suffering from significant therapeutic problems, such as delays by substituting from one medication to another until good prognosis is achieved.[1] Adverse drug reactions (ADRs) represent is frequently cited to be approximately between the fourth and sixth leading cause of death in the USA, with fatal ADRs occurring in 0.32% of patients.[2] Data from the UK[3] demonstrates the economic burden of ADRs on national healthcare systems, resulting to total costs of GB£380 million a year.[3] Pharmacogenomics (PG) is a biotechnological science that combines the techniques of medicine, pharmacology, and genomics and is concerned with developing drug therapies to compensate for genetic differences in patients which cause varied responses to a single therapeutic regimen.[4] If genetic factors are taken into account appropriately before starting drug treatment, the type of drug and its dosage can be tailored to the individual patient need. PG puts a substantial professionalism to the therapeutic approach, it is the relationship between dosage requirement and genetic variation in drug metabolizing enzymes like Cytochrome P450, G-6-D-P, NAT2, VKORCI and TPMT or in drug transporters like P-glycoproteins that is substantiated best.[5] PG has been defined as the study of variability in pharmacokinetics and pharmacodynamics in relation to human genomic variation. It was originated from biochemical genetics and the works of Archibald Garrot (1857–1936) who proposed that the chemical individuality of humans as a basis for certain inborn errors of metabolism such as alkaptonuria.[6] Pharmacists are publicly recognized as the content experts for drug therapy. The roles of Pharmacists in the team have been well pronounced and have led to enhanced patient outcomes.[7] Clinical interventions are based on patient variability and response, and one of the primary goals of pharmacists is to provide safe and effective drug therapy to their patients; pharmacists demonstrate this important role on the team through therapeutic drug monitoring of narrow-therapeutic-index medications. PG provides patient-specific predictors for response and safety. Therefore, predicting the probability of efficacy or potential toxicities, based on pharmacogenetic information, will help to improve the roles of pharmacists and therapy decisions at large. This might prevent adverse events and improve patient outcomes, despite the ethical, privacy concerns and potential implications of lifelong genetic-data availability.[8] Pharmacists must play a key role in integration of pharmacogenomics in to practice. Pharmacists are furnished with expert drug knowledge and can serve as a valuable resource with respect to dose adjustments and/or drug choice based on the outcomes of genetic tests. A concentrated professional education of all professional stake holders of medication use in medicinal chemistry, pharmacokinetics, pharmacology, and therapeutics provides the basis of their role as medication connoisseurs.

Incorporation of PG into this specialized background will allow us to provide more suitable recommendations, to improve therapy, and potentially to avoid adverse outcomes.[8]

Regarding communication and ethical issues, pharmacists would need to be proficient and confident in understanding the views of patients concerning genetics and modifying the information they provided to ensure that patients have understood the consequences of the PG testing.[9] It was generally agreed that education for health professionals should incorporate topics in genetics and pharmacogenetics; not only for drug prescribers but also those dispensing and monitoring them.[9] This article will systematically summarize pharmacists knowledge, attitudes, practice and views towards PG and its potential impact on their roles. It will then suggest further research areas and a foundation of how PG may impact on service delivery. One significant example of the impact of PG is the genetic polymorphism of HLA-B*1502 which has been shown to reduce adverse drug reactions and other drug related problems by genotyping of patients for HLA-B*1502 before carbamazepine is prescribed to patients at risk of Steven Johnson syndrome and Toxic Epidermal Necrolysis.[10] The roles of PG in most favorable health care is further synergized by Food and Drug Administration (FDA)'s approval of changes to labeling of warfarin, clopidogrel, trastuzumab, cetuximab, maraviroc, abacavir, mercaptopurine, carbamazepine, and irinotecan and dasatinib and many more drugs to include the potential usefulness of genetic testing.[11,12] Several Pharmacogenomic tests have been documented by the clinical and regulatory committees as important component of standard practice,[13] and it has been part of drug label for abacavir, warfarin, clopidogrel, irinotecan, maraviroc, cetuximab etc.[10,13,14]

AIM OF THE STUDY

- To explore previous researches conducted on pharmacists knowledge, views, attitudes and practice towards PG from 2004 to 2014.
- To communicate the outcome obtained by various studies.
- To find out the missing knowledge identified by the various researchers and make rational recommendations.

