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Knowledge and Attitudes of Pharmacogenetics Among Canadian Nurses: Implications for Nursing Education

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Each year more than 200,000 Canadians are injured or die from severe drug reactions, resulting in billions of dollars in health care costs annually (Adverse Drug Reaction Canada, 2020). One emerging genetic specialty that has the potential to mitigate the effects of adverse drug reactions on patients and the health care system is pharmacogenetic testing.

Pharmacogenetics is the branch of science that seeks to understand how variations in single genes affect an individual's response to drugs (Patil, 2015). In academia, pharmacogenomics is the study and identification of complex multigene patterns within the human genome and their effect on drug elimination and response (Patil, 2015). Although both *pharmacogenetics* and *pharmacogenomics* are used interchangeably, pharmacogenetics differs from pharmacogenomics in the level of its application. Both definitions are incorporated in a recent approach to medicine known as precision medicine. Precision medicine is an innovative approach for disease treatment that considers individual's unique genetic makeup, environment, and lifestyle (Gameiro et al., 2018). Precision medicine gives health professionals the resources they need to provide targeted drug treatment and reduce risk of adverse health outcomes.

Pharmacogenetic testing is one of the key pillars of precision medicine and is currently used in a wide range of clinical settings. It is a type of genetic test that examines individuals' genetic profile and assists clinicians to better predict drug response and guide patient drug therapy (Petit et al., 2020; Scott, 2011; Wang et al., 2011). By understanding patients' genetic variances and their genetically different responses to medications, clinicians can better manage medication selection and dosing to reduce the risk of adverse drug reactions. The increased use of pharmacogenetic testing ultimately leads to improved drug responsiveness, decreased side effects, and cost-effective drug development (World Health Organization, 2016). Currently, several commonly prescribed medications, such as clopidogrel and citalopram, have pharmacogenetic data to support appropriate selection or dosing (U.S. Food and Drug Administration, 2020). The U.S. Food and Drug Administration (2020) currently provides pharmacogenetic information for over 300 medication labels and identifies over 430 drug-biomarker pairs across therapeutic areas. Health Canada has incorporated pharmacogenetic information in over 105 drug labels (Loucks et al., 2020). New information is added regularly, reflecting the growth of precision health.

Findings from recent studies suggest pharmacogenetic testing is not widely used because of barriers with integrating it into clinical practice. Clinician knowledge of and attitudes to pharmacogenetic testing are a significant cause for delay in implementation (Roederer et al., 2012). Nurses in particular contribute to the slow integration of pharmacogenetic testing because of their lack of knowledge and familiarity with pharmacogenetic testing guidelines (Roederer et al., 2012). As patient advocates and educators, nurses must have a clear understanding of genetic health and recognize the purpose, benefits, and limitations of pharmacogenetic testing to fully inform patients and families (Haga & Mills, 2015). Hence, it is vital for nurses to be knowledgeable about pharmacogenetic testing and enhance approval of it (Dodson, 2011).

This cross-sectional study is the first in Canada to provide baseline information on the knowledge and attitudes of undergraduate nursing students, registered nurses, and nurse practitioners regarding pharmacogenetic testing. Our findings contribute to a global project comparing the knowledge and perspectives of practising nurses and nurse practitioners in several countries, including Canada. The global study has the potential to drive the construction and redesign of nursing policies and education to aid with the implementation of pharmacogenetic testing.

Literature Review

No studies to date have examined Canadian nurses' knowledge of and attitudes to pharmacogenetic testing, and few studies have examined nurses' knowledge of and attitudes to genetics. Bottorff (2005) assessed "the knowledge, professional involvement, and confidence of Canadian nurses and physicians in providing genetic services for adult-onset hereditary disease[s]" (Abstract). This descriptive exploratory study used an online survey questionnaire to assess clinician's genetic education, knowledge, confidence in providing genetic services, and interest in participating in genetics continuing education. Survey responses from 543 physicians and 975 nurses indicated that most were not prepared to integrate genetic services into practice. Results revealed that approximately half of the nurses and nearly a third of the physicians received no formal education in genetics. About one third of physicians and only 7% of nurses reported taking semester-long courses in genetics. The low mean level of confidence in providing genetic services for physicians (2.95 ± 0.09) and nurses (2.30 ± 0.08) was consistent with participants' lack of genetics education. Although the study did not examine clinicians' knowledge and attitudes regarding pharmacogenetic testing specifically, the findings indicate that nurses' knowledge of basic genetic principles is poor and a need for additional genetics education was identified.

