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REVIEW

Interprofessional approach in pharmacogenomics: A systematic review

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Abstract

Background: The expansion of pharmacogenomics for individualised therapy is slow. A multidisciplinary approach is critical for pharmacogenomics to achieve its full potential for optimising patient care. This systematic review aimed to determine the barriers, procedures, and benefits of using an interprofessional approach in the education and clinical practice of pharmacogenomics. **Methods** This systematic review was conducted using PubMed, Scopus, and ScienceDirect databases. A PRISMA flowchart was used to conduct the systematic review. **Results:** Seventeen of 236 manuscripts were included. The data were categorised into four major themes: interprofessional approaches, procedures, barriers, and benefits. Eight studies were on interprofessional education (IPE), and the rest were on interprofessional collaboration (IPC). The essential procedure addressed education, resources, and multidisciplinary clinical practice in patient selection/counselling, pharmacogenomic testing, and decision-making and implementation. Eleven barriers and four benefits were identified for IPE and IPC. **Conclusions:** Barriers were identified in IPE (knowledge/skills, confidence, time, finance, and geographical problem), IPC (resources, communication, and ambiguity about pharmacogenomic services), and IPE/IPC (stereotypes of other professions). Essential collaborative procedures include educational strategies with interprofessional approaches, support systems, and implementation of clinical practices. The benefits of IPE and IPC include improved communication/interaction, knowledge/skills, and therapeutic outcomes. IPE also increased students' confidence.

Introduction

Pharmacogenomics is an essential component of personalised medicine. Drug effectiveness and toxicity are influenced by pharmacokinetics and pharmacodynamics. This can result in medication-related problems (including adverse drug reactions or therapeutic failure) as genotype plays a major role in determining inter-individual differences that affect these therapeutic contexts. Pharmacogenetics has gained importance in clinical practice (Barbarino *et al.*, 2018; Hlaváč *et al.*, 2020). The United States Food and Drug Administration has released pharmacogenomics information on more than 140 drug labels (Drozda *et al.*, 2018; Yehya & Matalgah, 2021).

Medication-related problems and the complexity of pharmacogenomic services can be resolved through multidisciplinary teamwork (Karpa *et al.*, 2018; Swart *et al.*, 2019). Compared with usual care, interprofessional intervention reduces the risk of drug-related adverse events and the use of potentially inappropriate medications (Auvinen *et al.*, 2021; Stäuble *et al.*, 2021). Pharmacogenomic services significantly reduced medication side effects by approximately 30% (Swen *et al.*, 2023; Van Heukelom *et al.*, 2023).

Despite the development of public knowledge regarding the benefits of pharmacogenomic testing, its adoption in education curricula and the growing use of pharmacogenomics in clinical practices were slow (Calinski *et al.*, 2021; Yehya & Matalgah, 2021; Kabbani *et al.*, 2023; Van Heukelom *et al.*, 2023). Multiple aspects must be considered in the development and implementation of pharmacogenomics (Mroz *et al*., 2021). This systematic review aimed to determine the barriers, procedures, and benefits of using an interprofessional approach in the education and clinical practice of pharmacogenomics.

Methods

Two researchers independently reviewed this study. When there was disagreement between the two researchers, a third researcher was consulted to obtain the final version.

A PRISMA flowchart of the preferred reporting Items for Systematic Reviews and Meta-Analyses (Page *et al*., 2021) was used to conduct the systematic review. The authors searched three databases (Scopus, PubMed, and Science Direct) for relevant papers using Medical Subject Headings (MeSH) terms ((pharmacogenetics [MeSH Terms]), OR (pharmacogenomics [MeSH Terms]), AND (interprofessional relations [MeSH Terms]), and keywords (interprofessional AND pharmacogenomic). Original research with all study designs /institution experience written in English and manuscripts regarding interprofessional and pharmacogenomics/pharmacogenetics were included in this systematic review. Duplication and inaccessibility to the full text were excluded. Descriptive and thematic analyses were conducted for this systematic review. The data was systematically categorised to identify the main issues associated with interprofessional relations in pharmacogenomics.