The following definitions were adopted for the purpose of this review

Knowledge

A body of truths or facts accumulated in the course of time, the cumulated sum of information, or theoretical or practical understanding of the subject matter.

Attitude

An enduring learned predisposition to behave in a consistent positive or negative way towards a given class of idea, object, person, or situation, or a persistent mental and/or neural state of readiness to react to a certain class of objects, not as they are but as they are conceived to be.

Practice

Application of knowledge, experience or practical approach to subject matter.

MATERIAL AND METHODS

The texts search was designed to find Knowledge, attitudes and Practice concerning Pharmacogenomics among Pharmacists in EBSCO (host), PubMed, PubMed Central (PMC), Embase, Medline, and Google Scholar and Free Full PDF databases and search engines respectively, from the year 2004 to 2014. The queries were sought in either the title or the abstract. These search terms were used in connection with one another using Boolean/Phrase algebra (AND, OR). The search included all English written articles from January 2004 to November, 2014, to the best of our knowledge. In order to make sure all potentially relevant studies were included, the eligible studies were identified by using the following search terms: Pharmacogenetics, pharmacogenomics, pharmacogenetic testing, Pharmacists, pharmacy, knowledge, attitudes, perception, opinions, adoption, practice and experience. For articles to warrant consideration for inclusion, it had to be constituted of original peer-reviewed Drug related genetic research. These articles were then carefully hand-searched to identify those of relevance to this systematic review. Articles were analyzed for this review if they reported survey data on pharmacists attitudes, knowledge, or practice behaviors concerning PG.

Inclusion Criteria

- Only studies conducted from 2004 to 2014 were included,
- Studies conducted on knowledge, attitude and practice concerning PG among pharmacists were selected.
- Research articles published in English journals

Exclusion criteria

All non-research articles, all studies conducted earlier 2004 and studies done on general public were excluded, studies

conducted on other healthcare professionals and genetics of diseases were left out. The listed references in the included articles were further carefully searched by hand in order to take care of other surveys that had not been identified by the used database and search engine strategy.

RESULTS

After the first query, the search results displayed 536'879, 326'786 and 316'411 entries in EBSCO Host (Medline complete), 3'598, 2'762 and 2762 entries in PubMed, 11'677, 6'643 and 1109 entries in PubMed central (PMC), 1'830, 1'760 and 1'750 entries in Google Scholar respectively, for the knowledge, attitude and practice concerning pharmacogenomics, pharmacogenomics testing, pharmacogenetics, pharmacists and pharmacy terms. When the query was done with search terms combined, the displayed entries were 1'103, 10 and 37 for EBSCO Host, PubMed and PMC databases respectively, and subsequently a total of 36 unique articles. At the end, a total of thirteen studies met the inclusion criteria. Most of the researches were conducted in USA.[15–21] one in Nigeria,[22] one in Canada,[23] one in UK,[9] one in Malaysia,[12] one from Australia,[24] and one in Ukraine.[25] Three surveys were qualitative, that used one or combination of semi structure questionnaire, one-day meeting and case scenarios,[9,22,26] and with regard to design, four research were cohort study,[19,21,24,26] while the rest nine were Cross-sectional studies,[9,12,15,16,18,22–25] Pharmacogenetics or PG or pharmacogenetic testing and pharmacists or pharmacy students were discussed in all the articles. Table 1 presented the summary of included researches in this systematic review.

Most of the study participants were Pharmacists from different areas of practices. Seven studies have had a response rate of less than 60% for pharmacists,[12,15,16,18,19,23] while the remaining six have response rate more than 60%,[9,17,21,22,25] Only three researches used statistical analysis in questionnaire validation;[12,18,21] two studies used pilot study to validate the questionnaire in the studies;[17,19] majority of studies used experts reviews or kept silence on validity of questionnaire.[9,15,16,22–26] In total 4,624 pharmacists participated in the reviewed articles.

Pharmacists Attitudes Concerning PG

From our review, all of the 13 articles included reported attitudes, opinions or perceptions of pharmacists concerning pharmacogenomics. These articles were assessed based on four commonly cited parameters that were generated from the reviewed articles, for the purpose of this review processes; Ethical concerns or Discrimination, perceived benefits or interest, perceived roles or responsibilities, and Education as described below.