Few studies exist outside Canada that evaluate the knowledge of and attitudes to pharmacogenetic testing among nurses. Dodson (2011) conducted a literature review a decade ago on health professionals'—including nurses'—knowledge of pharmacogenetic testing. The review included 12 studies from 1999 to 2010, equally divided across quantitative and qualitative methodologies. The majority of the studies were conducted in the United States; however, some were conducted in Japan, Germany, Canada, and England. The findings revealed three studies that assessed nurses' knowledge of pharmacogenetic testing, but only one of those studies focused solely on nursing. No studies were found that focused on nursing attitudes alone. The review found that clinicians, including nurses, had minimal knowledge of pharmacogenetic testing. However, many had positive attitudes toward testing and believed it would reduce adverse drug reactions and improve patient outcomes. In addition, 8 of the 11 articles emphasized ethical concerns about pharmacogenetic testing among many disciplines, including nursing. The most common issues raised were increased discrimination by employer/insurance companies, breach of privacy, and lack of equitable access. The authors of the study concluded that gaps in knowledge exist and identified a need to assess nursing knowledge of and attitudes toward pharmacogenetic testing in order to integrate it into practice successfully.

In Canada, recent studies have shown that health care providers' perceived that the usefulness of pharmacogenetics education has increased and that they are more willing to provide pharmacogenetic testing in practice (Petit et al., 2020; Walden et al., 2015). With the recent advancement in medical genetics, the roles and responsibilities of all health care providers are being redefined. A greater and more detailed emphasis has to be placed on the nursing role in the provision of pharmacogenetic testing in Canada. Previous study findings support the need for in-depth and comprehensive research into nurses' knowledge of and attitudes to pharmacogenetic testing across Canada to address the literature gaps.

Study Purpose

The purpose of this cross-sectional descriptive study was to assess the knowledge and attitudes of undergraduate nursing students, registered nurses, and nurse practitioners across Canada regarding pharmacogenetic testing. This hypothesis-generating study aimed to identify

nurses' and nursing students' educational background, knowledge, attitudes, and comfort level in providing genetic-focused care. The overall objective was to identify the potential gaps in existing knowledge and the need for further education initiatives.

Methodology

Survey

A cross-sectional descriptive survey design was used to assess participants' knowledge of and attitudes to pharmacogenetic testing. The survey questionnaire used in this study was adapted and modified from Roederer et al.'s (2012) knowledge and attitude questionnaire about pharmacogenetic testing. The original questionnaire was created by a panel of experts from the University of North Carolina (UNC) Center for Genomics and Society and the UNC Institute for Pharmacogenomics and Individualized Therapy (Roederer et al., 2012). In collaboration with Dr. Marcia Van Riper, the original questionnaire was updated and modified to incorporate recent advancements in pharmacogenetics. The updated survey questions are included below with her agreement. Dr. Van Riper is a professor at UNC-Chapel Hill who holds joint appointments in the School of Nursing and the Carolina Center for Genome Sciences.

The modified survey questionnaire consisted of five sections with multiple-choice, true or false, and Likert scale questions. The first section included eight multiple-choice questions to provide information about the general demographic and background of participants. The second section had two questions that assessed participants' perception of their understanding of genetics and pharmacogenetics. These questions were measured on a 5-point Likert scale ranging from 1 (*excellent*) to 5 (*poor*). The third section included 10 questions that evaluated participants' knowledge of genetics and pharmacogenetics. Participants could choose "true," "false," or "do not know". The fourth section consisted of eight Likert scale questions to provide information about participants' attitudes regarding pharmacogenetic testing. The fifth section included two items to identify participants' interest in educational opportunities related to pharmacogenetic testing.

The survey questionnaire contained no identifying information that could connect study participants with findings, thus ensuring confidentiality. Following informed consent, participants were able to complete the online survey questionnaire. Participation in the study was voluntary, and participants could end the survey whenever they wanted. The study was reviewed and approved by the University of Calgary Conjoint Health Research Ethics Board (REB20-0550).