Results

Seventeen of 236 articles were selected for this systematic review (Figure 1). The descriptive analysis was structured into the following topics: year of publication, study location, and main findings of the papers. Thematic analysis was carried out to gain an in-depth comprehension of the published works on the topic of the interprofessional approach in pharmacogenomics. The included articles were categorised using a deductive method. The themes were as follows: (1) interprofessional approach; (2) barriers; (3) benefits; and (4) procedures for IPC or IPE in pharmacogenomics.

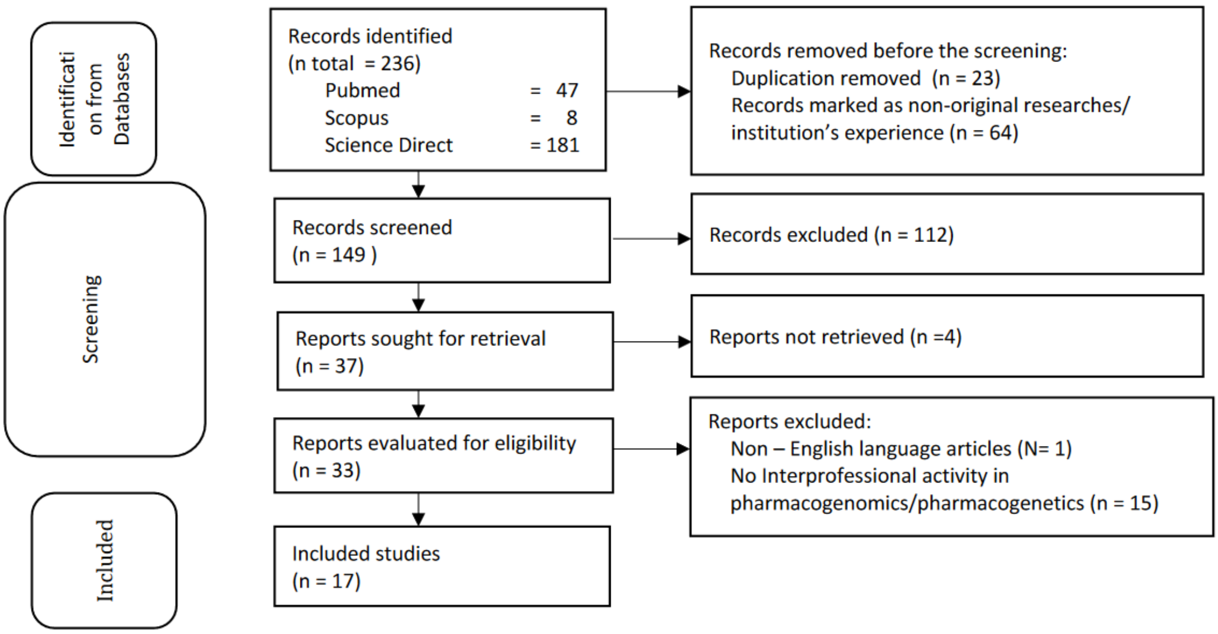

Figure 1: Prisma flowchart

The contributions of the included studies to these themes are summarised in Tables I-II and Figure 2. In 17 of the included studies, IPC and IPE were described in nine and eight studies, respectively (Table I). Table II presents the barriers and benefits of both interprofessional approaches. Figure 2 summarises the findings of interprofessional approaches for pharmacogenomics in educational and clinical settings.