Attitudes-Perceived Benefits

A total of 12 articles have shown information about the perceived benefits and or interest on PG. Significant consistency was observed among surveys with respect to general attitudes of pharmacists towards PG. In the overall participants, majority felt that PG is important and has benefits to patients which demonstrated good attitudes concerning PG among pharmacists. In U.S., seven studies have revealed consistent positive attitudes towards PG among pharmacists; 67% felt that PG should be focal point in patient care,[17] 83% of pharmacists believed that genetic can improve patients outcomes,[15] more than half of participants felt that PG can reduce ADRs and has promising benefits to healthcare systems.[16–19,26] Similar findings were revealed from UK that 80-95% considered PG as beneficial to patients, despite reported gross limited knowledge of PG reflected in only 6% felt well informed about PG;[9] from Malaysia 67% of pharmacists felt that PG is very important in drug safety;[12] these is in agreement with findings from Australia[24] and Nigeria.[20] Recently from Ukraine, 87% of future pharmacists perceived benefits from PG, but only one-third (1/3) of the participants that correctly understood PG and 70% not aware of PG[25] and this is comparable with results from Canada.[23]

Attitudes-Perceived Responsibilities

Under this domain, some of the reviewed articles revealed the attitudes of pharmacists towards their roles and responsibilities in PG as one of the components of healthcare delivery system. Four studies conducted in U.S revealed that pharmacists perceived themselves as the leading force for the integration of PG in to practice and also should be an important source of PG information to patients and other healthcare providers.[15–17,19] Similarly, one study each from UK,[9] Canada[23] and Ukraine[25] revealed same perceived roles and responsibilities towards PG among pharmacists.

Attitude-Ethical

Only four articles revealed concerns on ethical or legal consideration about PG, one study from U.S reported that pharmacists felt pharmacogenetic testing could lead to discrimination among patients and of legal concerns towards PG.[19] This finding is in similar to research conducted in Australia, Malaysia and Nigeria respectively.[12,22,24] The remaining articles did not discuss ethical or legal concerns issues.

Table 1: Summary of the Review Articles

Year	First Author	Study Design	Participants & Settings	Sample size & rate	Outcomes Measured	Findings	Suggestions	Country
2005	Latif AD *et al*.,	CrS, SCQ	PPS of pharmacists (Deans)	N=85 (48%)	Adoption of PG and interest	Majority provide some aspects of PG and interest towards PG	There is need for in-depth approach to PG	USA
2007	Newton R *et al*.,	CrS One-day meeting &case scenarios (qualitative)	PPS of pharmacists of different practices	N=20 (100%)	Pharmacists' roles and views of PG	Limited knowledge, All felt that they should be part of integrating PG into practice, & skills also needed for PG,	Increase awareness of PG, develop educational framework that recognizes PG needs	UK
2010	Zembles T. *et al*.,	CrS, Semi-structure questionnaire & case scenario	PPS of pharmacists	N=50 (80%)	Effectiveness of PG educational intervention and retention of PG knowledge	The PG education intervention was effective and good retention ability with high interest to PG	Further research with large sample and to include other areas of PG	USA
2011	McCullough B Kristen *et. al*.,	Cohort Study, SCQ	CnS sample of pharmacists	N=480 (63.1%)	Perceived-Knowledge & confident	Majority agree that PG is important, while less than half felt knowledgeable and confident to recommend PG tests	Further study to identify barriers, Coalition between the stake holders	USA
2011	Madali Parvaz *et. al*.,	CrS semi-structure questionnaire (Qualitative)	PPS of Pharmacists	N=5(100%)	perceptions towards pharmacogenomics	Majority have no formal training on PG but high awareness and expected benefits	Further efforts on funding, ethical and private concerns on PG	Nigeria
2011	McMAHON T. *et. al*.,	CrS SCQ	RS of Pharmacists	N=800 (36%)	Perceived/actual knowledge and Perception towards PG	Limited perceived and actual knowledge, Majority perceived benefits from PG, cost and ethical co	To educate pharmacists, and investigate economic consequences, ethical & accessibility issues on PG	Australia
2012	Kenza E. Benzeroual *et. al*.,	CrS, SCQ	RS of Pharmacists	N=319 (32%)	Knowledge, Experience and confidence on PG	Majority were exposed to basic PG, have confident and interest to PG, but less concern on more education	Pharmacogenetic education is needed for pharmacists.	USA
2012	Mary W. Roederer *et al*.,	CrS SCQ	CnS of pharmacists	N=737 (7.7%)	Knowledge, attitude and education of PG	Average knowledge, positive attitudes and high interest in PG education.	Need to build confident towards PG among pharmacists	U.S.A.(5)
2013	Sony Tuteja. *et. al*.,	CrS, SCQ	PPS of community pharmacists	N=611 (11%)	Knowledge & attitudes on utility, social, ethical & legal concerns of PG	Lack of perceived and actual knowledge of PG, Good attitudes towards PG but high legal and ethical concerns	Further research to include awareness of Genetic Information Nondiscrimination ACT(GINA), & ethical	U.S.A.