Sample

A convenience sampling strategy was used to recruit study participants across Canada. A social media recruitment campaign was launched in which three social media platforms, Instagram, Twitter, and Reddit, were used for recruitment. An Instagram page titled "PNC Research Study" was created to share recruitment posters, with the link to an online survey and information about the study. A Reddit account was also created titled "PNC Research Study" to share recruitment posters, including the link to the survey, on relevant subreddits that targeted our study population. The authors of the study also used their personal Twitter accounts to share recruitment posters. Recruitment emails were also sent to relevant nursing professional groups/organizations in Canada that requested permission to tag the organizations on our social media recruitment posts and asked them to share our posts on the organizations' respective social media pages. Some organizations also consented to share our recruitment poster in their monthly newsletters. Information about the study and the survey link were also distributed to faculty and

students in the Faculty of Nursing at the University of Calgary via email. The survey was open for participants from July 13, 2020, to August 14, 2020. No incentive for survey completion was provided. Survey instructions included the phone number and email addresses of the study investigators to contact with any questions or concerns and contact information for the University of Calgary Conjoint Health Research Ethics Board. The study sample included a total of 236 participants. Survey respondents included undergraduate nursing students, registered nurses, and nurse practitioners. Participants who indicated their highest nursing degree was as a licensed practical nurse did not meet the eligibility requirement for our study and hence were not included. Incomplete surveys or those with missing data were excluded from the study analysis.

Data Analysis

Missing data were treated as a declined response, and participants who did not complete the survey were not included in the study's data analysis (n = 209). Descriptive statistics were generated for all participants, including frequencies for categorical variables and means for continuous variables. For questions referring to knowledge, a total knowledge score was calculated by converting five genetic-based knowledge questions and five pharmacogenetic based knowledge questions into categorical variables with two possible responses, correct or incorrect. Answer scores were determined by averaging the rate of correct responses for each question. For attitude-based questions, an average positive attitude score was determined for each question using a 5-point Likert scale. Each Likert scale response was converted into a point system in which a high number of points was attributed to an increased positive attitude. An average attitude score was calculated for each question by summing the points obtained from each participant and dividing by the total number of participants. All opinion-based narrative responses were transcribed verbatim from surveys onto a Microsoft Word document. All statistical analyses were performed using IBM SPSS Statistics (Armonk, NY, USA) for Windows, Version 25.

Results

A total of 236 participants completed the online survey, and 219 additional participants with incomplete surveys or those with missing data were excluded from the study analysis. Survey participants included undergraduate nursing students, registered nurses, and nurse practitioners.

Demographics

Table 1 summarizes the characteristics of survey participants. Participants represented nine provinces and two territories, excluding Newfoundland and Labrador and Nunavut. More than half of the participants represented Alberta (n = 90, 38.1%) or Ontario (n = 50, 21.2%). The majority of those surveyed identified themselves as registered nurses (n = 143, 60.6%). Only 6.8% (n = 16) of participants were educators/faculty members, most of them teaching in undergraduate nursing programs (n = 12, 75.0%). Approximately one third of the participants were current students who had never practised (n = 80, 33.9%). Among participants who were practising registered nurses, nurse practitioners, and nurse clinicians most had worked five or more years (n = 89, 37.7%), while some worked less than five years (n = 67, 28.7%). More than half of the participants (56.8%, n = 134) reported their highest level of education (nursing or another field) was a baccalaureate degree. The majority of participants had completed their nursing education in Canada (n = 228, 96.6%). A total of 172 survey participants did not have any education in genetics (65.9%). Of those participants who did have education in genetics, only 17.2% (n = 45) had taken an undergraduate genetics course.