Table I: Characteristics of included study

(Study), country	Study objectives associated with Interprofessional	Team members	The procedure of interprofessional activity*
Interprofessional collaboration (IPC)			
(Empey *et al.*, 2018) USA	To compare the implementation of two years of experience in PGx testing for antiplatelet medication (in 12 institutions with 6340 patients)	Geneticists/ pathologists, pharmacists, physicians (in primary care, cardiology)	Preparation / System by providing - **E**: Education Strategy - **S**: Lab section in EHR for PGx result and CDS alert Application on PGx service - **PS**: CDS alert - **PGx-T**: PGx testing (platform choice to get the PGx result) - **Post-C:** Communication for PGx result - **PGx- I:** Implementation Antiplatelet (P2Y12 inhibitor) ● clopidogrel for normal, rapid, and ultra-rapid metaboliser (CYP2C19*1/*1, *1/*17, and *17/*17 genotypes, respectively). ● alternative therapy (prasugrel or ticagrelor) for intermediate and poor metabolisers;
(Johnson *et al.*, 2017) USA	To determine the feasibility of pharmacist-led genotype-guided recommendations for cardiologists in outpatient practice (with 43 patients)	Pharmacists, physicians/cardiologists (in cardiology)	Application on PGx service - **PS**: □ EHR to determine patient eligibility (pharmacist) - **Pre-C with IP-D**□Patient recruitment (discussion (pharmacist, cardiologist, and patient about the implication of clinical PGx) and informed consent) - **PGx T**: buccal swab - **PGX-R**: PGx results were stored in EHR □ Pharmacists interpreted the results and gave recommendations □ Cardiologist response. PGx recommendation for antiplatelet (P2Y12 inhibitor): ● CYP2C19*1/*17 (rapid metaboliser): clopidogrel 75 mg daily with increased monitoring for bleeding. ● CYP2C19*1/*1 (normal metaboliser): clopidogrel 75 mg daily. ● CYP2C19*1/*2 genotype (intermediate metaboliser): ticagrelor 90 mg twice daily ● For a combination of one loss-of-function allele (*2) and one increased-function allele: an alternative to clopidogrel
(Rendell *et al.*, 2022) UK	To determine barriers and enablers of PGx services in the community (26 participants)	Pharmacists, physicians	Focus Group Discussion
(Smith *et al.*, 2018) USA	To identify the effects of IP training on clinical and system outcome (38 groups (faculty staff, trainee)	Physicians, nurses, pharmacists, and psychologists	Preparation: **E:** Steps to provide crosswalk-professional competency-based assessment instruments: - Review of the competency documents, - Iterative creation: a. To make a crosswalk of the four professional competency documents (include: Knowledge, Approach to Practice, Communication, Professional Expectations, Continuous Professional Development, Functioning in a Health Care System, and Advocacy/ Improvement) b. To create interprofessional clinic assessment tools (focused on team-patient engagement) c. To generate validation
(Stäuble *et al.*, 2022) Switzerland	- To design a pharmacist-led PGx service in interprofessional relations (based on 142 patient cases)	Pharmacists, physicians (in cardiology, physiatry)	Preparation: - **S:** providing PGx platform and procedure Application on PGx service - Refining steps of PGX service by conducting a case series observational study in 152 patients - **PS, IP-D**: patient referral (Physician-pharmacist), - **Pre-C**: pre-test counselling (physician); - **PG -Tx**: Test in PGx laboratory (CYP2D6 testing); - **PGx-R with IP-D**: Pharmacists delivered pharmacogenetic information to support a rational basis for shared decision-making together with physicians and patients; - **Post -C with IP-D:** pharmacists- physicians- patients;