2013	Simon De Denus. *et. al.*,	CrS, SCQ	CnS of Pharmacists	N=284, (3%), response rate not stated	Expectation and opinion towards PG	Limited knowledge, Few felt comfortable to advise patients on PG. Almost all were willing to recommend PG & get more PG education,	There is need for knowledge in order to integrate PG into practice.	Canada
2013	Christine MF *et al.*,	CrS, CQ	PPS of pharmacists,	N=272 (68%)	Knowledge and effect of educational intervention	More than half belief PG is important components for practice, knowledge increase at post intervention but with low retention.	Further educational programs with more focuses on competency. Larger investigation.	U.S.A
2014	Bannur Z. *et. al.*,	CrS, SCQ	PPS of Pharmacists	N=324 (33.5%)	Attitudes, knowledge, adoption and education of PG	Lack of PG knowledge, low adoption & prior education, but positive attitudes & high interest to learn PG	Adequate knowledge and positive attitudes toward PG should be installed among pharmacists	Malaysia
2014	Filiptsova OV *et. al.*,	CrS, SCQ	No sampling method of Future Pharmacist	N=637 (87%)	Understanding and awareness of PG	Limited understanding and lack of awareness about PG	Educating provider and administrator Dedicate resources to PG	Ukraine

CrS=Cross-sectional; SCQ=self-completed Questionnaire; PPS= Purposeful sample; RS= Random sample; ConvS =Convenient Sampling; CnS =Census sampling; ChS=Cohort study.

Attitude-Education

From our systematic review, it has been demonstrated that a strong agreement among pharmacists for the high interest to have more training on PG.

Pharmacists Knowledge of PG

Review of pharmacogenomic knowledge among pharmacists principally included measures for 'perceived', as opposed to 'actual' knowledge.

Perceived Knowledge

It is obvious that pharmacists have not met the pharmacogenomic expectations on them. From this review, all thirteen included articles have assessed some aspect of pharmacists knowledge concerning PG. Here the assessment of perceived knowledge was based on self- reported knowledge, experiences, awareness, have had any formal training on PG. Among the included articles, 7 studies conducted in the USA revealed similar limited knowledge among U.S. pharmacists regardless of the reported high awareness and interest on PG, but with little improvement in knowledge across the years under review; In one conducted study, 14.2% and 25% felt confident to interpret test and with their knowledge concerning PG respectively,[17] 39% felt confident with pharmacogenetic test,[16] 40% felt adequately informed but only 1% have ever discussed PG with patients.[19] Recently in US, there was little improvement in the reported perceived PG knowledge among pharmacists; majority have confident on their PG knowledge and 83% were exposed to basic PG;[15] 19-53% felt comfortably understand and 83% fairly understand PG, but 47% have no any formal PG education.[18,19] Two studies from USA that used educational intervention have successfully improved knowledge level of pharmacists regarding PG.[21,26] Similar limited PG knowledge was revealed from study conducted in Canada where 7.7% of pharmacists felt confident with their PG knowledge.[23] In one study from Nigeria revealed that majority of participants have no any formal training on PG, but high awareness about PG was reported;[22] more than half of Malaysian pharmacist perceived fair knowledge, were exposed to and 85% were aware of PG PG,[12] this is in contrary to earlier findings form British pharmacists that only 6% felt confident with PG and 79% have not had formal training on PG;[9] another contrasting results were reported from recent research conducted among Ukrainian future pharmacist where only 1/3 demonstrated understanding of PG and more than 70% were not aware of PG testing.[25]