Table 1

*Characteristics of the Study Sample (*n *= 236)*

Characteristics	All participants *n* (%)
Province or territory	
Alberta	90 (38.1)
Manitoba	20 (8.5)
New Brunswick	9 (3.8)
Nova Scotia	14 (5.9)
Ontario	50 (21.2)
Prince Edward Island	4 (1.7)
Quebec	3 (1.3)
Saskatchewan	16 (6.8)
Northwest Territories	1 (0.4)
Yukon	1 (0.4)
British Columbia	28 (11.9)
Primary role	
Undergraduate nursing student	84 (35.6)
Registered nurse	143 (60.6)
Nurse practitioners/nurse clinician	9 (3.8)
Highest degree	
Current student	67 (28.4)
Bachelor's degree in nursing or another field	134 (56.8)
Diploma in nursing or another field	10 (4.2)
Master's degree in nursing or another field	21 (8.9)
Doctoral degree in nursing or another field	4 (1.7)
Country of completion of nursing education	
Canada	228 (96.6)
Outside Canada	8 (3.4)
Years of practice	
Current student/never practised	80 (33.9)
Less than 5 years	67 (28.4)
5 or more years	89 (37.7)

Education in genetics	
No education in genetics/genomics	172 (65.9)
Undergraduate genetics/genomics course	45 (17.2)
Graduate school genetics/genomics course	2 (0.8)
Grand rounds in genetics/genomics	15 (5.7)
Seminar or workshop in genetics/genomics	9 (3.4)

Knowledge

Participants were asked to evaluate their understanding of genetics and pharmacogenetics based on one of five categories: *excellent*, *very good*, *good*, *fair*, and *poor*. The majority of the participants (n = 207, 87.7%) felt they had a poor or fair understanding of genetics, and 94.2% (n = 222) of participants had a poor or fair understanding of pharmacogenetic testing. Table 2 presents participants' self-reported genetic and pharmacogenetic knowledge assessments. Only one participant (0.4%) reported an excellent understanding of both genetics and pharmacogenetic testing.

Table 2

*Self-Reported Understanding of Genetics and Pharmacogenetic Testing (*n = *236)*

Current understanding of genetics/genomics	*n* (%)
Excellent	1 (0.4)
Very good	3 (1.3)
Good	25 (10.6)
Fair	92 (39.0)
Poor	115 (48.7)
Current understanding of pharmacogenetic testing	*n* (%)
Excellent	1 (0.4)
Very good	2 (0.8)
Good	13 (5.5)
Fair	48 (20.3)
Poor	172 (72.9)

The mean genomic knowledge score was 3.1/5 (61.1%), with a median of 3.0/5 (60.0%) and a standard deviation of 0.5. The majority of participants correctly answered one to four questions, with 5.1% (n = 12) not answering any of the items correctly and 12.7% (n = 30) answering all five items correctly. More than half of the participants recognized which nucleotides paired together to form DNA base pairs (61.0%, n = 144). The majority correctly identified that single-gene mutations can cause genetic conditions such as sickle cell anemia (85.6%, n = 202).

The mean pharmacogenetic knowledge score was 1.7/5 (34.5%), with a median of 2/5 (40%) and a standard deviation of 0.5. Twenty-six participants (11%) answered all five survey items incorrectly, while only one participant (0.1%) answered all five items correctly. The majority of the participants were not aware that pharmacogenetic testing is currently available for most medications (96.6%, *n* = 228). Overall, the participants had a higher correct percent knowledge score for the genetic-based questions (61.0%) than for the pharmacogenetic based questions (34.5%). Table 3 presents the participants' responses to the 10 items used to assess their knowledge of genetics and pharmacogenetics.

Table 3

Questions Assessing Knowledge of Genetics and Pharmacogenetics (n = 236)

Items assessing genetics knowledge	Correct answer	Answering correctly *n* (%)	Answering incorrectly or "do not know" *n* (%)	Mean (*M*) and standard deviation (*SD*) (*n* = 236)
Humans are over 99% identical at the DNA level.	True	142 (60.2)	94 (39.8)	*M*: 0.6 *SD*: 0.5
Most cells in the human body contain 47 chromosomes.	False	177 (75.0)	59 (25.0)	*M*: 0.8 *SD*: 0.4
Every time the human body produces sperm or an egg, approximately 3 billion nucleotides (bases) must be copied and packaged so they can be passed along to future offspring.	True	108 (45.8)	128 (54.2)	*M*: 0.5 *SD*: 0.5
The nucleotides (bases) in DNA always match up the same way—Adenine (A) always pairs with the Cytosine (C) and Guanine (G) always pairs with the Thymine (T).	False	92 (39.0)	145 (61.0)	*M*: 0.4 *SD*: 0.5
A number of conditions, such as sickle cell anemia, are caused by a mutation in a single gene.	True	202 (85.6)	34 (14.4)	*M*: 0.9 *SD*: 0.4