(Study), country	Study objectives associated with Interprofessional	Team members	The procedure of interprofessional activity*
			- **PGx-I with IP-D**: pharmacists – physicians
(Stäuble *et al.*, 2021) Switzerland	- To select antidepressants based on individualised PGx data (1 patient case)	Pharmacists, physicians/ psychiatrists (in psychiatry)	Application: - **PS**: Medication review to select patients by identifying the history of therapeutic failure and adverse drug reaction - **PGx -T**: genotyping with buccal swab sample - **PGx-R include IP-D**: for clinical decisions making. Vortioxetine was recommended for genotyping result of CYP2C19 (*17 /*17), CYP2D6 and CYP2B6 (*1 /*1), CYP1A2 (*1F/*1F), ABCB1 rs2032583(T/T), and HTR2A rs7997012 (C/C). Effect on Escitalopram: CYP2C19 (*17 /*17) and CYP1A2(*1F/*1F together with the smoking habit increased the risk of therapeutic failure; HTR2A rs7997012: decreased therapeutic response, and ABCB1 influenced the drug transport - **PGx-I:** Follow-up and monitoring
(Swart *et al.*, 2019) USA	- To establish/validate genotype-guided therapy for oncology (with 189 DNA samples)	Interprofessional teams in molecular tumour board (in oncology)	Preparation - **E**: A literature review on oncology PGx to select relevant genetic variants associated with treatment efficacy or toxicity: Ondansetron (ABCB1), Anthracycline (CBR3, HAS3, SLC28A3), Cisplatin (COMT, TMPT, SLC16A5), CYP3A substrates (CYP3A7), Irinotecan (C8ORF34, SEMA3C), Trastuzumab, rituximab (FCGR2A, FCGR3A), Gemcitabine (NT5C2), Mercaptopurine, thioguanine (NUDT15), (Taxane, SBF2), Asparaginase, (SOD2), Methotrexate (TLR4) Application - **PGx-T**: Obtaining DNA samples for PGx testing, designing primers, and providing real-time PCR (TaqMan) reagent PCR process Sanger Sequencing. **PGx-R with IP-D**: Interpretation and implementation of test results through molecular board discussion forums.
(Weinstein *et al.*, 2020) USA	- To explore pharmacist and physician perspectives on a pharmacist-run PGx service in primary care practices (21 participants)	Pharmacists, physicians (in Allergy/ immunology dermatology, gastroenterology, haematology/oncolog y rheumatology, internal medicine, neurology, pulmonology)	Based on the interview with pharmacists and physicians who have experience working in IP teams for 15.6 years and 13.6 years, respectively: - **E**: Prior to implementing, PGx service, education/training may be needed - **PS, Pre-C with IP-D**: PGx service was started with physician-patient interaction, and followed by a team-based approach with open-line communication - **PGx-T**: PGx test. - **PGx-R: with IP-D approach**: Trained pharmacists (who had collaborative with physicians), interpreted PGx test results and selected an appropriate therapy - **PGx-I with IP-D approach**: Patient monitoring/follow-up
(Weitzel *et al.*, 2018) USA;	- To develop of *TPMT genotyping* testing service - To compare genotyping and phenotyping of TMPT services in multidisciplinary populations. (834 patients)	Pharmacist, clinical staff/ prescribers, and nurses	Preparation **(S):** Identifying clinical services that ordered thiopurine S-methyltransferase (*TPMT)* testing (: IP team determines the procedure for PGx and therapeutic recommendation for CDS that was built on the system; and pathologist developed and validated the genotyping method). The PGx recommendation was provided for TPMP with normal metaboliser (no alert), intermediate metaboliser (malignancy: refer to the protocol for 6-MP and TG; and for non-malignancy: reduced dose by 30-70% (for 6 Azathioprine and 6-mercaptopurine) and by 30-50% (for thioguanine)), and poor metaboliser (for malignancy: refer to protocol (for 6-MP and TG) and use alternative agents (Azathioprine); and for non-malignancy: use alternative agents (6-mercaptopurine and thioguanine) and reduce dose ten fold and frequency to thrice weekly (Azathioprine)) Application on PGx service **PS:** Application CDS (Steps: firing advisory alert on the system CDS alert-fired pharmacogenetic staff/resident was notified