Actual Knowledge

Seven studies in U.S assessed some aspect of pharmacists actual knowledge of pharmacogenetic testing. Overall, pharmacists pharmacogenetic knowledge test scores were poor to average in US, with range from 25.8 to 89%.[15–19,21,26] However, only two studies used statistically validated instrument for data collections.[18,21] Furthermore, only one research that used random sampling method in getting the participants,[15] while the rest US studies used either convenient, purposeful sampling or census sampling in getting the sample from the population.[16–19,21,26] Two US researches provided participated pharmacists with pharmacogenomic educational intervention with subsequent knowledge assessment and the interventions were found to be effective with low knowledge-retention capacity.[21,26] In UK only 6% were well informed about PG and 79% have had no any forms of PG training,[9] this is in agreement with findings from Canadian and Australian pharmacists;[23,24] also similar to Nigeria.[22] Furthermore, with regard to formal training on PG; all of the studies from US revealed that pharmacists were exposed to some level of pharmacogenomic training ranging from 21% to 100%;[15–19,21,26] In one UK studies, only 6% were well informed about PG and 79% have had no any forms of PG training,[9] which is in agreement with results from Canadian and Australian pharmacists;[23,24] In another study from Nigeria majority of pharmacists were not exposed to formal PG training despite the high awareness,[22] In Ukraine, up to more than 70% of future pharmacists were not exposed to any forms of training on PG.[25] In contrast, one study from Malaysia revealed more than average in actual knowledge and 85% were exposed to some forms of PG.[12] Irrespective of whether measures was for 'perceived' or 'actual' knowledge, reviewed data clearly indicates lack of knowledge on pharmacogenetic among pharmacists.

Pharmacists Practice Regarding PG

The major parameters that explain PG practice behaviors among pharmacists from the reviewed studies include: recommending pharmacogenetic tests, source of pharmacogenetic-based drug information and used of literature sources by pharmacists.

Providing Pharmacogenetic Based Drug Information

PG practice is low among pharmacists across the countries. Studies conducted in U.SA, revealed low level of practice among pharmacists. In one of these studies, 4% were reported to disseminate PG information comfortably despite 76.1% agree that it's their primary role to do so, in same research 57% agree PG is their professional obligation but only 1% have ever discussed PG with patients;[19] only 18% felt excellently confident to inform other on PG in spite of 90% pharmacists have high interest to PG;[18] in another similar finding 25.8% applied PG but still 73.9% agree that application is very important.[17] Similarly in Australia, only 1-24.3% felt confidently can counsel and inform others on PG despite 79% show strong interest to PG,[24] this is in accordance with finding from UK pharmacists,[9] Nigeria[22] and Ukraine.[25] In contrast, 61.7% and 79.3% of Malaysian Pharmacists reported to considered pharmacists as their source of PG-based drug information.[12]

Recommending Pharmacogenetic Tests

Pharmacists can serve many roles when it comes to the drug-related matters. Based on this review, it was revealed that the level of recommendation of PG has been very low ranging from 1%-33%, with Malaysia taking the highest, but in terms of future recommendation of PG all the articles reported more that 70% willing to recommend.[9,12,15–19,21–26]

The Used of Literature Sources by Pharmacists

From our literature reviewed, the most commonly cited courses of pharmacogenomic information among pharmacists includes; from US, Continues education/ certificate 42%,[15,16,26] preferred lectures-64%;[17] web-based continues education(CE) course -51%, Continues Mandatory education(CME/CE course-55% Area Health Education Center(AHEC)-40%, half-day conference-28%, all-day conference-15%, and ward round-9%.[18] In Canada, 96.6% preferred to undertake continues education,[23] while in Australia, the cited options for their pharmacogenomic education includes; undergraduate 66.7%, workshop and seminar 79%, during internship-13.1% and by internet 37.8%.[24] Another study from Malaysia also revealed, drug label 59.3%, internet-79.3%, genetic laboratories-56.8%,[12] similarly in Nigeria internet was cited as the most commonly used source of PG information.[22]