Items assessing pharmacogenetics knowledge	Correct answer	Answering correctly *n* (%)	Answering incorrectly or "do not know" *n* (%)	Mean (*M*) and standard deviation (*SD*) (*n* = 236)
Subtle differences in a person's Genome can have a major impact on how the person responds to medications.	True	200 (84.7)	36 (15.3)	*M*: 0.8 *SD*: 0.4
Genomic determinants of drug response change over a person's lifetime.	False	149 (63.1)	87 (36.9)	*M*: 0.1 *SD*: 0.3
Guidelines providing therapeutic recommendations based on pharmacogenetic testing results are available for some medications.	True	95 (40.3)	141 (59.7)	*M*: 0.4 *SD*: 0.5
The package insert for warfarin includes a warning about the altered metabolism of warfarin in individuals who have specific genomic variants.	True	73 (30.9)	163 (69.1)	*M*: 0.3 *SD*: 0.5
Pharmacogenetic testing is currently available for most medications.	True	8 (3.4)	228 (96.6)	*M*: 0.03 *SD*: 0.2

Attitudes

The survey contained 12 questions related to attitudes regarding genetics and pharmacogenetic testing. Questions 1, 3, 6, 9, and 11 had five possible responses for each question ranging from 1 (*not likely*) to 5 (*very likely*); for Questions 2 and 4, responses ranged from 1 (*not concerned*) to 5 (*very concerned*); and responses to Questions 5, 7, 8, 10, and 12 ranged from 1 (*not comfortable*) to 5 (*very comfortable*). The responses to Questions 2 and 4 were reverse coded so that larger values for all 12 questions corresponded to more positive attitudes. A total positive attitude score was then calculated as the mean of the 12 attitude-based questions. For this attitude scale, Cronbach's $\alpha = 0.75$. A score of 3 or more indicated a positive attitude score for each question.

The overall mean attitude score of participants was 3.1 (positive attitude). Most participants' recognized the benefits of pharmacogenetic testing and felt that it is somewhat likely (*n* = 153, 64.8%) or very likely (*n* = 39, 16.5%) to decrease the number of adverse drug reactions. The majority were either not comfortable (*n* = 122, 51.7%) or somewhat uncomfortable (*n* = 51, 21.6%) answering patients' questions about pharmacogenetic testing related to antiplatelet therapy. Regarding ethical concerns, many participants were either very concerned (*n* = 46, 19.5%) or somewhat concerned (*n* = 109, 46.2%) about pharmacogenetic testing causing an increase in

discrimination by employers and insurance companies. Table 4 shows the individual mean attitude scores for the 12 items.

Table 4

*Questions Assessing Attitude Towards the Use of Pharmacogenetic Testing (*n = *236)*

Question number	Question assessing attitudes concerning pharmacogenetic testing and pharmacogenetic testing to guide antiplatelet therapy	Mean	Standard deviation
1	In your opinion, how likely is it that pharmacogenetic testing will help to decrease the number of adverse drug reactions?	3.9	0.8
2	How concerned are you that unauthorized persons may gain access to the results of a patient's pharmacogenetic testing?	3.0	1.3
3	In your opinion, how likely is it that pharmacogenetic testing will help to decrease the cost of developing new drugs?	2.7	1.1
4	How concerned are you that pharmacogenetic testing may result in discrimination by employers and/or insurance companies?	2.4	1.2
5	How comfortable would you be having genetic information incorporated into decision-making about antiplatelet therapy for your patients?	3.7	0.9
6	In your opinion, how likely is it that pharmacogenetic testing will help decrease the adverse reactions associated with clopidogrel (Plavix)?	3.6	0.7
7	How comfortable would you be answering your patient's questions about pharmacogenetic testing related to antiplatelet therapy?	1.9	1.2
8	If you were a patient with a history of the acute coronary syndrome, how comfortable would you be having pharmacogenetic testing done to help guide decision-making about your antiplatelet therapy?	3.9	1.0
9	In your opinion, how likely is it that pharmacogenetic testing will help to decrease the time it takes to find the optimal dose of warfarin for patients?	3.6	0.8
10	How comfortable would you be having genetic information incorporated into the determination of your patient's initial warfarin dose?	3.6	0.9
11	In your opinion, how likely is it that pharmacogenetic testing will help to decrease the adverse reactions experienced by patients on warfarin?	3.7	0.8
12	If you were the patient, being started on warfarin, how comfortable would you be having genetic information incorporated into the determination of your initial dose of warfarin?	3.8	1.0