(Study), country	Study objectives associated with Interprofessional	Team members	The procedure of interprofessional activity*
			by the contact prescriber for the order **PGx-T** and clinical implementation **PGx-R and PGx- I with IP-D approach**
Interprofessional Education (IPE)			
(Formea *et al.*, 2015) USA	To describe the approach to multidisciplinary pharmacogenomics education strategy at Mayo Clinic, The goal of IPE was to create collaborative teams that provide patient-centred care. (500 students	Pharmacy and medical students (in oncology)	Preparation: **(S)**to provide - A facility for the centre of individualised medicine was provided for multidisciplinary teams to work together to make clinical practice decisions, support algorithms, and education. - the system to support PGx education and service (i.e.: electronic PGx alert as point-of-care education, EHR, trackability lifetime PGx result) - a multidisciplinary role in PGx service (CYP2D6 (**1/*4) testing* for tamoxifen): a) physicians: evaluating genetic risks, ordering genetic testing, and prescribing medicine based on PGx results); b) pharmacists: Providing PGx testing support and guidance to prescribers, interpreting PGx results, and evaluating PGx therapeutic results. **E: Theory:** Module (through lectures, courses, grand rounds, journal clubs, and conferences) **E: Practice:** - Problem-based learning: face-to-face case-based session - Clinical experience (delivery into the daily workflow at the clinic). Pharmacogenomic education from healthcare providers was provided at the time of prescribing medications at the point of care.
(Calinski *et al.*, 2021) USA	To educate students about PGx, and to demonstrate the interprofessional responsibilities in PGx implementation (164 students)	Pharmacy and medical students	**E: Practice** - Problem-Based learning: Small IPE group (consisting of 2-3 students) to resolve patient cases, - PGx test for CYP2C19*2 - Role: Based on the patients' PGx profiles, medical students wrote prescriptions for altered drug therapy, and pharmacy students provided feedback to medical students on the prescriptions.
(Karpa *et al.*, 2018) USA	To strengthen students' medication management skills (23 students)	Pharmacy, medical, and nursing students (in cardiology, nephrology, oncology)	Pharmacology curricular theme: (1) medication optimisation, (2) medication communication with patients, (3) medication dosing, (4) pharmacokinetics and medication selection in a special population: pharmacogenetic, pharmacodynamic, and geriatric; and (5) Medication Monitoring and Intensification. **E: Theory**: Pre-works instruction (to deepen the understanding of the topic): reading module/ handbook, completing tech back module, and viewing the video **E: Practice:** Problem-Based Learning: Conducting activity based on an instructional methodology to complete the topic course (including medication reconciliation activity, patient communication–counselling, applying pharmacokinetics, identifying medication for special population cases, and patient monitoring. Evaluation process (pre-, mid-, and post-test).
(Haidar *et al.*, 2017) USA;	To describe the first accredited post-graduate clinical pharmacogenetics residency program's design, implementation, and ongoing evaluation to develop professionalism and leadership (7 residents)	an interdisciplinary team	**E: Practice:** - Clinical experience: Hands-on experience in PGx service - Leadership skill: Opportunity to lead a meeting for case discussion and be involved in follow-up actions. (12 months-residency program at St. Jude Children's Research Hospital)
(Perwitasari *et al.*, 2023) Indonesia	- To explore students' perception of IPE (pre and post-IPE activities) in PGx (in 205 students)	Pharmacy and nursing students.	IPE activities were supervised by a facilitator (: lecturer who has qualifications in training to work as an IPE facilitator) **E: Theory:** Lecture about IPE **E: Practice** – Problem-Based Learning IPE activities: (1) Pre-Test; (2) PGx problem-based learning on physiatry disorder, (3) Delivering problem solution in 100 minutes; (4) Post-test
(Quesnelle *et al.*, 2018) USA	- To design IPE for institutional collaboration	Pharmacy and medical students	- To overcome the geographic and financial constraints, telehealth-based learning was chosen

(Study), country	Study objectives associated with Interprofessional	Team members	The procedure of interprofessional activity*
	- to student attitudes toward interprofessional collaboration and PGx confidence (96 students).	(in pulmonology)	- **E: Practice:** The Telehealth learning activity (moderated by pharmacists, pharmacologists, haematologists, and medical ethicists) designed for two hours- exercise: (a) large group for multidiscipline (96 students), (b) class discussion for each discipline, (c) small group (consisting eight students from medical and pharmacy) to plan clinical diagnosis, drug therapy, and PGx analysis Pre- and post-survey were administered to evaluate IPE-Telehealth-based learning.
(Ward *et al.*, 2021) USA	- to create and assess a psychiatric PGx online continuing education program for medical professionals (32 students)		**E: Theory and Practice**: At blend of lecture and interactive Problem-Based Learning. The psychiatric PGx course curriculum includes basic background knowledge, exam selection, interpretation, and application of the results.
(Yehya & Matalgah, 2021) Jordan	- to determine knowledge among genetics and pharmacology healthcare students - to assess their exposure to and perceptions of pharmacogenomic (300 students)	Pharmacy and medical students (in cardiology)	**E: Theory:** PGx topic was limited (only presented as a sub-topic in the introduction to pharmacology chapter) □ CYP2C9 testing for warfarin treatments

CDS = clinical decision support; IPC = interprofessional collaboration; IPE = Interprofessional Education; PGx = Pharmacogenomics; (*)Procedure associated with IPC activity with major themes in the following order: E (education), S (system support for PGx service), PS (patient selection from patient referral, medication review to identify eligible patients, and/or system alert), Pre-C (pre-concealing for patient engagement), PGx-T (PGx- testing), PGx-R (PGx-Results: result interpretation and select therapeutic management), Post-C (counselling post-PGx test result), PGx -I (PGx implementation, include patient monitoring/ follow-up), and IP-D = (Interprofessional discussion and work/responsibilities shared among interprofessional team members).