Barriers towards Adoption of PG by Pharmacists

Several factors that influence adoption of PG were identified from the reviewed studies. All reviewed articles, cited limited knowledge as a barrier to adoption of PG in to routine practice. Other cited barriers towards practice of PG among pharmacists include; discrimination/privacy issues,[12,19,22,24] Cost/insurance coverage,[12,22] and lack of clinical guideline/ clinical evidences.[24] Generally, there is no observed significant variation between countries concerning barriers to adoption of PG by pharmacists, but developing countries put more concerns on funding and cost coverage.[12,22]

DISCUSSION

Pharmacists have long been considered as the medication experts among the healthcare providers. It has gone beyond doubt that PG is evolving into a more sophisticated essential tool to ensure optimal pharmacotherapy in a growing area of clinical practice. Therefore, it is vital that pharmacists are prepared to appropriately use pharmacogenetic information towards individualized medication therapy for appropriate patients currently and beyond. The pharmacist serves many roles in the implementation of PG in the healthcare setting.[18,27]

This article evaluated pharmacists attitudes, knowledge and practice exposes their limited knowledge concerning PG and pharmacogenetic testing. In general, there are little regular patterns in the assessed parameters the countries and across the years from 2004 to Sept, 2014. This marked limited knowledge of PG among pharmacists is almost the same across the seven countries, with that of US showing progression of knowledge from 38% in 2005, 89% in 2010, 83% in 2012, 56% and 53% in 2013, with the average perceived and actual knowledge of more than 50%. Furthermore, only one survey that involved more than four different specialists pharmacists, this may limit generalization of our findings. From the included articles, most of them were conducted in USA and only one research each from UK, Australia, Malaysia, Nigeria, Ukraine and Canada respectively, but it still gives representation of all the important continents like; Americas, Europe, Asia, Africa and Australia. This skewed distribution of the included researches may be related to restriction to only articles published in English, and there might be some relevant articles that were published in other languages. Two studies that provided PG knowledge intervention revealed the effectiveness of the intervention but with low knowledge retention capacity in one of them.[21,26] This low retention may be attributed to complexity nature of PG or the medium used in delivering the intervention. The high desired for and interest to PG education was also revealed among pharmacists, and this can be related to the promising roles of PG towards individualized medicine. For attitudes, according our findings, pharmacists have good attitude towards PG, regardless of the reported knowledge gap of PG. This was revealed by strong interest to recommend PG in the future and also to get more pharmacogenomic education. This good attitude among pharmacists is almost same across the six countries irrespective of economic and technological status of the countries, and it can be attributed to the expected benefits from PG through individualize medicine. The attitude-ethical and or discrimination concern towards pharmacogenetic testing among pharmacists is alarming barrier towards adoption of PG into clinical practice. The practice of PG among pharmacists was analyzed by using three key determinants; recommending pharmacogenetic tests by pharmacists, providing pharmacogenetic-based drug information, and the used of literature sources by pharmacists. Based on these determinants, the practical application of PG among pharmacists was very low. For example in one US research, it was reported that only 1% of pharmacists have ever discussed PG with patients despite the reported high interest towards PG among same population.[19] And the possible explanation to this is limited knowledge on the PG and confident. Interestingly, one most recent study was conducted among future pharmacists, therefore by widening the emphasis to include future health professionals, the reported lack of pharmacogenomic knowledge from school would become history, and this is very important, in order to evaluate their readiness towards unfolding pharmacogenomic based challenges.

Some barriers to application of PG in to practice were reported in this review, which include among others; ethical, discrimination, limited knowledge on PG, cost, insurance coverage, privacy, lack of clinical guidelines, lack of clinical evidences, approval by regulatory bodies. This is in agreement to similar review done on medical-doctor.[26] Another observation is that, only two researches used random sampling for recruiting the participants, and this may seriously affects the results because of possible biases from the researchers. Furthermore, only three articles that reported the statistical validation of the instruments used, therefore the validity and reliability of the remaining researches are remained questionable as well as their findings. Furthermore, more than half of the studies evaluated have response rate of less than 60% for pharmacists,[12,15,16,18,19,23,24] which may limits the generalizability of the results.