Educational Offerings

Most survey participants (*n* = 174, 73.7%) reported that they were interested in learning more about pharmacogenetic testing, with the majority (*n* = 132, 28.8%) preferring a Web-based course option. Table 5 summarizes participants' preference in educational offerings related to pharmacogenetic testing.

Table 5

*Interest in Educational Offerings Related to Pharmacogenetics (*n = *236)*

Types of educational offerings of interest	*n* (%)
Grand rounds	45 (9.8)
Seminar or lecture	116 (25.3)
CME/CE course	50 (10.9)
Web-based course	132 (28.8)
Half-day conference	70 (15.3)
All-day conference	45 (9.8)

Note. More than one response was allowed for each category.

Discussion

This study is the first in Canada to determine registered nurses' and undergraduate nursing students' current knowledge and attitudes regarding pharmacogenetic testing. The study results add to the small body of literature that has documented nurses' knowledge and perception of new genomic practice advancements. It is clear from our findings that the majority of nurses and undergraduate nursing students in Canada lack knowledge surrounding genetic health and pharmacogenetic testing. The current results raise important concerns and provide baseline information that will help with the development of pharmacogenetic practice in Canada and the implementation of educational opportunities and resources for nurses to integrate genomic health practices.

The study findings revealed that most participants had no formal education in genetics/genomics (65.9%), which explains why the majority reported their understanding of genetics (87.7%) and pharmacogenetic testing (93.2%) as poor or fair. Although the mean total knowledge score of genetics was higher (3.05/5) than of pharmacogenetics (1.75/5), most participants still lacked knowledge of basic genetic concepts, such as which DNA nucleotides pair together in a DNA sequence (55.5%). The most concerning result was that most participants were not aware that pharmacogenetic testing is currently available for most medications (96.6%), highlighting the need to address knowledge gaps. Another interesting finding from the study was that the majority of nurses recognized the benefits of pharmacogenetic testing and believed it would decrease the risk of adverse drug reactions (81.3%). However, they were not comfortable discussing pharmacogenetic test results with their patients (73.3%). This lack of self-confidence in educating patients likely stems from nurses' deficiency in pharmacogenetics knowledge and

lack of genomic education, although physicians are primarily responsible for providing pharmacogenetic test results to patients rather than nurses. Nurses play a significant role in understanding the range of clients' psychosocial responses to genetic and genomic test results and assessing client response to genetic/genomic information. Hence, it is important for nurses to be knowledgeable about pharmacogenetics and discuss pharmacogenetic test results with patients (Consensus Panel on Genetic/Genomic Nursing Competencies, 2008)

Furthermore, ethical concerns played a significant role in shaping nurses' attitudes toward pharmacogenetic testing. The majority of the participants identified the belief that pharmacogenetic testing may result in employment or insurance discriminatory practices (65.7%), which prompted resistance to its implementation in practice. These results raise concerns that nursing knowledge related to the provisions and limitations of the *Genetic Non-Discrimination Act* in Canada may be lacking (Government of Canada, 2017). This federal law prevents genetic discrimination by prohibiting any person (e.g., employers and insurers) from collecting, using, or disclosing the results of a genetic test as a condition for providing goods or services or entering into a contract (Government of Canada, 2017). Nurses' limited knowledge of this Act may cause increased resistance to educating themselves or advocating for the use of pharmacogenetic testing. Future studies should focus on conducting a more in-depth qualitative analysis to examine nurses' concerns related to insurance discrimination and their awareness of the *Genetic Non-Discrimination Act*. Additional research has the potential to uncover useful insights regarding these concerns and guide the development and promotion of educational efforts.