Table II: Barriers and benefits

Interprofessional approach	(Study), country	Barriers/challenges**									Benefits*			
		C1	C2	C3	C4	C5	C6	C7	C8	C9	B1	B2	B3	B4
Interprofessional collaboration	(Empey *et al.*, 2018) USA							V	V	V			V	V
	(Johnson *et al.*, 2017) USA								V				V	V
	(Rendell *et al.*, 2022) UK						V	V	V	V				V
	(Smith *et al.*, 2018) USA											V	V	
	(Stäuble *et al.*, 2022) Switzerland							V		V		V	V	V
	(Stäuble *et al.*, 2021) Switzerland													V
	(Swart *et al.*, 2019) USA													V
	(Weinstein *et al.*, 2020) USA													V
	(Weitzel *et al.*, 2018) USA							V		V				V
Interprofessional education	(Formea *et al.*, 2015) USA	V										V	V	
	(Calinski *et al.*, 2021) USA	V									V	V	V	
	(Karpa *et al.*, 2018) USA					V							V	
	(Haidar *et al.*, 2017) USA											V		
	(Perwitasari *et al.*, 2023) Indonesia	V	V				V				V		V	
	(Quesnelle *et al.*, 2018) USA			V	V						V		V	
	(Ward *et al.*, 2021) USA	V			V						V	V		
	(Yehya & Matalgah, 2021) Jordan	V												V

(*)Benefits associated with interprofessional activity were categorised into four major theme: **B1** (increased confidence), **B2** (improved knowledge and skill), (improved communication, established close work relationship, and increased appreciation of Interprofessional role and contributions of other health professions to patient care); and **B4** (improve therapeutic outcome); **(**)Barriers/ challenges** were classified into nine major theme: **C1** (lack of knowledge and skill); **C2** (lack of confidence); **C3** (financial constraints); **C4** (geographical constraints); **C5** (time constraints)); **C6** (negative professional stereotype), **C7** (ambiguity regarding implementation was associated with benefits, cost/insurance reimbursements, confidence, knowledge, pharmacogenomic guidance, and shared responsibilities in pharmacogenomic services); **C8** (lack of communication (among health care profession (associated with IP relation and role of profession) and between IP team – patients for patient engagement); and **C9** (limited resources include limited validated PGx method, infrastructure/ instrument, computer system support, and longer duration turnaround time to get the PGx result due to the limited instrument/facility).

Barriers / Challenges	Students	Benefits
a. Lack of knowledge and skills b. Lack of confidence c. The negative stereotype of other professions. d. Multiple geographical regions e. Time constraints f. Financial constraints	Interprofessional Education (IPE) strategies A. The theories of IPE and pharmacogenomics (PGx) can be delivered through online or offline learning B. Practice To increase knowledge and skills: ▪ Problem-based learning with pre-work instruction and instruction activity (combination of online and offline learning) ▪ Experience in clinical practice (offline) ▪ Hands-on experience in pharmacogenomic testing (offline) To increase leadership: ▪ Opportunity to lead a meeting for case discussion (online/offline) and to be involved in the monitoring and follow-up actions (offline) C. Assessment: with pre –, mid –, and post–test ↓	a. Increased knowledge and skills b. Increased confidence c. Improved communication and appreciation of Interprofessional role in patient care. d. Improved therapeutic outcome
a. Ambiguity regarding implementation is associated with benefits, cost/insurance reimbursements, confidence, knowledge, pharmacogenomic guidance, and shared responsibilities in pharmacogenomic services. b. Limited resources c. Difficulty in communication with patient d. Negative stereotype of other profession	Interprofessional Collaboration (IPC) practice for PGx services. A. Patient selection with Interprofessional (IP) approach (: clinical decision support (CDS) alert for notification/ Electronic Health Record (HER) with lifetime trackability of genetic results/medication review/ referral system) B. Pre-counselling for patient engagement with IP approach C. PGx testing (a validated platform with a short turnaround time for performing the test result based on PGx result) D. PGx test result interpretation and therapeutic recommendation (pharmacist) for shared decision-making together with physician and patients E. Post-counselling with IP approach F. PGx implementation =with IP approach includes monitoring and follow-up	a. Enhanced knowledge and skills b. Improved communication and established close working relationship c. Improved therapeutic outcome
Barriers/ Challenges	**Health Professionals**	**Benefits**