Limitations of the Review

The major drawback of this review is that open access journals were the major sources of the literature reviewed. Therefore this review may not represent the complete selectable articles within the time under review. In addition only survey findings published in English language were included, which might have narrowed the number of relevant articles to be included and could subsequently affects the generalization to our findings. Of note, the included articles were not critically scrutinized for quality standardization, this was considered acceptable since each study integrated some aspect of review and or pilot and or validation of the instruments used in the methodology discussion. However, the assumption made may not be

reliable representation of what U.S., Nigeria, Malaysia, Canada, Australia, and Ukraine pharmacists know, perceive and practice with respect to PG as a distinctive category. The skewed distribution of the studies also reduced the ability of the review to digest key trends. Although most of studies were from US, but were conducted in different parts of US and at different points in time, therefore this may also make it difficult to point out definite patterns. Only one study each done from other involved countries. In addition, surveys differed in the design of the response scales, including the wording of the items and the medium utilized for the research also can affect our findings.

CONCLUSION

It can be deduced from current literature review that there is limited knowledge of PG and low level of practice despite the good attitudes towards PG among pharmacists. Therefore, there is an urgent call for additional training in the area of PG and also to incorporate PG into curriculum of pharmacy schools. Pharmacists and future pharmacists should be trained on how to critically evaluate the use, efficacy, and safety of common pharmacogenetic testing, and also how to ethically and professionally interact and relate with patients and other healthcare professionals in order to mitigate ethical, privacy and other issues associated with common Pharmacogenetic testing. Furthermore, stakeholders should come together and focus on assuaging those cited barriers toward adoption of pharmacogenetic in to general practice. Conclusively, this review will be decisive to policy makers in educational and healthcare systems towards an excellent professionalism.

ACKNOWLEDGEMENT

Authors are much grateful to the authority Universiti Sultan Zainal Abidin. No fund was obtained to conduct this study.

CONFLICT OF INTEREST

The authors possess no conflict of interest.

Highlights of Paper

- Out 13 included articles 11 of the articles reported on practice, recommendation and or adoption of pharmacogenomics among pharmacists.
- Knowledge and practice regarding pharmacogenetics among pharmacists were poor despite revealed good attitudes.
- There has been an advancement in average knowledge score from 38% in 2005 to more than 50% in 2014 in some countries.
- Ethical concerns, discrimination, limited knowledge on pharmacogenetics, cost, insurance coverage, privacy, lack of clinical guidelines, lack of clinical evidences, approval by regulatory bodies were reported as barriers to application of pharmacogenomics in to practice.

Author Profile

- Yau Adamu, is a Graduate student of Unit of Pharmacology, Faculty of Medicine, Universiti Sultan Zainal Abidin, Kuala Terengganu, Malaysia. Adamu is an Assistant Lecturer Faculty of Pharmaceutical Sciences, Bayero University Kano, Nigeria. His research interest is in the areas of maximizing drug safety and efficacy though clinical research, cigarette smoking, drug addiction, pharmacovigilance, public health pharmacogenomics, clinical Pharmacogenomics and individualized medicine. In addition, He has clinical and hospital pharmacy experience and pharmaceutical care including pediatrics.

REFERENCES

1. Spear BB, Heath-Chiozzi M, Huff J. Clinical application of pharmacogenetics. Trends Mol Med. 2001; 7(5): 201-4.
2. Davies EC, Green CF, Mottram DR, Pirmohamed M. Adverse drug reactions in hospitals: a narrative review. Curr Drug Saf. 2007; 2(1): 79-87.
3. Wiffen P, Gill M, Edwards J, Moore A. Adverse drug reactions in hospital patients A systematic review of the prospective and retrospective studies. Bandolier Extra. 2002; (June) 101(4): 1-15.
4. Merriam-Webster Dictoinary. An Encyclopedia Britannica Company. Available form http://www.merriam-webster.com/dictionary/pharmacogenomics
5. Goldstein DB, Need AC, Singh R, Sisodiya SM. Potential Genetic Causes of Heterogeneity of Treatment Effects. Am J Med. 2007;120(4 SUPPL.).
6. Garrod Archibald E. The Incidence of Alkaptonuria: Astudy in Chemical Individuality. Lancet. 1902; 2(3): 1616-20.
7. Shah A. Pharmacy Intervention in the Medication - Use Process the Role of Pharmacists in Improving Patient Safety. International Pharmaceutical Federation (FIP), Den Haag, Netherlands 2009. Available from https://www.fip.org/files/fip/Patient%20Safety/PatientSafetyAdvidShah.pdf
8. Kennedy MJ, Phan H, Benavides S, Potts A, Sorensen S. The role of the pediatric pharmacist in personalized medicine and clinical pharmacogenomics for children: pediatric pharmacogenomics working group. J Pediatr Pharmacol Ther. 2011;16(2): 118-122.
9. Newton R, Lithgow J, Li A, Po W, Bennett C, Farndon P. How will pharmacogenetics impact on pharmacy practice ? Pharmacists views and educational priorities impact on pharmacy practice ? Pharmacists ' views and educational priorities Contents. 2007; (November)
10. Ginsburg GS, Willard HF. Genomic and personalized medicine: foundations and applications. Transl Res. 2009; 154(6): 277-87.