Our findings are consistent with those of Dodson (2014), who examined pharmacogenetic testing knowledge and attitudes among oncology nurses in North Carolina, United States. Dodson found that most nurses had a poor or fair perceived understanding of genetics (68%) and pharmacogenetic testing (72%), similar to our findings. However, participants' mean knowledge score on pharmacogenetic testing was comparatively higher (2.61) than our Canadian findings (1.70). The findings revealed that previous education in pharmacogenetic testing and increased exposure to it correlated to enhanced knowledge and acceptance of pharmacogenetic testing among nurses. An interesting finding from that study was that most nurses believed they should educate patients about pharmacogenetics (77%); however, in practice, the majority of nurses had never educated a patient regarding pharmacogenetic testing (75%). These findings further illustrate that nurses may not have the knowledge or confidence to incorporate genomics into their practice despite having positive attitudes toward pharmacogenetic testing. Dodson (2014) concluded that nurses having increased knowledge of pharmacogenetics and a positive attitude toward this innovation would lead to increased adoption of pharmacogenetic information into patient education and practice.

The results of our study mirror the findings from Bottorff (2005) in which only a small percentage of nurses reported taking any formal education in genetics. These similarities are concerning as this study was conducted almost 16 years ago and reflects minimal change in genetics/genomic nursing education. Our recommendations are consistent with those proposed by Bottorff (2005), which encouraged the incorporation of genetics content into nursing education programs.

Unfortunately, there are no studies in Canada that assess nurses' attitudes and knowledge of pharmacogenetic testing for comparison. Empirical evidence and results from our study suggest that nurses have insufficient understanding and knowledge of Canada's pharmacogenetic testing approach. However, the positive attitudes and increased interest in continuing education related to

pharmacogenetics reported in this study are promising (73.7%). Other studies have recognized the need to revise curricula and create educational opportunities to provide nurses with the knowledge and skills to deliver genetics care (Umberger et al., 2013). More educational programs regarding genetics and pharmacogenetics are needed to promote and implement pharmacogenetic testing in clinical settings across Canada.

Limitations

This study has several limitations that may impact the validity of our findings. First, the use of convenience sampling through social media is a limitation since there is a possibility that participants are not a representation of the population of nurses and undergraduate nursing students across Canada. However, through the use of social media platforms, we targeted low-prevalence and remote populations who would have been otherwise difficult to reach. Furthermore, not all provinces and territories were represented equally in the sample because of recruitment- and funding-related constraints. Despite these limitations, we did have representation from all but one province and one territory in Canada. Given the resources at our disposal, participants whose highest degree was a practical nursing diploma did not meet the eligibility criteria to participate in our study. However, it would be interesting to conduct future studies on the competencies of licensed practical nurses and their genetic literacy. Finally, the study was also subject to recruitment bias because of individual's self-selection to participate.

Conclusion and Future Considerations

The present findings reveal that despite having positive perceptions of pharmacogenetics and its potential clinical applications, nurses' limited knowledge, lack of preparation, and confidence in this subject are barriers to implementing pharmacogenetics into clinical practice. Ethical concerns and misconceptions regarding the potential for discrimination by employers or insurance companies were also identified as a barrier and need to be further assessed. Moreover, nurses' lack of education in pharmacogenetics and high level of interest in learning more about it suggests a need for further education and preparatory opportunities in pharmacogenetics. With increased availability of clinical pharmacogenetic testing, and new pharmacogenetic-based guidelines, nurses will need to be better prepared and confident in educating patients and families on the use of pharmacogenetic testing, as well as on its impact on patient care. The challenges related to a lack of pharmacogenetics education in the nursing curriculum presents an opportunity to better prepare the future nursing workforce. Integration of targeted educational programs focusing on genetics and pharmacogenetics into nursing baccalaureate and master of nursing curricula should be strongly encouraged to ensure nurses have a foundation in basic pharmacogenetic knowledge and the skills to effectively communicate evidence-based information to patients. As per our findings, educational programs should include Web-based courses and seminars/lectures to increase student engagement and learning. Currently, entry-level competencies for registered nurses related to basic genetic and pharmacogenetic knowledge has not been established in Canada. However, there are international examples of pharmacogenetic and genetic nursing competencies that could be used to shepherd the development of the Canadian competence framework and curriculum guidelines for nursing schools in Canada (Calzone et al., 2018).

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