Figure 2: Map of IPE and IPC in pharmacogenomics

Discussion

A multidisciplinary approach (Tables I-II) is a basic part of pharmacogenomics to accomplish the full potential of streamlining patient care to improve therapeutic outcomes. One of the major barriers to multidisciplinary pharmacogenomic services is the unclear allocation of responsibilities (Table II, Figure 2). This review identified that shared responsibility should be cleared among team members, which was initiated by identifying the role of each profession in pharmacogenomics (Table I). The main team members in IPC were pharmacists and physicians, who worked together in preparing education and system support, selecting patients, providing treatment plans and services (monitoring and follow-up), and delivering patient counselling (Johnson et al., 2017; Empey *et al*., 2018; Smith *et al*., 2018; Weinstein et al., 2020Stäuble *et al*., 2021; Stäuble et al., 2022). Pharmacists have also interpreted pharmacogenomic results and provided therapeutic recommendations to serve as a rational basis for shared decision-making with physicians and patients (Weinstein *et al*., 2020). Other professionals who supported pharmacogenomic services were nurses (with responsibilities in supporting patient education, providing individual care, and monitoring the patient's condition), pathologists/genetic laboratories (through validated pharmacogenomic platforms), and psychologists (providing effective negotiation plans related to conflicting relationships) (Empey *et al*., 2018; Smith *et al*., 2018; Weitzel *et al*., 2018).

The essential components of the interprofessional approach that have been developed and established were education, resources, and clinical practice (Table I). Providing education to healthcare professionals and establishing effective support systems were essential for supporting pharmacogenomics services (Rohrer Vitek et al., 2017; Empey *et al*., 2018; Weitzel *et al*., 2018); minimising barriers and increasing benefits in multidisciplinary clinical practice (Table II). This systematic review identified six steps in clinical practice (Figure 2). Interpretation of pharmacogenomic test results for patients is highly intricate because of the presence of germline and somatic DNA alterations. These somatic alterations provide valuable information for identifying targeted therapeutic agents. Germline variation provides genetic information to identify the potential risks of toxicity or a lack of therapeutic efficacy. The complexity of pharmacogenomics can be resolved using a multidisciplinary approach (Swart *et al*., 2019). Close work relations improve communication and appreciation among healthcare professionals and increase therapeutic outcomes (Table II).

The development and establishment of resources/support systems and multidisciplinary pharmacogenomic services are also essential for IPE (Table I). The major barrier to IPE was the lack of knowledge and skills (mentioned in five studies). Therefore, providing a good learning method is essential for developing educational strategies. Despite theoretical training, practical training was also used for learning (Figure 2). Practical learning using a multidisciplinary approach has provided clinical experience in pharmacogenomic services. Both learning methods (Table II) enhance knowledge/ skills, increase confidence, and improve communication/ appreciation, which supports improving therapeutic outcomes (Formea *et al*., 2015; Haidar *et al*., 2017; Karpa *et al*., 2018; Quesnelle *et al*., 2018; Calinski et al., 2021; Ward *et al*., 2021; Yehya & Matalgah, 2021; Perwitasari et al., 2023;).

Conclusion

The barriers identified in IPE were knowledge, skills, confidence, finance, multiple geographical regions, time, and stereotypes of the profession. Meanwhile, challenges in IPC include limited resources, ambiguity regarding pharmacogenomic services, communication constraints, and negative stereotypes of other professions.

Pharmacogenomic services were categorised into essential components, addressing pharmacogenomic education with an interprofessional approach (through online and offline learning), resources/system support, and clinical practice. The six steps of multidisciplinary clinical practice in pharmacogenomics include patient selection, pre-counselling for patient engagement, pharmacogenomic testing, interpretation of test results for decision-making in treatment selection, post-counselling, and implementing individualised medicine.

The complexity of pharmacogenomics can be resolved by using a multidisciplinary approach. The benefits of the interprofessional approach in education and clinical practice were the establishment of close work relationships, increased confidence, enhanced knowledge and skills in pharmacogenomics, and increased therapeutic outcomes.

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