11. Gage BF, Lesko LJ. Pharmacogenetics of warfarin: Regulatory, scientific, and clinical issues. J Thromb Thrombolysis. 2008; 25(1): 45-51.
12. Bannur Z, S B, MZ S, LKT. Pharmacogenomics Based Practice in Malaysia : The Attitude , Knowledge and Adoption by the Healthcare Demographics of Respondents. IMJM. 2014; 13(1): 41-50.
13. Bakhouche H, Slanař O. Pharmacogenetics in clinical practice. Prague Med Rep. 2012; 113(4): 251-61.
14. Brockmöller J, Tzvetkov M V. Pharmacogenetics: Data, concepts and tools to improve drug discovery and drug treatment. Eur J Clin Pharmacol. 2008; 64(2): 133-57.
15. Benzeroual KE, Shah B, Shinde S. Pharmacogenomics: assessing educational exposure, confidence in knowledge and training elements of pharmacists. *Per Med*. 2012;9(4):387-393.
16. Latif D, McKay AB. Pharmacogenetics and Pharmacogenomics Instruction in Colleges and Schools of Pharmacy in the United States. Am J Pharm Educ. 2005; 69(2): 23.
17. Mccullough KB, Formea CM, Berg KD, *et al*. Assessment of the pharmacogenomics educational needs of pharmacists. Am J Pharm Educ. 2011; 75(3): 1-6.
18. Roederer MW, Van Riper M, Valgus J, Knafl G, McLeod H. Knowledge, attitudes and education of pharmacists regarding pharmacogenetic testing. Per Med. 2012; 9(1): 19-27.
19. Tuteja S, Haynes K, Zayac C, Sprague JE, Bernhardt B, Pyeritz R. Community pharmacists attitudes towards clinical utility and ethical implications of pharmacogenetic testing. Per Med. 2013;10(8): 793-800.
20. Powell KP, Cogswell W, Christianson C, *et al*. Primary care physicians' awareness, experience and opinions of direct-to-consumer genetic testing. J Genet Couns. 2012; 21(1): 113-16. Formea CM, Nicholson WT, McCullough KB, *et al*. Development and evaluation of a pharmacogenomics educational program for pharmacists. Am J Pharm Educ. 2013; 77(1): 10.
21. Parvaz Madadi, Ehijie FO, Enato EOB. Perceptions of health care professionals towards pharmacogenomics in Nigeria: Preliminary Results. West African J Pharm. 2011; 22(2): 97-101.
22. De Denus S, Letarte N, Hurlimann T, *et al.* An evaluation of pharmacists expectations towards pharmacogenomics. Pharmacogenomics. 2013; 14(2): 165-75.
23. McMahon T, Tucci J. The perceptions of pharmacists in Victoria, Australia on pharmacogenetics and its implications. Pharm Pract (Granada) 2011; 9(3): 141-7.
24. Filiptsova OV, Kobets MN, Kobets YN. Some aspects of genetics and pharmacogenetics understanding by pharmacy students in Ukraine. Egypt J Med Hum Genet. 2014.
25. Zembles T. An inservice program on pharmacogenetics to individualize drug therapy. Am J Pharm Educ. 2010; 74(1): 10.
26. Murphy JE, Green JS, Adams LA, Squire RB, Kuo GM, Mckay A. Pharmacogenomics in the curricula of colleges and schools of pharmacy in the United States. Am J Pharm Educ. 2010; 74(1): 7.